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Korea Photovoltaic Society
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한국태양광발전학회
2023 춘계학술대회

Korea Photovoltaic Society



3. 30.(목)~3. 31.(금)
웨스틴조선부산

초록집

주 최 한국태양광발전학회

공 동 주 관 한국에너지기술연구원, 전북대학교 에너지-AI융합대학원인력양성사업단, 전남대학교 광전자융합기술연구소, 고려대학교 에너지 · 환경 기후기술인재양성센터, 고려대학교 유무기복합형 태양전지 에너지혁신연구센터, 서울대학교 기후변화사업(삼중접합 기술개발 연구단) 태양에너지재료연구실(SEML), 고려대학교 투명태양전지플랫폼개발사업단, 성균관대학교 학생성공형 인테크소재 글로벌 인재양성 교육연구단, 녹색에너지연구원, 동국대학교 광에너지융합기술연구소, 한양대학교 청정에너지연구소, 인천대학교 차세대에너지 융합연구소

후원 및 협찬 세미랩코리아㈜, 한화솔루션 큐셀부문, ㈜엘케이켐, ㈜코에스, ㈜나인테크, ㈜에스케이솔라에너지, 와이아이테크㈜

전 시 업 체 ㈜맥사이언스, 오엠에이, ㈜한양솔라에너지, 한빅솔라㈜

한국태양광발전학회 2023 춘계학술대회 프로그램

3월 30일(목요일)

11:00~13:00		등록(그랜드볼룸(1F) 로비)					이사회	
Room		그랜드볼룸 A(1F)						
13:00~13:30	30"	개회식						
13:30~14:10	40"	기조강연 | 한국에너지공단 이상훈 이사장						
14:10~14:50	40"	Plenary 1 | 울산과학기술원 석상일 교수						
14:50~15:00	10"	휴식						
Room		1F		2F				
		그랜드 볼룸 A	그랜드 볼룸 B	코스모스	바이올렛	로즈/ 라일락	튤립	오키드
15:00~15:55	55"	QPOD 1	CSi 1	HPV 1	MSI 1	CiS 1	특별세션 (Closed)	Poster Exhibition CSi, QPOD, MSI, HPV
15:55~16:10	15"	휴식						
16:10~17:20	70"	QPOD 2	CSi 2	HPV 2	MSI 2	CiS 2		
17:20~17:30	10"	휴식						
17:30~18:30	60"	Poster Presentation 1						
18:00~18:30	30"	총회 (그랜드볼룸 B(1F))						
18:30~20:00	90"	만찬 (그랜드볼룸 A(1F))						

3월 31일(금요일)

Room		1F		2F				
		그랜드 볼룸 A	그랜드 볼룸 B	코스모스	바이올렛	로즈/ 라일락	튤립	오키드
09:00~10:55	115"	QPOD 3	CSi 3	HPV 3	MSI 3	CiS 3	PV-AI 특별세션	Poster Exhibition CiS, QPOD, ReS, GaP
10:55~11:10	15"	휴식						
11:10~11:50	40"	Plenary 2 | 스코트라㈜ 원창섭 전무 (그랜드볼룸 A(1F))						
11:50~12:50	60"	중식						
12:50~13:40	50"	BIPV산업 생태계 활성화를 위한 산업포럼	Poster Presentation 2					
13:40~14:50	70"		CSi 4	ReS 1	GaP 1	QPOD 4		-
14:50~15:00	10"	휴식						
15:00~15:30	30"	폐회식 (그랜드볼룸 A(1F))						

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공 동 주 관 한국에너지기술연구원, 전북대학교 에너지-AI융합대학원인력양성사업단, 전남대학교 광전자융합기술연구소, 고려대학교 에너지 · 환경 기후기술인재양성센터, 고려대학교 유무기복합형 태양전지 에너지혁신연구센터, 서울대학교 기후변화사업(삼중접합 기술개발 연구단) 태양에너지재료연구실(SEML), 고려대학교 투명태양전지플랫폼개발사업단, 성균관대학교 학생성공형 인테크소재 글로벌 인재양성 교육연구단, 녹색에너지연구원, 동국대학교 광에너지융합기술연구소, 한양대학교 청정에너지연구소, 인천대학교 차세대에너지 융합연구소

후원 및 협찬 세미랩코리아㈜, 한화솔루션 큐셀부문, ㈜엘케이켐, ㈜코에스, ㈜나인테크, ㈜에스케이솔라에너지, 와이아이테크㈜

전 시 업 체 ㈜맥사이언스, 오엠에이, ㈜한양솔라에너지, 한빅솔라㈜



한국태양광발전학회 2023 춘계학술대회

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초대의 글



존경하는 한국태양광발전학회 회원 여러분

전 세계적으로 기후변화 대응을 위한 탄소중립 추진전략을 수립하여 온실가스 배출량을 제로(0)로 만들겠다는 방안(Net Zero)을 발표하고 있습니다. 이러한 추진전략 중 경제구조의 저탄소화 정책 핵심과제로 산업 및 에너지 전환 가속화가 진행되고 있으며, IEA는 재생에너지가 2027년 글로벌 전력원의 90% 이상을 점유할 것으로 예측하고 있습니다.

태양광 에너지를 이용한 태양광발전은 탄소중립을 달성하기 위한 가장 핵심적인 재생에너지원으로 RE100, 유럽 탄소국경조정제도 (CBAM, 탄소국경세) 등에 의해 최근 급격히 보급이 확대되고 있습니다. 이미 우리 생활 주변에서 흔하게 태양광발전시스템을 볼 수 있으며, 미래 핵심에너지원으로 그 흐름을 피할 수 없습니다. 태양광 산업은 탄소중립 사회 구현을 위한 산업 대전환의 시기에 에너지 혁신을 이끌 촉매로써 그 역할이 더욱 기대됩니다.

국내 태양광 연구 및 정책 분야를 대표하는 한국태양광발전학회는 올해 설립된 지 11주년이 되는 해로써 새로운 10년을 도약하는 첫해입니다. 이번 학술대회는 변화되는 산업 및 에너지 대전환에 맞춰 태양광 기술의 한계를 뛰어넘는 혁신기술과 다양한 응용 시스템 개발에 대한 산학연 연구자들 및 젊은 대학원생들의 뜨거운 토론의 장이 될 것입니다.

이번 춘계학술대회가 성공적으로 준비할 수 있도록 아낌없는 격려와 후원을 해주신 본 학회 김진혁 회장님, 신원석 수석부회장님을 비롯한 회장단 여러분께 깊이 감사드립니다. 또한, 최신 연구결과 및 산업 핵심 이슈로 프로그램을 풍성하게 구성해준 박노창 프로그램위원장님, 대내외적인 제반 업무를 모두 맡아서 진행해주신 김진영 사무총장님과 조직위원회 및 프로그램위원회의 모든 위원분, 그리고 본 학술대회를 성공적으로 준비해 주시고 마무리할 수 있도록 지원해 주신 사무국 이혜정 국장님께도 깊이 감사드립니다.

새로운 도약을 준비하는 태양광 분야 산학연 연구자들과 젊은 대학원생들의 유익한 학문적 교류와 지적 호기심을 채울 수 있는 뜻깊은 시간이 될 수 있도록 많은 참석을 부탁드리며 한국태양광발전학회 모든 회원 여러분의 건강과 발전을 기원합니다.

감사합니다.

2023. 3

사단법인 한국태양광발전학회

2023 춘계학술대회 조직위원장 **이 해 석** 올림



서 문



2023년 춘계 한국태양광 발전 학술대회에 참여하신 모든 분들께 진심으로 감사의 말씀을 드립니다. 태양광 발전 분야에서 여러분의 연구와 개발은 국내 태양광 발전 산업의 성장과 발전에 큰 도움이 될 것이라 확신합니다.

태양광 발전 분야는 미래 에너지 시장에서 중요한 역할을 담당하고 있으며, 국내 태양광 발전 산업은 매우 높은 성장 잠재력을 가지고 있습니다. 앞으로도 국내 태양광 발전 산업의 성장과 발전을 위해서 지속적인 노력이 필요하며, 이를 위해서 학계와 산업계가 함께 노력하여 새로운 기술과 방법을 개발해 나가야 할 것입니다.

미국의 IRA는 인플레이션을 줄이기 위한 법안으로, 에너지 분야에서 비용적으로 효율적인 기술의 개발과 도입을 강조하고 있습니다. 이에 따라 태양광 발전 분야에서는 더욱 효율적이고 경제적인 기술의 개발이 요구되고 있습니다. 이는 본 학회에 참석하신 모든 분들께도 새로운 도전이자 기회가 될 것으로 예상됩니다. 또한, 태양광 에너지는 RE100에 대한 기여도가 상당히 높은 에너지원입니다. 이 역시 국내 태양광 발전 분야가 향후 진행해야 할 방향을 보여주고 있다고 말씀 드릴 수 있습니다.

본 학회 참석자분들은 태양광 기술의 발전을 위해 신소재 개발, 효율성 향상, 비용 절감, 그리고 태양전지의 새로운 응용 분야를 연구하고 있습니다. 이러한 노력은 국내 태양광 발전 산업의 성장과 발전, 그리고 국내 산업 경쟁력 향상에 필수적인 요소입니다. 이러한 노력에 감사의 말씀을 드립니다.

이 자리를 빌어 이번 대회가 가능하도록 애써주신 김진혁 회장님, 신원석 수석부회장님, 조직위원장님이신 이해석 교수님, 사무총장 김진영 교수님께 깊은 감사 말씀드립니다. 아울러 프로그램 부위원장을 맡아주신 서관용 교수님, 전남중 박사님과 각 세션별 프로그램 부문위원장님들, 그리고 이혜정 국장님께 진심 어린 감사 말씀드립니다.

마지막으로, 이번 학회를 위해서 좋은 발표를 해주신 키노트 및 플래너리 연사분, 발표자 및 참가자 분들께도 감사드립니다.

2023. 3

사단법인 한국태양광발전학회

2023 춘계학술대회 프로그램위원장 **박 노 창** 올림



한국태양광발전학회 2023 춘계학술대회 운영조직

▶ 춘계학술대회 조직위원회

업무	이름	소속	역할
1. 조직위원회	이해석	고려대학교	위원장
	정현석	성균관대학교	부위원장
1) 총무/진행	김진영	서울대학교	사무총장
	임종철	충남대학교	공동위원장
	이진욱	성균관대학교	부위원장
2) 프로그램	박노창	한국전자기술연구원	위원장
	서관용	울산과학기술원	부위원장
	전남중	한국화학연구원	부위원장
3) 재무	김대환	대구경북과학기술원	위원장
	김기환	한국에너지기술연구원	공동위원장
4) 전시/협찬	양정엽	군산대학교	위원장
	최종민	맥사이언스	공동위원장
	박종성	경상국립대학교	위원
	강윤묵	고려대학교	위원
5) 강좌/워크숍	김경수	한국에너지기술연구원	위원장
	김창헌	(재)녹색에너지연구원	공동위원장
6) 홍보/홈페이지	박진주	청주대학교	위원장
	이선화	한화큐셀	부위원장
2. 사무국	이혜정	한국태양광발전학회	국장

▶ 춘계학술대회 프로그램위원회

TPC Chair	박노창	한국전자기술연구원
TPC Vice-chair	서관용	울산과학기술원
TPC Vice-chair	전남중	한국화학연구원

Topic	Position	Name	Organization
Topic 1. Silicon solar cells and materials (CSi)	**Chair**	**송희은**	**한국에너지기술연구원**
	Co-chair	강민구	한국에너지기술연구원
	Co-chair	김영국	성균관대학교
	Co-chair	김성탁	한국생산기술연구원
	Co-chair	박성은	한국에너지기술연구원
Topic 2. II-VI & chalcogenide compound based cells and materials (CiS)	**Chair**	**성시준**	**대구경북과학기술원**
	Co-chair	황대규	대구경북과학기술원
	Co-chair	신동협	한국에너지기술연구원
	Co-chair	김지영	한국과학기술연구원
	Co-chair	조대형	한국전자통신연구원
Topic 3. Quantum dot, perovskite, organic, dye solar cells and materials (QPOD)	Chair	**김진영**	**울산과학기술원**
	Co-chair	김동석	울산과학기술원
	Co-chair	김영훈	국민대학교
	Co-chair	이상규	한국화학연구원
	Member	최종민	대구경북과학기술원
	Member	유형근	한국과학기술연구원
	Member	김민	전북대학교
	Member	조임현	한국에너지기술연구원
	Member	김기환	경상대학교
	Member	임동찬	한국재료연구원
	Member	정인환	한양대학교
Topic 4. III-V compound based concentrator and space PV systems (GaP)	**Chair**	**이성민**	**국민대학교**
	Co-chair	강호관	한국나노기술원
	Member	김효진	한국광기술원
	Member	정대환	한국과학기술연구원
Topic 5. PV module, system and integration (MSI)	**Chair**	**임철현**	**(재)녹색에너지연구원**
	Co-chair	박종성	국립경상대학교
	Member	윤정호	경희대학교
	Member	김소연	한국재료연구원
	Member	배수현	한국에너지기술연구원
	Member	김수민	구미전자정보기술원
	Member	황혜미	한국에너지기술연구원
Topic 6. PV reliability and standardization (ReS)	**Chair**	**김경수**	**한국에너지기술연구원**
	Co-chair	신정현	한국기계전기전자시험연구원
	Member	김창헌	(재)녹색에너지연구원
	Member	김필규	한국산업기술시험원
Topic 7. Hybrid photovoltaics (HPV)	**Chair**	**김재현**	**대구경북과학기술원**
	Co-chair	김유권	아주대학교
	Co-chair	김동욱	이화여자대학교
	Co-chair	강동원	중앙대학교
	Co-chair	이진욱	성균관대학교

한국태양광발전학회 2023 춘계학술대회 프로그램

▶ 일시 : 2023년 3월 30일(목)~31일(금)

▶ 장소 : 웨스틴조선부산

3월 30일(목요일)

11:00~13:00		등록(그랜드볼룸(1F) 로비)					이사회	
Room		그랜드볼룸 A(1F)						
13:00~13:30	30"	개회식						
13:30~14:10	40"	기조강연 | 한국에너지공단 이상훈 이사장						
14:10~14:50	40"	Plenary 1 | 울산과학기술원 석상일 교수						
14:50~15:00	10"	휴식						
Room		1F		2F				
		그랜드 볼룸 A	그랜드 볼룸 B	코스모스	바이올렛	로즈/ 라일락	튤립	오키드
15:00~15:55	55"	QPOD 1	CSi 1	HPV 1	MSI 1	CiS 1	특별세션 (Closed)	**Poster Exhibition** CSi, QPOD, MSI, HPV
15:55~16:10	15"	휴식						
16:10~17:20	70"	QPOD 2	CSi 2	HPV 2	MSI 2	CiS 2		
17:20~17:30	10"	휴식						
17:30~18:30	60"	Poster Presentation 1						
18:00~18:30	30"	총회 (그랜드볼룸 B(1F))						
18:30~20:00	90"	만찬 (그랜드볼룸 A(1F))						

3월 31일(금요일)

Room		1F		2F				
		그랜드 볼룸 A	그랜드 볼룸 B	코스모스	바이올렛	로즈/ 라일락	튤립	오키드
09:00~10:55	115"	QPOD 3	CSi 3	HPV 3	MSI 3	CiS 3	PV-AI 특별세션	**Poster Exhibition** CiS, QPOD, ReS, GaP
10:55~11:10	15"	휴식						
11:10~11:50	40"	Plenary 2 | 스코트라㈜ 원창섭 전무 (그랜드볼룸 A(1F))						
11:50~12:50	60"	중식						
12:50~13:40	50"	BIPV산업 생태계 활성화를 위한 산업포럼	Poster Presentation 2					
13:40~14:50	70"		CSi 4	ReS 1	GaP 1	QPOD 4		-
14:50~15:00	10"	휴식						
15:00~15:30	30"	폐회식 (그랜드볼룸 A(1F))						

한국태양광발전학회 2023 춘계학술대회 특별세션

▶ 특별세션 : BIPV 산업생태계 활성화를 위한 산업포럼

- 일 시 : 3월 31일(금) 12:00~14:50
- 장 소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 주 최 : 산업통상자원부, 한국에너지기술평가원
- 주 관 : 한국태양광발전학회

2022년 5월 글로벌 태양광 누적보급용량이 1TW를 돌파하는 마일스톤을 수립하였고 연간 3,080억불 투자에 신규설치용량 260GW를 기록하며 사상 최초로 200GW를 초과하였습니다. 국내 태양광 보급의 경우에도, 2022년에 연간 3.1GW의 신규설치용량을 잠정적으로 기록하며 누적보급용량이 25GW 수준에 도달하였습니다. 산지가 많고 도심에 건물이 밀집된 국내 환경에서는 건물형 태양광 발전이 RE100과 탄소배출 저감을 단기간에 실행할 수 있는 효과적인 에너지 기술입니다. 특히, RE100 이행은 반도체, 자동차, 배터리 등 수출 중심 국내 주요 산업의 미래경쟁력 강화와 직결된 심각한 난제입니다.

지금까지 글로벌 태양광 시장은 전 가치사슬의 80% 가량을 중국이 독점하면서 주도해왔습니다. 그러나 독자적인 산업 공급망을 형성하고 미래 패권을 차지하기 위해서 미국의 IRA 법안 통과, 유럽의 REpowerEU 정책 시행과 그린 딜 산업계획 약속, 중국의 14차 5개년 계획, 인도의 PLI 프로그램 지원, 일본의 20조엔 규모의 녹색전환채권 발행 등 자국우선주의 정책이 경쟁적으로 발표되고 있습니다. 건물형 태양광에 있어서도 미국의 태양광 투자세액공제(ITC) 10년 연장, EU의 2029년까지 모든 신축건물 지붕 태양광 의무화 및 인허가 시간 단축, 중국의 2025년까지 건물 누적설치용량 50GW 달성 목표, 일본 도쿄도의 2025년부터 신축건물 지붕 태양광 의무화 등 경쟁적으로 우대정책을 쏟아내고 있습니다. 산업부에서도 최근에 BIPV 산업생태계 활성화 방안을 발표하여 국내 건물형 태양광 산업의 경쟁력을 제고하고 RE100에 기여하려고 노력하고 있습니다.

2026년 세계태양광총회(WCPEC-9) 유치를 기념하기 위하여 태양광발전학회 2023년 춘계학술대회에서 개최하는 태양광 산업포럼의 주제는 BIPV 산업생태계 활성화 방안입니다. 이를 위해서 한국에너지기술평가원에서 2022년에 지원한 건물형 태양광 대표 기술개발 과제와 한국산업기술평가원에서 지원한 국가표준기술개발 사업 내용을 공유합니다. RE100 및 탄소중립 실현 등 BIPV 산업의 혁신성장 토대를 마련하기 위한 제언과 논의가 활발히 이루어질 수 있도록 패널토론도 준비되어 있으니 많은 관심과 참석 부탁드립니다.

시 간	내 용	비 고
12:00~12:50	접수 및 등록	
<세션-1> 좌장 : 정성훈 박사		
12:50~12:55	인사말	이해석 조직위원장 (2023 춘계학술대회)
12:55~13:00	환영사	하종한 국가표준코디네이터 (국가기술표준원)
13:00~13:15	건물형 태양광 연계 BIMS 설계 개방형 라이브러리 구축	안성우 본부장 (㈜정림건축종합건축사사무소)
13:15~13:30	강화된 내화성능의 건물형 태양광 표준모델 개발	윤석규 대표이사 (아이솔라에너지㈜)
13:30~13:45	건물형 태양광 MLPE 개발 및 실증	홍석훈 대표이사 (㈜티이에프)
13:45~14:00	태양광 국가표준기술개발 사업	신정현 선임연구원 (한국기계전기전자시험연구원)
14:00~14:10	Break	
<세션-2 패널토론> 좌장 : 명승엽 태양광PD		
14:10~14:50	주제 : BIPV 산업생태계 활성화 방안 - 김철영 산업통상자원부 재생산업과 서기관 - 김준태 공주대학교 교수(IEA PVPS Task15 위원) - 문은경 (주)거광기업 대표이사 - 김규진 한국건설생활환경시험연구원 책임연구원 - 허영준 한국에너지공단 태양광사업실 부장	

*포럼 조직위원 : 명승엽 PD, 유지은 PM, 황주연 PM, 이상훈 PM, 이창구 실장(이상 KETEP)

한국태양광발전학회 2023 춘계학술대회 특별세션

▶ 특별세션 : PV-AI 특별세션

- 일 시 : 2023년 3월 31일(금) 09:00~12:00
- 장 소 : 웨스틴조선부산 튤립(2F)
- 주 최 : 전북대학교 에너지-AI융합공학과
- 주 관 : 한국에너지기술평가원

좌장 : 이승법 교수(전북대학교)

시 간		발표제목	발표자
공개	09:00~09:15	Dual Effects of Perovskite-PCBM Solar Cells with Nanopatterned TiO_2 Layer with the Assistance of Machine Learning	Hasanah Sanimu (전북대학교)
	09:15~09:30	기계 학습을 이용한 실험데이터 증강에 따른 페로브스카이트 태양전지의 에너지 변환 효율 예측정확도 분석	문예총 (전북대학교)
	09:30~09:45	The Development of Optimization Framework for Designing Silicon Solar Cell	Nur Amilya (전북대학교)
	09:45~10:00	Performance Prediction of Perovskite Solar Cells Using Numerical Modeling and Machine Learning	차정범 (전북대학교)
	10:00~10:15	머신러닝을 이용한 글래스 프릿 공정 처리 조건에 따른 접촉 저항 예측	이승태 (고려대학교)
비공개	10:15~10:30	행사장 정리	
	10:30~12:00	에너지-AI융합대학원 사업단 발표	

Keynote & Plenary Session

Keynote Session

- 일 시 : 2023년 3월 30일(목) 13:30~14:10
- 장 소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 좌 장 : 박노창 (한국전자기술연구원)

KPVS-K-1 13:30~14:10	기조강연	탄소중립 국제 동향과 우리의 대응 - 이상훈 (한국에너지공단)

Plenary Session

- 일 시 : 2023년 3월 30일(목) 14:10~14:50
- 장 소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 좌 장 : 전남중 (한국화학연구원)

KPVS-P-1 14:10~14:50	Plenary 1	더 높은 효율의 페로브스카이트 태양전지의 제조를 향하여 - 석상일 (울산과학기술원)

- 일 시 : 2023년 3월 31일(금) 11:10~11:50
- 장 소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 좌 장 : 임철현 ((재)녹색에너지연구원)

KPVS-P-2 11:10~11:50	Plenary 2	탄소중립을 위한 수/해상 태양광 발전 시스템의 현황과 미래 - ***원창섭, 김동찬, 강명길, 한진구 (스코트라(주))

Oral Session (CSi)

Topic 1. CSi : Silicon solar cells and materials

CSi-1

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 그랜드볼룸 B(1F)
- 좌 장 : 김가현 (충북대학교)

CSi-I-1 Invited-1 15:00~15:20	실리콘 태양전지 온도에 따른 fill factor 손실 분석 - *이상희, 민관홍, 강민구, 송희은, 정경택, **박성은 (한국에너지기술연구원 태양광 연구단)
CSi-I-2 Invited-2 15:20~15:40	투명히터를 이용한 실리콘 태양전지 및 열전 융합 발전소자 측성 시스템 - 이용환 (Korea Electronics Technology Institute, New and Renewable Energy Center)
CSi-O-1 Oral-1 15:40~15:55	미세구조와 전자 및 정공 선택형 poly-Si/SiO_x TOPCon의 전하수송 메커니즘간의 상관관계 연구 - 모성인[1,2], 최성진[3], 안정호[1,2], 김보종[4], 민관홍[3], 박성은[3], **송희은[3], *,**오준호[3], **김가현[3] [1]한국에너지기술연구원 울산차세대전지연구개발센터, [2]고려대학교 신소재공학부, [3]한국에너지기술연구원 태양광연구단, [4]충북대학교 물리학과

CSi-2

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 그랜드볼룸 B(1F)
- 좌 장 : 김영국 (성균관대학교)

CSi-I-3 Invited-3 16:10~16:30	Development of Highly Efficient p-TOPCon Solar Cells - *,**김도형, **김용진, 이상희, 임규현, 박준성, 조윤애, 정경택, 박성은, 강민구, **송희은 (한국에너지기술연구원 태양광연구단)
CSi-I-4 Invited-4 16:30~16:50	결정질 실리콘 기반의 유연 태양전지 개발 - *엄한돈[1], 최덕재[2], **서관용[2] [1]강원대학교 춘천캠퍼스, [2]울산과학기술원
CSi-I-5 Invited-5 16:50~17:10	Hydrogen incorporated microstructure in plasma assisted epitaxial silicon - *,**김가현[1], 오준호[2], 안정호[2], 모성인[2], 홍지은[2] [1]Department of Physics, Chungbuk National University, [2]Ulsan Advanced Energy Technology R&D Center, Korea Institute of Energy Research
CSi-O-2 Oral-2 17:10~17:25	p-n 접합을 이용한 고효율 결정질 실리콘 광음극 - *진원주, **서관용 울산과학기술원

CSi-3

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 그랜드볼룸 B(1F)

▶ 좌 장 : 송희은 (한국에너지기술연구원)

CSi-I-6 Invited-6 09:00~09:20	고효율 TOPCon 태양전지 구현을 위한 전극화 공정 최적화 및 전극 형성 메커니즘 규명 - ***조윤애[1)], 박준성[1,2)], 김용진[1)], 김도형[1)], 이상희[1)], 정경택[1)], 강민구[1)], 박성은[1)], 송희은[1)], 이해석[2)] [1)]한국에너지기술연구원, 태양광연구단, [2)]고려대학교, 그린스쿨대학원
CSi-I-7 Invited-7 09:20~09:40	고효율 결정질 실리콘 태양전지용 부동태화 접촉 기술 - ***서동철[1)], 황성호[2)] [1)]호서대학교, [2)]고려대학교
CSi-O-3 Oral-3 09:40~09:55	증착 온도에 따른 SiN_x layer의 수소 함량 및 결합 구조 특성 분석 - *임규현[1,3)], 이진영[2)], 심서우[2)], 김문세[1,2)], 박준성[1,3)], 정경택[1)], 박성은[1)], 강민구[1)], 이해석[3)], 송희은[1)], **조윤애[1)], **김가현[2)] [1)]한국에너지기술연구원, [2)]충북대학교 물리학과, [3)]고려대학교 에너지환경정책기술학과
CSi-O-4 Oral-4 09:55~10:10	습식 표면처리 기술을 통한 고효율, 대면적 투명 결정질 실리콘 태양전지 개발 - *박정환, 이강민, **서관용 울산과학기술원
CSi-O-5 Oral-5 10:10~10:25	기생흡수 저감을 위한 top contact-free 페로브스카이트/실리콘 탠덤 태양전지 구현 - *편도원[1)], 이상원[1,2)], 김영웅[3)], 장경순[3)], 최동진[1)], 정석현[1)], 송호영[1)], 이솔희[1)], 조수진[1)], 김지량[4)], 강동균[1)], 이하은[1)], 현지연[1)], 이창현[1)], 박현정[1,5)], 황재근[1)], 이원규[1)], 전남중[3)], 서장원[3,6)], 강윤묵[4)], 김동환[1)], **이해석[4)] [1)]고려대학교 신소재공학과, [2)]스탠포드대학교 화학공학과, [3)]한국화학연구원(KRICT), [4)]고려대학교 에너지환경대학원(KU-KIST 그린스쿨 대학원), [5)]난양공과대학교 전기전자공학과, [6)]한국과학기술원(KAIST) 생명화학공학과
CSi-O-6 Oral-6 10:25~10:40	Controlling the light trapping capability of microwire solar cells via microsphere lithography - *Namwoo Kim[1)], Deokjae Choi[2)], Han-Don Um[1)], **Kwanyong Seo[2)] [1)]Department of Energy Engineering, Ulsan National Institute of Science and Technology (UNIST), [2)]Division of Chemical Engineering and Bioengineering, Kangwon National University
CSi-O-7 Oral-7 10:40~10:55	Monolithic 페로브스카이트/실리콘 탠덤 소자의 구조별 바텀 실리콘 태양전지 최적화 방향 - *송호영[1)], 이상원[2)], 강윤묵[3)], 김동환[1)], **이해석[3)] [1)]Department of Materials Science and Engineering, Korea University, [2)]Department of Chemical Engineering, Stanford University, [3)]KU-KIST Green School, Graduate School of Energy and Environment, Korea University

CSi-4

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 그랜드볼룸 B(1F)

▶ 좌 장 : 박성은 (한국에너지기술연구원)

CSi-I-8 Invited-8 13:40~14:00	Bottom subcell optimization for high-efficiency III-V//Si tandem solar cells - *Suresh Kumar Dhungel[1)], Seungyong Han[2)], Muhammad Quddamah Khokhar[3)], Duy Phong Pham[3)], Youngkuk Kim[1)], **Junsin Yi[1)] [1)]College of Information and Communication Engineering, Sungkyunkwan University, [2)]Interdisciplinary Program in Photovoltaic System Engineering, Sungkyunkwan University, [3)]Department of Electrical and Computer Engineering, Sungkyunkwan University
CSi-I-9 Invited-9 14:00~14:20	결정질 실리콘 태양전지 광열화 현상에 관한 계산과학 연구 - 이태경 (경상국립대학교 나노·신소재공학부)
CSi-O-8 Oral-8 14:20~14:35	산업용 CVD의 실시간 모니터링을 위한 PSG 박막 성장의 잔류가스 분석방법 - *김문세[1,2)], 송희은[1)], 박성은[1)], 조윤애[1)], 김용진[1)], 김도형[1)], 정경택[1)], **강민구[1)], **이상희[1)], **김가현[2)] [1)]한국에너지기술연구원 태양광연구단, [2)]충북대학교 물리학과
CSi-O-9 Oral-9 14:35~14:50	Improved SiO_x/poly-Si passivated contacts via inserting intrinsic poly-Si layer - *Haejung Lee[1)], Dongjin Choi[2)], Dongkyun Kang[2)], Hoyoung Song[2)], MyeongSeob Sim[2)], Donghwan Kim[2)], Yoonmook Kang[1)], **Hae-Seok Lee[1)] [1)]Green School Graduate School of Energy and Environment (KU-KIST), Korea University, [2)]Department of Material Science and Engineering, Korea University

Oral Session (CiS)

Topic 2. CiS : II-VI & chalcogenide compound based cells and materials

CiS-1

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 로즈 & 라일락(2F)
- 좌 장 : 조대형 (한국전자통신연구원)

CiS-I-1 Invited-1 15:00~15:20	CIGS 박막태양전지 재료의 전기적 특성 분석을 위한 측방향 광전류법 - 정중희 (한밭대학교 신소재공학과)
CiS-I-2 Invited-2 15:20~15:40	Tailoring band-gap grading via a hybrid growth method achieving $Sb_2(S,Se)_3$ solar cells with 8% efficiency - Yazi Wang, Seunghwan Ji, *,***Byungha Shin (Korea Advanced Institute of Science and Technology)
CiS-I-3 Invited-3 15:40~16:00	CIGS 태양전지의 빛 젖음 효과를 통한 광시냅스 소자 - *,***정광식[1)], 이동준[1)], 이우정[2,3)], 조대형[2,3)], 황태하[2,3)], **정용덕[2,3)] [1)]동국대학교 물리반도체과학부, [2)]한국전자통신연구원 ICT 창의 연구실, [3)]과학기술연합대학원대학교 신소재소자공학과

CiS-2

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 로즈 & 라일락(2F)
- 좌 장 : 김지영 (한국과학기술연구원)

CiS-I-4 Invited-4 16:10~16:30	케스터라이트 태양전지 내 결함 특성 - *,***양기정[1,2)], 손대호[1,2)], 김대환[1,2)], 강진규[1,2)], 성시준[1,2)], 김준호[3)], 전찬욱[4)], 조윌렴[5)] [1)]Division of Energy Technology, DGIST, [2)]Research Center for Thin Film Solar Cells, DGIST [3)]Department of Physics, Incheon National University, [4)]School of Chemical Engineering, Yeungnam University, [5)]Department of Physics, Ewha Womans University
CiS-I-5 Invited-5 16:30~16:50	결함이 포함된 CZTS 태양전지의 최대 효율에 대한 제일원리 연구 - 김성현 (삼성종합기술원)
CiS-I-6 Invited-6 16:50~17:10	재결합 방지를 통한 작은 밴드갭 $CuInSe_2$ 솔라셀 효율 향상 - *,***황대규[1)], 전동환[1)], 박시내[2)],이재백[1)],김대환[1)], 양기정[1)], 강진규[1)], 성시준[1)] [1)]대구경북과학기술원 에너지융합연구부, [2)]경북대학교 전기전자공학부
CiS-O-1 Oral-1 17:10~17:25	The Se/(S+Se) Compositional Ratio Optimization Towards Highly Efficient Vapor-Transport-Deposited SnS_xSe_{1-x} Thin-film Solar Cells - *Pravin Pawar, **Jaeyeong Heo (Department of Materials Science and Engineering and Optoelectronics Convergence Research Center, Chonnam National University)

CiS-3

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 로즈 & 라일락(2F)

▶ 좌 장 : 신동협 (한국에너지기술연구원)

CiS-I-7 Invited-7 09:00~09:20	고효율 대면적 초경량·유연 무독성 CIGS 박막 태양전지 기술개발 - *황인찬, 정인영, 신동협, 박주형, 어영주, 조아라, **김기환 (한국에너지기술연구원 태양광연구단)
CiS-I-8 Invited-8 09:20~09:40	Study on defect control through double cation substitution to improve low-illumination efficiency of CZTSSe solar cell - *,**박종성[1)], Vijay Karade[2)], Kuldeep Singh Gour[2)], Jae Sung Yun[3)], **김진혁[2)] [1)]Gyeongsang National University, [2)]Chonnam National University, [3)]University of Surrey
CiS-O-2 Oral-2 09:40~09:55	비정질 TiO_2 패시베이팅 컨택 도입을 통해 계면 특성이 강화된 초박막 CIGS 태양전지 개발 - *박기순, 김다슬, **민병권 (한국과학기술연구원 청정신기술연구본부)
CiS-O-3 Oral-3 09:55~10:10	폴리이미드 코팅된 유리기판을 이용한 ITO 후면전극 기반 유연 CIGS 박막 태양전지 모듈 - *정성훈, 김지영, 김원목, **정증현 (한국과학기술연구원)
CiS-O-4 Oral-4 10:10~10:25	반투광형 및 양면수광형 광전변환을 위한 초박막 $CuInSe_2$ 광흡수층 최적 성장조건 연구 - *안진기[1,2)], 김동렬[1)], 조아라[1,3)], 이아름[1)], 이상민[1)], 안승규[1)], 정인영[1)], 조준식[1,3)], 김태완[2)], **박주형[1,3)] [1)]한국에너지기술연구원, 태양광연구단, [2)]전북대학교, 전기공학과 및 스마트그리드연구센터, [3)]과학기술연합대학원대학교, 재생에너지공학
CiS-O-5 Oral-5 10:25~10:40	Simulation analysis on Ga grading effect in $Cu(In,Ga)Se_2$ solar cells with local contact Al_2O_3 rear passivation layer - *김준용[1)], 성시준[2)], 김대환[2)], **도윤선[1)] [1)]School of Electronic and Electrical Engineering, Kyungpook National University, [2)]Division of Energy Technology, Daegu-Gyeongbuk institute of Science and Technology (DGIST)
CiS-O-6 Oral-6 10:40~10:55	Improvement of charge loss at $Cu(In,Ga)Se_2$/CdS interface by tuning band gap grading - *Ha Kyung Park[1)], Yunae Cho[1)], Kihwan Kim[2)], Inyoung Jeong[2)], Jae Ho Yun[3)], Jihye Gwak[2)], **William Jo[1)] [1)]Department of Physics, Ewha Womans University, [2)]Photovoltaic Laboratory, Korea Institue of Energy Research (KIER), [3)]Department of Energy Engineering, Korea Institute of Energy Technology (KENTECH)
CiS-O-7 Oral-7 10:55~11:10	알칼리 후열처리 공정이 $Cu(In,Ga)Se_2$ 광흡수층의 전기적 비저항 특성 및 단일집적모듈의 션트손실에 미치는 영향 - *최은평[1,2)], 주병권[2)], 유형근[1)], **정증현[1)] [1)]Advanced Photovoltaics Research Center, Korea Institute of Science and Technology (KIST), [2)]Department of Electrical and Computer Engineering Korea University

Oral Session (QPOD)

Topic 3. QPOD : Quantum dot, perovskite, organic, dye solar cells and materials

QPOD-1

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 좌 장 : 김동석 (울산과학기술원)

QPOD-I-1 Invited-1 15:00~15:15	유기태양전지용 비플러렌 억셉터 소재 개발 - 김윤희 (경상국립대학교)
QPOD-I-2 Invited-2 15:15~15:30	Charge transfer dynamic in non-fullerene organic solar cells - Shinuk Cho (Department of Physics & EHSRC, University of Ulsan)
QPOD-I-3 Invited-3 15:30~15:45	Liquid-State Dithiocarbonate-based Polymeric Additives with Monodispersity rendering Perovskite Solar Cells with Exceptionally- High Certified Photocurrent and Fill Factor - *,**Il Jeon[1)], Kyusun Kim[1)], Jiye Han[1)], Sangsu Lee[1)], Dong Suk Kim[2)], Jung Yun Do[3)] [1)]Department of Nano Engineering and Department of Nano Science and Technology, SKKU Advanced Institute of Nanotechnology (SAINT), Sungkyunkwan University (SKKU), [2)]School of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), [3)]Department of Chemistry Education, Pusan National University
QPOD-O-1 Oral-1 15:45~15:55	쯔비터 이온 작용기를 가진 이온 포획층을 활용한 고효율 역구조 페로브스카이트 태양전지 - *하정민[1)], 노영욱[2)], **송명훈[2)], **우한영[1)] [1)]고려대학교 화학과, [2)]울산과학기술대학교 신소재공학부
QPOD-O-2 Oral-2 15:55~16:05	Strain engineering of SnO_2 electron transport layer for stable and efficient perovskite solar cells - *Dong-Am Park[1)], **Nam-Gyu Park[1,2)] [1)]School of Chemical Engineering, Center for Antibonding Regulated Crystals, Sungkyunkwan University (SKKU), [2)]SKKU Institute of Energy Science and Technology (SIEST), Sungkyunkwan University (SKKU)

QPOD-2

▶ 일 시 : 2023년 3월 30일(목)

▶ 장 소 : 웨스틴조선부산 그랜드볼룸 A(1F)

▶ 좌 장 : 조신욱 (울산대학교)

QPOD-I-4 Invited-4 16:10~16:25	페로브스카이트 내 전하 이동 현상 규명 - 임종철 (충남대학교 에너지과학기술대학원)
QPOD-I-5 Invited-5 16:25~16:40	Various Trap Passivation Strategy for infrared QD Photodetectors - *,**황규원[1)], 진준영[1)], 박태환[1)], 위상우[1)], 장세환[2)] [1)]한국과학기술연구원 차세대반도체연구소 인공뇌융합연구단, [2)]한국과학기술연구원 차세대반도체연구소 광전소재연구단
QPOD-I-6 Invited-6 16:40~16:55	물분자의 수소이온이동을 매개로한 알킬암모니움의 안정성 유도와 금속할라이드 페로브스카이트 결정 성장과의 관계 - *,**박병욱[1)], 김진철[2)], 신태주[3)], 김영삼[4)], **김민규[5)], **석상일[1)] [1)]Department of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), [2)]School of Engineering, Macquarie University Sustainable Energy Research Centre, Macquarie University, [3)]UNIST Central Research Facilities & School of Natural Science, Ulsan National Institute of Science and Technology (UNIST), [4)]Department of Chemistry, Ulsan National Institute of Science and Technology (UNIST), [5)]Beamline Research Division, Pohang Accelerator Laboratory (PAL), Pohang University of Science and Technology (POSTECH)
QPOD-I-7 Invited-7 16:55~17:10	SnO_2 전자전달층을 적용한 고효율 페로브스카이트 태양전지 제조 및 대면적 응용연구 - *,**조임현, 김민진, 김학범, 최인우, 최승주 (한국에너지기술연구원)
QPOD-O-3 Oral-3 17:10~17:20	Green Solvent Based Air-Processed Highly Efficient Organic Solar Cells with Power Conversion Efficiency of 17.38% - *Shafket Rasool[1)], **Jin Young Kim[1,2)] [1)]School of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology, [2)]Graduate School of Carbon Neutrality, Ulsan National Institute of Science and Technology
QPOD-O-4 Oral-4 17:20~17:30	용액 공정으로 만든 PbS 버퍼 층 도입으로 안정성이 향상된 페로브스카이트 태양전지 - *김수아[1)], 김현서[2)], 이원종[3)], 전남중[2)], 임종철[3)], **양태열[1,2)] [1)]충남대학교 공과대학 신소재공학과, [2)]한국화학연구원 화학소재연구본부 에너지소재연구센터, [3)]충남대학교 에너지과학기술대학원
QPOD-O-5 Oral-5 17:30~17:40	Bending Fracture Behavior Depending on Composition of Halide Perovskite Films - *Yeon-Woo Choi[1)], Yong-Jun Park[1)], Seul-Gi Kim[1,2)], **Nam-Gyu Park[1,3)] [1)]School of Chemical Engineering and Center for Antibonding Regulated Crystals, Sungkyunkwan University (SKKU), [2)]Chemistry and Nanoscience Center, National Renewable Energy Laboratory, [3)]SKKU Institute of Energy Science and Technology (SIEST), Sungkyunkwan University

QPOD-3

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 그랜드볼룸 A(1F)

▶ 좌 장 : 김영훈 (국민대학교)

QPOD-I-8 Invited-8 09:00~09:15	KIER 페로브스카이트 기반 탠덤 태양전지 연구 현황 - 안세진 (한국에너지기술연구원)
QPOD-I-9 Invited-9 09:15~09:30	Design Strategy of Colloidal Quantum Dot Heterostructure for Downshifting Layer - Byeong Guk Jeong (School of Chemical Engineering, Pusan National University)
QPOD-I-10 Invited-10 09:30~09:45	Effects of Optical Interference on Quantum Dot Solar Cells - Jung Hoon Song (Department of Semiconductor and Applied Physics, Mokpo National University)
QPOD-I-11 Invited-11 09:45~10:00	순간 고전압에 의한 Perovksite 태양전지 열화 - ***송형준[1)], 박준형[2)], 고명근[1)], 이한길[1)] [1)]서울과학기술대학교 안전공학과, [2)]서울대학교 기계공학과
QPOD-I-12 Invited-12 10:00~10:15	Defect engineering of metal-halide perovskites for next-generation optoelectronic devices - Hobeom Kim (Gwangju Institute of Science and Technology)
QPOD-I-13 Invited-13 10:15~10:30	Universal perovskite nanocrystal ink for optoelectronic devices - Hyosung Choi (Hanyang University)
QPOD-I-14 Invited-14 10:30~10:45	Realizing defect-less perovskite QDs by surface passivation and alkali metal doping for opto-electronic applications - Chang-Lyoul Lee (Advanced Photonics Research Institute (APRI), Gwangju Institute of Science and Technology (GIST))
QPOD-O-6 Oral-6 10:45~10:55	Low-dose TEM study on the microstructure of $GA_xMA_{1-x}PbI_3$ perovskites - *Byeongjun Gil, So Jeong Park, Jin Young Kim, **Miyoung Kim (Department of Materials Science and Enginnering, Seoul National University)
QPOD-O-7 Oral-7 10:55~11:05	페로브스카이트 간 열압착 접합 공정을 이용해 향상된 성능과 장기 안정성을 확보한 페로브스카이트 태양전지 - *정희윤[1)], 오은성[2)], 김동준[2)], 심홍재[3)], 이원종[4)], 윤순길[1)], 임종철[4)], 윤재성[3,5)], 김택수[2)], **양태열[1,6)] [1)]Department of Materials Science and Engineering, Chungnam National University, [2)]Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST), [3)]School of Photovoltaic and Renewable Energy Engineering, University of New South Wales, [4)]Graduate School of Energy Science and Technology (GEST), Chungnam National University, [5)]School of Computer Science and Electronic Engineering, Advanced Technology Institute (ATI), University of Surrey, [6)]Division of Advanced Materials, Korea Research Institute of Chemical Technology (KRICT)

QPOD-4

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 로즈 & 라일락 & 튤립(2F)

▶ 좌 장 : 최종민 (대구경북과학기술원)

QPOD-I-15 Invited-15 13:40~13:55	대면적 고기계적 내구성 태양전지를 위한 유기소재 및 소자 기술 개발 - 손해정 (한국과학기술연구원)
QPOD-I-16 Invited-16 13:55~14:10	Method for fabricating high-crystalline perovskite for high-efficiency perovskite solar cells - 김기환 (경상국립대학교 나노신소재공학과)
QPOD-I-17 Invited-17 14:10~14:25	유기전해질을 Dual-side Passivation 층으로 도입한 고효율 고안정성 페로브스카이트 태양전지 - *,**김희주[1)], 김주현[2)], 김용윤[3)], 서홍석[4)], 이광희[2)] [1)]광주과학기술원 에너지융합대학원, [2)]광주과학기술원 신소재공학부, [3)]광주과학기술원 차세대에너지연구소, [4)]부산대학교 화학과
QPOD-I-18 Invited-18 14:25~14:40	유기, 주석 기반 태양전지의 소재 및 소자기술 - 송창은 (에너지소재연구센터, 한국화학연구원)
QPOD-O-8 Oral-8 14:40~14:50	Surface manipulation of lead halide perovskite quantum dots and enhanced deposition processability - *Jigeon Kim[1)], Wooyeon Kim[1)], Seongyeon Hwang[1)], In Choi[1)], **Younghoon Kim[2)], **Min Jae Ko[1)] [1)]Department of Chemical Engineering, Hanyang University, [2)]Department of Applied Chemistry, Kookmin University
QPOD-O-9 Oral-9 14:50~15:00	스퍼터링 및 이온교환법을 통한 요철구조 실리콘 기판 위 균일한 wide-bandgap 페로브스카이트 박막 증착 - *황재근[1)], 조수진[1)], 이원규[1)], 이솔희[1)], 정석현[1)], 편도원[1)], 황지성[1)], 강윤묵[2)], 김동환[2)], **이해석[2)] [1)]고려대학교 신소재공학과, [2)]고려대학교 에너지환경대학원(그린스쿨)

Oral Session (GaP)

Topic 4. GaP : III-V compound based concentrator and space PV systems

GaP-1

- 일 시 : 2023년 3월 31일(금)
- 장 소 : 웨스틴조선부산 바이올렛(2F)
- 좌 장 : 이성민 (국민대학교)

GaP-I-1 Invited-1 13:40~14:00	마이크로 프리즘 배열이 집적된 유연 GaAs 태양광 모듈 - ***최광성[1)], 주지호[1)], 최광문[1)], 이찬미[1)], 장기석[1)], 윤호경[1)], 문석환[1)], 이우정[1)], 정용덕[1)], 엄용성[1)], 강호관[2)], 신현범[2)], 좌성훈[3)], 정지원[4)], 장재형[4)] [1)]한국전자통신연구원 초지능창의연구소, [2)]한국나노기술원, [3)]서울과학기술대학교, [4)]한국에너지공과대학교
GaP-I-2 Invited-2 14:00~14:20	본딩기술을 이용한 저가형 고효율 InGaP/GaAs 이중접합 태양전지 개발 - ***김효진, 박광열, 양창규 (한국광기술원 광전융합소자연구센터)
GaP-I-3 Invited-3 14:20~14:40	InAlAs/GaAs 응력기반 슈퍼레티스 결함 필터 MBE 성장을 이용한 모노리식 GaAs/실리콘 탠덤 태양전지 - ***정대환, 김연화, 메이 마다랑, 주은교 (한국과학기술연구원)

Oral Session (MSI)

Topic 5. MSI : PV module, system and integration

MSI-1

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 바이올렛(2F)
- 좌 장 : 탁성주 ((재)포항산업과학연구원)

MSI-I-1 Invited-1 15:00~15:15	내화특성이 향상된 강판일체형 컬러 태양광 모듈의 신뢰성 향상에 대한 연구 - ***김영수, 김아롱, 탁성주 (포항산업과학연구원)
MSI-I-2 Invited-2 15:15~15:30	수직입면형 BIPV의 신규 화재시험방법 구성방안에 대한 연구 - 박계원 (방재시험연구원 재난안전연구센터)
MSI-I-3 Invited-3 15:30~15:45	건물 태양광 시스템 표준 현황 및 인증기준 - *류의환, 김덕성, **김규진 (한국건설생활환경시험연구원)
MSI-O-1 Oral-1 15:45~15:55	건물일체형태양광(BIPV) 시스템의 SHGC 성능 분석 - *안종권[1], 김진희[1], **김준태[2] [1]공주대학교 그린에너지기술연구소, [2]공주대학교 그린스마트건축공학과/에너지시스템공학대학원
MSI-O-2 Oral-2 15:55~16:05	분산 브래그 반사경-확산기 구조를 이용한 건물 일체형 태양전지의 다양한 색상 구현 - *김용기[1], **신명훈[1], 최수원[2], **권정대[2] [1]한국항공대학교 스마트항공모빌리티학과, [2]한국재료연구원 나노표면재료연구본부 에너지전자재료연구실

MSI-2

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 바이올렛(2F)
- 좌 장 : 박종성 (경상국립대학교)

MSI-I-4 Invited-4 16:10~16:30	Nanomaterials for energy and environmental applications - Dong Han Seo (Energy Materials & Devices Track, Department of Energy Engineering, Korea Institute of Energy Technology (KENTECH))
MSI-I-5 Invited-5 16:30~16:50	저비용 에너지 소자를 위한 균열기반 박막 분리 기술 - 이용환 (Korea Electronics Technology Institute, New and Renewable Energy Center)
MSI-I-6 Invited-6 16:50~17:10	Unique Optoelectrical Properties and Applications of Halide Perovskite Single Crystals - 윤정호 (경희대학교 환경학 및 환경공학과 대기환경에너지융합연구실)

MSI-3

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 바이올렛(2F)

▶ 좌 장 : 임철현 ((재)녹색에너지연구원)

MSI-I-7 Invited-7 09:00~09:15	수로형적합 태양광 국·내외 현황 및 적용기술 개발 - *,**한운기[1], 서호영[2], 권경영[2], 문주완[2] [1]위에너지, [2]위에너지 기술연구소
MSI-I-8 Invited-8 09:15~09:30	태양광 플랫폼 기반 스마트 O&M 플랫폼 구축 사업 현황 - 박대현 (엔라이튼)
MSI-O-3 Oral-3 09:30~09:40	고장 I-V 곡선과 딥러닝을 이용한 태양광 고장 진단 기술 - *신우균, 배수현, 강기환, 주영철, 황혜미, **고석환 (한국에너지기술연구원)
MSI-O-4 Oral-4 09:40~09:50	1선 지락 위치 검출을 위한 반 전압법 기반 태양광 시스템 개발 - *홍순일, 이용규, **최의성 (주)네오에너지커넥터
MSI-I-9 Invited-9 09:50~10:05	영농형 태양광 발전시스템의 경제성 있는 구조물의 연구 - *,**이경호, 김민혁, 김성길, 도기일, 임종호, 채종윤 (주식회사 모든솔라)
MSI-O-5 Oral-5 10:05~10:15	독립지주식 영농병행 태양광의 발전량 및 고부가가치 작물의 경제성 분석 - *조건영[1], 박정재[2], **임철현[1] [1](재)녹색에너지연구원, 태양에너지연구실, [2]한국수력원자력 중앙연구원, 사업추진실 엔지니어링부
MSI-O-6 Oral-6 10:15~10:25	수직형 태양광 시스템의 최대 출력을 위한 설치 방법 모색 - *장홍준[2], 이해정[2], 정준영[2], 김동환[1], 황성호[2], **강윤묵[2], 이해석[2] [1]Department of Materials Science and Engineering, Korea University, [2]KU-KIST Green School, Graduate School of Energy and Environment, Korea University

Oral Session (ReS)

Topic 6. ReS : PV reliability and standardization

ReS-1

- 일 시 : 2023년 3월 31일(금)
- 장 소 : 웨스틴조선부산 코스모스(2F)
- 좌 장 : 김창헌 ((재)녹색에너지연구원)

ReS-O-1 Oral-1 13:40~13:50	태양광연계 ESS용 재사용 배터리 분류 표준화 연구 - *,***김창헌, 김주희, 김지현 ((재)녹색에너지연구원)
ReS-I-1 Invited-1 13:50~14:10	Photovoltaic R&D direction and the analysis on the product performance in field - *Sungho Hwang[1)], Yoonmook Kang[2)], **Hae-seok Lee[2)] [1)]Research Institute for Energy Technology, Korea University, [2)]Graduate School of Energy and Environment, Korea University
ReS-I-2 Invited-2 14:10~14:30	재 제조 태양광모듈의 내구성능 평가 및 분류 기준 제안 - 김경수 (한국에너지기술연구원 재생에너지연구소 태양광연구단)
ReS-I-3 Oral-3 14:30~14:50	IEC TC82 WG2 태양광모듈 국제표준화동향과 국내 태양광표준인증로드맵 - *,***신정현, 최현동, 김승주, 조성대, 황수현, 전무이, 이승재, 황재옥 (한국기계전기전자시험연구원)

Oral Session (HPV)

Topic 7. HPV : Hybrid photovoltaics

HPV-1

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 코스모스(2F)
- 좌 장 : 조창희 (대구경북과학기술원)

HPV-I-1 Invited-1 15:00~15:15	태양열 에너지 저장소재 및 열전변환 소자 - 류학기 (아주대학교 첨단신소재공학과 & 에너지시스템학과)
HPV-I-2 Invited-2 15:15~15:30	Electrochemical exfoliation of optoelectronically-active 2D materials - Joohoon Kang (Sungkyunkwan University)
HPV-I-3 Invited-3 15:30~15:45	Ultra-flexible and skin-compatible organic optoelectronic devices - Sungjun Park (Department of Electrical and Computer Engineering, Ajou University)

HPV-2

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 코스모스(2F)
- 좌 장 : 강주훈 (성균관대학교)

HPV-I-4 Invited-4 16:10~16:25	Si 기반 광전극을 이용한 광전기화학적 물분해 수소 생산 최적화 연구 - 이민서[1)], 김준[2)], 김지혜[1)], **장윤정[1)], *,**김진영[2)] [1)]한양대학교, [2)]한국과학기술연구원
HPV-I-5 Invited-5 16:25~16:40	반도체 물질의 엑시톤-광자 상호작용 연구 - 조창희 (Department of Physics and Chemistry, Daegu Gyeongbuk Institute of Science and Technology (DGIST))
HPV-I-6 Invited-6 16:40~16:55	Synthesis and Property control of N-doped Graphene Quantum Dots for Energy Applications - Byung Joon Moon, *,**Sukang Bae (Korea Institute of Science and Technology)
HPV-I-7 Invited-7 16:55~17:10	광전기화학 물분해용 분자 잉크 기반 신흥 칼코겐 광흡수층 - 양우석 (성균관대학교 화학공학/고분자공학부)

HPV-3

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 코스모스(2F)

▶ 좌 장 : 박성준 (아주대학교)

HPV-I-8 Invited-8 09:00~09:15	Contact-Resistance-Free, Millimeter-Scale Gas Sensor Compatible with Surface Mount Process: Towards Wearable Flexible Electronics - Hyo-Ryoung Lim (Major of Human Biocovergence, Division of Smart Healthcare, College of Information Technology and Convergence, Pukyong National University)
HPV-I-9 Invited-9 09:15~09:30	미래 모빌리티용 방열 세라믹 소재기술 연구현황 - ***최종진, 안철우, 차현애, 문영국, 김정환, 한병동 (한국재료연구원 기능세라믹연구실)
HPV-I-10 Invited-10 09:30~09:45	바이오/나노재료의 스마트한 디자인을 통한 센서 기반 플랫폼 개발 - 이준민 (포항공과대학교 신소재공학과)
HPV-I-11 Invited-11 09:45~10:00	Laser-based Selective Reaction for Synthesis of Nanomaterial and its Sensor Application - Min-Ji Jeon, ***Seoung-Ki Lee (School of Materials Science and Engineering, Pusan National University)
HPV-I-12 Invited-12 10:00~10:15	Composite materials for transient electronics - Sang Min Won (Department of Electrical and Computer Engineering, Sungkyunkwan University)
HPV-I-13 Invited-13 10:15~10:30	이차원 단결정 금속나노시트의 합성과 응용 - 김태욱 (전북대학교 유연인쇄전자전문대학원 유연인쇄전자공학과)

Poster Session

Topic 1. CSi : Silicon solar cells and materials

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 오키드(2F)
- 좌 장 : 강민구 (한국에너지기술연구원)

CSi-P-1 MoO_x 국부접합을 사용한 정공선택형 구조를 적용한 후면 접합 실리콘 태양전지의 특성

*강동균[1], 강윤묵[2], 이해석[2], **김동환[1]
[1]고려대학교 신소재공학과, [2]KU-KIST 에너지환경대학원(그린스쿨)

CSi-P-2 보론, 갈륨으로 도핑 된 결정질 실리콘 내에서 철 농도에 따른 광열화 분석

*오승현[1], 최동진[1], 심명섭[1], 김동환[1], 이해석[2], **강윤묵[2]
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CSi-P-3 초미세선폭 및 높은 종횡비 구현을 위한 금속스크린 마스크 제작 및 평가

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CSi-P-4 n-TOPCon 태양전지 공정을 위한 에미터 보호막 공정 최적화 연구

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CSi-P-5 쉉글링 실리콘 태양광 모듈 적용을 위한 실리콘 웨이퍼 절단면 패시베이션

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CSi-P-6 실리콘 나노와이어 기반의 온칩형 마이크로 수퍼커패시터 연구

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CSi-P-7 Improving PV module efficiency and power by forming a regular pattern

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CSi-P-8 실리콘 이종접합 태양전지에서 비정질 실리콘 적층 시 표면 부동태화와 Si-H 결합 변화의 상관관계 연구

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CSi-P-9 수소 플라즈마 처리 후 수소에 의한 plasma epitaxial 실리콘 박막의 미세구조 변화에 대한 연구

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CSi-P-10 자연 잎을 모방한 태양광 물분해 시스템

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CSi-P-11 레이저 스크라이빙의 공정 조건에 따라 Heterojunction 태양전지에 미치는 영향에 관한 연구

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CSi-P-13 Al_2O_3와 doping 물질의 표면 passivation 에 의한 Si 태양전지 효율 향상

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CSi-P-14 결정질 실리콘 마이크로와이어를 이용한 대면적/웨이퍼스케일 실리콘 태양전지

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CSi-P-15 수직 배열된 실리콘 마이크로구조 위 금 나노갭이 형성된 고성능 3D SERS 기판

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CSi-P-16 Simulation-based Feasibility Study on The Optimization Method For Solar Cell Design

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CSi-P-17 태양광-수증기 생성 및 SERS 검출, 이중 기능성 플라즈모닉 나노구조체 기판

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CSi-P-18 태양광-수증기 생성을 위한 dry plasma 환원 기반 광대역 플라즈모닉 흡수체 제작

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CSi-P-19 Applications of zirconia nanocomposites with high refractive index and transparency, and diffusion in silicon solar cells

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CSi-P-20 n-TOPCon 태양전지의 랩어라운드 검출을 위한 머신비전시스템 개발

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CSi-P-21 보론 에미터의 도핑 프로파일과 Ag/Al 전극의 상관관계

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CSi-P-22 유연 박막 결정질 실리콘 태양전지의 효과적인 광흡수 설계

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CSi-P-23 Optimal solar cell sorting method for high module production reliability

*Minseo Kim, Yunae Cho, Sang Hee Lee, Dohyung Kim, Min Gu Kang, Hee-eun Song, Kyung Taek Jeong, **Yong-Jin Kim, **Sungeun Park
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CSi-P-24 RF 스퍼터링 파워 변화에 따른 ITO의 면저항의 변화

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CSi-P-25 실리콘 태양 전지의 터널 산화물 패시베이션 접촉에 대한 열 프로파일 효과

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CSi-P-26 알칼리 폴리싱을 이용한 실리콘 웨이퍼 표면 형태 조절

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CSi-P-27 Polycrystalline on oxide 구조 태양전지의 붕소 도핑된 폴리실리콘을 위한 새로운 패시베이션 층 적용 : 붕소 도핑된 실리콘 옥사이드 (SiO_2 : B)

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CSi-P-28 블록 타입 대면적 일체형 태양광 수전해 시스템

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CSi-P-29 Optimization of radiative cooling effect by anti-reflection layer PDMS for silicon solar cell efficiency

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CSi-P-31 Intrinsic poly-Si을 삽입한 TOPCon 태양전지 후면구조에서의 열적 안정성 분석

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CSi-P-32 Si-Ag 접촉형성을 이용한 페로브스카이트/실리콘 탠덤 태양전지 인터레이어 분석 연구

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CSi-P-33 Analysis of carrier induced degradation in Cz wafer via hydrogen behavior

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**Hae-Seok Lee[2)]
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CSi-P-34 넓은 시야각을 위한 마이크로 카운터보어 배열이 적용된 투명 결정질 실리콘 기판

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CSi-P-35 마이크로 키리가미 구조가 적용된 유연 실리콘 기판

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CSi-P-36 유전체층 및 도핑 농도를 제어를 통한 결정성 실리콘 태양전지 후면 최적화

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CSi-P-37 마이크로 홀의 종횡비에 따른 투명 결정질 실리콘 기판의 광학적 특성 연구

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CSi-P-38 투명 마이크로 구를 이용한 결정질 실리콘 마이크로선 태양전지의 입사각에 따른 효율 감소 개선 연구

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Topic 2. CiS : II-VI & chalcogenide compound based cells and materials

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CiS-P-1 밴드갭 튜닝된 (A)CI(G)S와 페롭스카이트로 제조된 2단자 탠덤 태양전지의 최적화

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CiS-P-2 Tailoring the Bandgap Grading of Ag-Alloyed CIGS Solar Cells for Enhanced Photocurrent and Efficiency

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CiS-P-3 유연 CIGS 박막 태양전지의 기계적 내구성 분석

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CiS-P-4 RF 마그네트론 스퍼터링법으로 증착된 Cu_2O 박막의 물리적 특성에 대한 산소 유량의 영향

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CiS-P-5 과열된 태양열 공기 히터를 냉각시키기 위한 그래핀 플레이크와 은 나노와이어로 표면처리 된 고다공성 구리 폼

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CiS-P-6 모놀리식 2단자 CZTSe/Perovskite 탠덤 태양전지의 개방 회로 손실 최소화 및 이해

*무하마드 레한[1,2)], 트란 반 홍[1,2)] 조아라[1,2)], 정인영[1)], 김기환[1,2)], 조준식[1)], 박주형[1,2)], 조윤애[1)], 홍성준[1,2)], 안세진[1,2)], **윤재호[3)], **곽지혜[1,2)], **신동협[1,2)]
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CiS-P-7 과량 Cu_{2-x}-Se 액상에 따른 Cu(In,Ga)Se_2 박막 미세구조 영향 및 이를 적용한 유연 태양전지에 대한 연구

*아웻 마나 아마레, 황인찬, 정인영, 박주형, 송수민, 어영주, 조아라, 안승규, 유진수, 안세진, 곽지혜, **신동협, **김기환
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CiS-P-8 Process dependent physical properties of zinc tin oxide films deposited by sputtering

*Minsu Kim, Yeonju Shin, Donghyo Kim, **Yujeong Ahn, Boyeon Kim, Songhee Lee, Hyomin Kim, **Woo Kyoung Kim
School of Chemical Engineering, Yeungnam University

CiS-P-9 Fabrication and characterization of alkali-alloyed kesterite CZTSSe solar cells

*Namuundari Otgontamir, Hamim Sharif, Temujin Enkhbat, Enkhjargal Enkhbayar, **JunHo Kim
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CiS-P-10 단일집적모듈을 위한 Cu(In,Ga)Se_2 박막 태양전지의 P3 레이저 가공 방식에 따른 전기적 손실 분석

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CiS-P-11 Se 분압이 KF-PDT CIGS 광흡수층의 표면구조 및 셀효율에 미치는 영향

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CiS-P-12 SUS기판을 이용한 유연 CIGS 태양전지 제조

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CiS-P-13 Ag-passivation effects on high efficiency ACZTSSe solar cell

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[1)]Incheon National University, [2)]Daegu Gyeongbuk Institute of Science &Technology

CiS-P-14 Spray-based low band gap CIGSSe colar cell

*Namuundari Otgontamir[1)], Md Salahuddin Mina[1)], Emkhjargal Enkhbayar[1)], SeongYeon Kim[2)], **JunHo Kim[1)]
[1)]Incheon National University, [2)]Daegu Gyeongbuk Institute of Science &Technology

CiS-P-15 투광성 및 광흡수층 두께 차이에 따른 양면수광형 초박막 CIGSe 태양전지 성능에 대한 영향

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CiS-P-16 Physical and Optical Properties of $Zn_{(1-x)}Mg_xO$ for CIGS Solar Cell Application

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CiS-P-17 Investigation of conduction flow and surface potential in S/Se ratio controlled $Sb_2(S,Se)_3$ thin-film solar cells

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CiS-P-18 SnO_2 패시베이션 층을 갖춘 Flexible CZTSSe 박막 태양전지의 성능 향상

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CiS-P-19 Reduced interfacial defects and roughness in $Cu_2ZnSn(S,Se)_4$ thin-film solar cells with In_2S_3 passivation layers

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CiS-P-20 셀레늄 후 열처리 및 정공 수송층 적용을 통한 슈퍼스트레이트 구조 Sb_2Se_3 태양전지의 후면 패시베이션에 관한 연구

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CiS-P-21 유연기판 상에 제조된 무카드뮴 기반 $Cu(In,Ga)Se_2$ 박막 태양전지의 i-ZnO 창층의 물성에 따른 영향

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CiS-P-22 Selective scribing of ITO/glass substrate with picosecond laser

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CiS-P-23 전기도금에 의한 금속 메쉬 투명전극

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CiS-P-24 Sb_2Se_3 박막 태양 전지 효율 향상을 위한 기체 수송 증착법에서 정밀한 Se 유량 제어의 중요성

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CiS-P-25 Application of atomic layer deposited tin dioxide for tandem solar cells

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CiS-P-26 페로브스카이트 탠덤용 전착기반 CZTSSe 박막 태양전지 계면 제어

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CiS-P-27 박막 태양전지를 위한 계층적 금속 네트워크 투명전극

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CiS-P-28 흡수층 형성을 위한 열처리 시간이 CZTSSe 태양전지의 특성에 미치는 영향

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CiS-P-29 화합물 박막 태양전지에서의 Zn(S,O,OH) 버퍼층 연구

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CiS-P-30 용액성장법으로 매우 빠르게 증착된 Zn(O,S) 버퍼층을 가진 $Cu(In,Ga)Se_2$ 박막 태양전지의 p-n 접합 특성

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CiS-P-31 Ag 혼입 순서가 동시진공증발법으로 형성된 CIGS 박막 태양전지 특성에 미치는 영향

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CiS-P-32 thin-CIGS 태양전지의 고효율을 위한 효과적인 후면 패시베션층 연구

*박시내[1], 김준용[1], 김영일[2], 강진규[3], **성시준[3], **김대환[3], **도윤선[1]
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CiS-P-33 광 산란 특성이 우수한 ZnO nanorods

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CiS-P-34 고효율 $CuInSe_2$ 광흡수층 형성을 위한 표면처리 방법 연구

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CiS-P-35 지구상에 풍부한 Kerterite 기반 물질을 이용한 PEC 물분해 광음극과 박막태양전지의 특성

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CiS-P-36 Current path and charge barrier at grain boundaries in heavy alkali doped flexible $Cu(In,Ga)Se_2$ thin film solar cells

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CiS-P-37 DC 스퍼터링 공정을 사용하여 Zn 증착 시간을 조절한 $Cu_2ZnSn(S_xSe_{1-x})_4$ 박막 태양전지의 광전지 성능 향상 분석

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CiS-P-38 ITO 기반 전도성 광학필터를 활용한 컬러 $Cu(In,Ga)Se_2$ 박막 태양전지

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CiS-P-39 효율적인 기상 수송 증착 SnS 박막 태양 전지: 승온 속도의 역할

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CiS-P-40 SnS/CdS 박막 태양전지 성능 향상을 위한 VTD-SnS 흡수체의 상부 표면 개질 연구

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CiS-P-41 열화상 분석법을 이용한 CIGS 박막 태양광 모듈의 단락 결함 특성화

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CiS-P-42 열처리를 통한 CIGS 박막 조성제어

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CiS-P-43 Ge and Cd double cation study to achieve high-efficiency of CZTSSe thin film solar cells

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CiS-P-44 Effect of cation substitution on device performance of $Cu_2ZnSn(S,Se)_4$ thin film solar cells

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Topic 3. QPOD : Quantum dot, perovskite, organic, dye solar cells and materials

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QPOD-P-1 Synthesize various compositions of organolead halide perovskite nanoparticles using ultrasonic spray
*Dong-Jun Kim, Bongjun Choi, **Jung-Yong Lee
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QPOD-P-2 Manipulated Interface for Enhanced Energy Cascade in Quasi-2D Blue Perovskite Light-Emitting Diodes
*Yun Seop Shin, **Jin Young Kim
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QPOD-P-3 Ternary Organic Solar Cells Using New Non-Fullerene Acceptors Based on the Y Series Structure
*Donghwan Yun, Yunhye Jeong, Gwangyong Shin, **Gi-Hwan Kim
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QPOD-P-4 Effect of PFI buffer-HIL with PEDOT:PSS for High Efficiency of Perovskite Nanocrystal Light-Emitting Diodes
*Gwangyong Shin[1)], Minsik Gong[1)], Donghwan Yun[1)], Yeongwoo Ha[1)], Yunhye Jeong[1)], Vivek Vishal Sharma[2)], **Gi-Hwan Kim[1)]
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QPOD-P-5 평면 이종 접합을 이용한 고효율 유무기 하이브리드 태양전지 설계
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QPOD-P-6 단분자 브릿지 도입을 통한 양자점/유기 하이브리드 태양 전지의 근적외선 흡수 향상
*김병수[1)], 백세웅[2)], **이정용[1)]
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QPOD-P-7 Improvments perovskite solar cell with surface passivation by using $SnCl_4$
*Jiwon Song[1,2)], Minjin Kim[1)], **Dong Suk Kim[2)]
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QPOD-P-8 스핀코팅법을 통한 대면적 페로브스카이트 태양전지 기술개발
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QPOD-P-9 용해된 분자의 동적 THz 스타크 효과

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QPOD-P-10 반도체의 초고속 전계 유도 캐리어 생성 역학

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QPOD-P-11 시간 분해 분광법을 통해 혼합 페로브스카이트 박막의 향상된 광전자 특성 규명

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QPOD-P-12 1.5V 이상 고전압 태양전지 제작을 위한 와이드 밴드갭 페로브스카이트 소재의 격자면 최적화

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QPOD-P-13 Passivation Strategy for Perovskite film via Schiff Base Reaction for Highly Stable Perovskite Solar Cells

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QPOD-P-14 Suppression of Undesirable Losses in Organometal Halide Perovskite-Based Photoanodes

Hojoong Choi[1)], *Young Yun Kim[2)], Sehun Seo[3)], Yoonsung Jung[1)], Seungkyu Kim[1)], So-Min Yoo[2)], **Nam Joong Jeon[2)], **Jangwon Seo[2,4)], **Sanghan Lee[1)]
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[2)]Korea Research Institute of Chemical Technology,
[3)]Lawrence Berkeley National Laboratory,
[4)]Korea Advanced Institute of Science and Technology (KAIST)

QPOD-P-15 TFSI 용액을 이용한 CsPbI3 페로브스카이트 태양전지의 안정성 향상

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QPOD-P-16 적외선 하베스팅 양자점 태양전지에서의 광흡수층 두께 조절 연구

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QPOD-P-17 High Performance and Long-Term Stability of PM6:Y6 based Inverted Organic Photovoltaic Device

*Eun Hye Kwon[1)], Febrian Tri Adhi Wibowo[1)], Bomin Kim[1)], Seo-Hyun Park[1)], Dong-Hu Kim[1)], **Sung-Yeon Jang[1,2)]
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QPOD-P-18 Rationally Designed Eco-friendly Solvent System for High-performance, Large-area Perovskite Solar Cells and Modules

*Young Yun Kim[1)], Su-Mi Bang[2)], Geunjin Kim[2)], Jason J. Yoo[1)], Eun Young Park[1)], **Nam Joong Jeon[1)], **Jangwon Seo[3)]
[1)]Korea Research Institute of Chemical Technology, [2)]Hanwha Solutions,
[3)]Korea Advanced Institute of Science and Technology(KAIST)

QPOD-P-19 Scalable Fabrication of High-performance Perovskite Solar Modules and their Application to High Power Output Solar Rechargeable Batteries

*Young Yun Kim, Se-Hee Kim, You-Hyun Seo, Hyunseo Kim, **Jungdon Suk, **Nam Joong Jeon
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QPOD-P-20 열적으로 안정하고 비할로겐 용매 가공 가능한, 트라이플루오로메틸기가 도입된 비대칭 비풀러렌 수용체 개발과 이 물질 기반 유기태양전지 특성 연구

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QPOD-P-21 Surface-functionalized self-assembled monolayer for high efficiency single wide-bandgap and monolithic tandem perovskite solar cells

*Yeonghun Yun[1)], Sung Woong Yang[1)], Sunwoo Kim[1)], Doyun Im[1)], Yewon Kim[1)], Yunmo Kang[1)], Myeong-geun Choi[1)], **Jaeyeong Heo[2)], **Dong Hoe Kim[3)], **Sangwook Lee[1)]
[1)]Kyungpook National University, [2)]Chonnam National University, [3)]Korea University

QPOD-P-22 Strategy for Reducing Non-radiative Recombination in Dye-sensitized Solar Cell

*Seungrok Kim, **Tae-hyuk Kwon
Department of Chemistry, Ulsan National Institute of Science and Technology

QPOD-P-23 확산을 통해 캐리어 이동성이 향상된 고효율 납 셀렌화물 콜로이드 양자점 태양전지

*임채연[1,2)], **송정훈[3)], **정소희[1,2)]
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[2)]Sungkyunkwan Institute of Energy Science & Technology,
[3)]Department of Semiconductor Applied Physics, Mokpo National University

QPOD-P-24 CPEK segment improving stretchability of PEDOT:PSS as Hole Transport Layer in Organic Solar Cells

*Min-Seong Ju[1,2)], Jong-Woon Ha[1)], Byoungwook Park[1)], Seunghyun Rhee[1)], **Seo-Jin Ko[1)]

[1)]Division of Advanced Materials, Korea Research Institute of Chemical Technology (KRICT), [2)]Department of Chemistry, Research Institute for Convergence of Basic Science, and Research Institute for Natural Sciences, Hanyang University

QPOD-P-25 Inverted perovskite photocathode boosting photocurrent of lignin-based bias-free solar hydrogen production

*Sang-Hak Lee[1)], Jin-Ha Hwang[1)], Su-Ho Lee[1)], Seung-Hee Han[1)], Jeong-Ye Baek[1)], **Sung-Yeon Jang[1,2)]

[1)]School of Energy and Chemical Engineering, UNIST,
[2)]Graduate School of Carbon Neutrality, UNIST

QPOD-P-26 Thermally stable perovskite solar cells realized by regulating additives of the thermally unstable Spiro-MeOTAD

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[1)]School of Chemical Engineering, Center for Antibonding Regulated Crystals, Sungkyunkwan University (SKKU), [2)]SKKU Institute of Energy Science and Technology (SIEST), Sungkyunkwan University (SKKU)

QPOD-P-27 페로브스카이트 첨가제 및 조성비 조절을 통한 반투명 페로브스카이트 태양전지 성능 개선

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한국화학연구원

QPOD-P-28 Polymer Electrode with High Stretchability and Conductivity Based PEDOT:PSS

*Se Eun Cho, **Seunghyun Rhee, **Seo-Jin Ko
Division of Advanced Materials, Korea Research Institute of Chemical Technology (KRICT)

QPOD-P-29 Phase-Pure Quasi-2D Perovskite by Protonation of Neutral Amine

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QPOD-P-30 Crystal growth control of perovskite via urea additives in vacuum-processed perovskite solar cells

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QPOD-P-31 Non-fullerene acceptor based organic photovoltaics with thermal stability: Sequential deposition and use of quasi-orthogonal solvents

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QPOD-P-32 Self-assembled monolayer passivated on NiOx hole transport layer for p-i-n perovskite solar cells

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QPOD-P-33 전극 형성용 Plasma Assisted Vapor Deposition(PAVD) 기술 페로브스카이트 태양전지 적용 가능성 연구

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QPOD-P-34 Preparation of alkali metal-doped TiO_2 nanoparticles for application to electron transport layer of mesoscopic perovskite solar cells

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QPOD-P-35 공액고분자 전해질을 리간드로 사용한 페로브스카이트 박막 위의 리간드 치환 방식

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QPOD-P-36 광활성을 σ-홀을 이용한 스마트 윈도우 태양전지

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QPOD-P-37 라만분광분석을 통한 염료감응형 광전극의 비파괴 깊이 프로파일 분석

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QPOD-P-38 Enhancing photovoltaic performance by controlling crystallization kinetics of α-$FAPbI_3$

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QPOD-P-39 Suppressing process-dependent PbI_2 residue to enhance stability of efficient perovskite solar cell

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QPOD-P-40 The Fabrication of Tin-lead Perovskite Solar Cells via Metal-assistant Precursor Solution Strategy

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QPOD-P-41 효과적인 플렉서블 페로브스카이트 태양전지를 위한 SnO_2-TiO_2 하이브리드 전자 수송층

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QPOD-P-42 금속보호층과 촉매층이 도입된 NIP구조의 페로브스카이트 태양전지를 통한 태양광 물분해

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QPOD-P-43 Highly Efficient and Stable Perovskite Solar Cell with 1D-3D Mixed Dimensional Perovskite
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QPOD-P-44 Interfacial Hydrazine Derivatives for High Voltage Tin Lead Alloyed Perovskite Solar Cells
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QPOD-P-45 Unassisted photoelectrochemical water splitting with coupled lead halide perovskite photoelectrodes
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QPOD-P-46 Achieving 9.16% Applied Bias Photon-to-Current Efficiency with monolithic lead halide perovskite photoelectrochemical cell
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QPOD-P-47 High-performance Inverted Perovskite Solar Cells via Vacuum Thermally Evaporated N-type Rylene Diimide Derivatives as Cathode Interlayer
*Hye Seung Kim, Min Ah Park, **Myoung Hoon Song
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QPOD-P-48 Enhancing Reverse Bias Stability of the Planar Perovskite Solar Cells by TiO_2 Hole Blocking Layer
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QPOD-P-49 Stabilizing α-$FAPbI_3$ at the $FAPbI_3/SnO_{2-x}$ Interface by Reducing Oxygen Vacancies in SnO_{2-x}
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QPOD-P-50 고효율 대면적 유기 태양전지를 위한 고분자 억셉터 개발
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QPOD-P-51 역구조 페로브스카이트 태양전지에서 자가조립단층의 알킬 사슬 길이에 따른 페로브스카이트 박막 특성

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QPOD-P-52 백금복합체 기반 광하향변환 전략을 통한 페로브스카이트 태양전지의 성능 및 안정성 향상

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QPOD-P-53 Development of Dye-Sensitized Photo-Rechargeable Flow battery for indoor light harvesting

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QPOD-P-54 Ternary Blend Based High Performance Organic Solar Cells Under Indoor Conditions

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QPOD-P-55 Highly improved photocurrent density and efficiency of perovskite solar cells via inclined fluorine sputtering process

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QPOD-P-56 페로브스카이트 태양전지의 보관 안정성과 유동이온 확산의 상관관계 해석

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QPOD-P-57 Anti-solvent dripping에 따른 준-2차원 페로브스카이트 상 분포 분석

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QPOD-P-58 Manipulating Trap Density with Anti-solvents for Perovskite-based Indoor Photovoltaic Devices in Self-Sustaining IoT Systems

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QPOD-P-59 Spiro-OMeTAD 정공수송층의 유기 도펀트 도입을 통한 페로브스카이트 태양전지 안정성 향상

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QPOD-P-60 Effective solvent recycling strategy for the eco-friendly perovskite solar cell

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QPOD-P-61 Recovery of Toxic Solvents for Eco-friendly Recycling Strategy of Perovskite Solar Cells

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QPOD-P-62 Engineering Halide Perovskite-Based Green Photodetectors for Enhanced Responsivity and Detectivity by Composition, Additive, and Process Optimization

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QPOD-P-63 비대칭 단분자 어셉터를 이용한 대면적 유기태양전지 개발

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QPOD-P-64 Enhanced Reproducibility of Tin-based Perovskite Solar Cells Using 2D Material as a Cathode Interfacial Layer

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QPOD-P-65 Improved performance and stability of perovskite solar modules by interface modulating with multifunctional ligand

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QPOD-P-66 Atomic Layer Deposition of Vanadium Containing Hole Transport and Passivation Bi-Functional Layer for Highly Efficient and Stable α-$FAPbI_3$ Perovskite Solar Cells (>23%)

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QPOD-P-67 Achieving long-time operational perovskite solar cells through multifunctional additive engineering

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QPOD-P-68 근적외선 흡수 스펙트럼을 통한 고성능 페로브스카이트/유기 하이브리드 태양전지

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QPOD-P-69 Impact of passivation of SnO_2 film surface on efficiency and stability of perovskite solar cells

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QPOD-P-70 Pseudo-bilayered inverted organic solar cells using Marangoni effect

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QPOD-P-71 비금속 프탈로시아닌을 이용한 고효율/고안정성 페로브스카이트 태양전지

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QPOD-P-72 발광 태양 집광기를 이용한 염료감응형 태양광결합의 전력변환효율 향상

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QPOD-P-73 MAPbI3 페로브스카이트 태양전지의 매립 계면을 위한 A-π-D-π-A 구조의 효율적인 다기능 패시바이터

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QPOD-P-74 평탄한 표면의 고효율 페로브스카이트 태양전지 제작을 위한 고온 반용매 처리법
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QPOD-P-75 대면적 OSC용 고결정성 레지오레귤러 폴리머 반도체
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QPOD-P-76 Improved photovoltaic performance due to the introduction of quinoxaline-based polymeric donors through engineering of non-fullerene backbones for organic solar cells
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QPOD-P-77 습윤성 차이를 활용한 Sn-Pb 기반 저밴드갭 페로브스카이트 패터닝 및 8 by 8 crossbar array 근적외선 검출기 개발
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QPOD-P-78 $CsPbBr_3$ 페로브스카이트 태양전지 제조를 위한 양이온 교환 전략
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QPOD-P-79 혼합 할로겐 페로브스카이트에서의 광유도 할로겐 편석 In-situ 관측
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QPOD-P-80 Self-assembled electron transport layer in polymer solar cells using Indolocarbazole-based conjugated small molecular electrolytes
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QPOD-P-81 전기증착으로 만든 염료감응형 태양전지용 효요적이고 투명한 FeNiCoSe상대전극
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QPOD-P-82 In-situ intramolecular synthesis of tubular carbon nitride S-scheme homojunctions with exceptional in-plane exciton splitting and mechamism insight

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QPOD-P-83 기능성 유기 분자의 정공수송층 표면처리를 통한 고효율 저밴드갭 페로브스카이트 태양 전지 개발

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QPOD-P-84 상분리 억제를 통한 고안정 페로브스카이트/페로브스카이트/실리콘 삼중접합 탠덤 태양전지

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QPOD-P-85 광전자분석을 이용한 HTL 두께에 따라 달라지는 광전하 특성

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QPOD-P-86 SCLC 방법을 사용한 하이브리드 페로브스카이트 박막의 전하 이동 양상과 결함 밀도 규명

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QPOD-P-87 첨가물 작용기에 따른 페로브스카이트 광 안정성 향상 및 passivation 특성 분석

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QPOD-P-88 Efficient Monolithic Perovskite/Perovskite/Si Triple Junction Tandem Solar Cells with an Efficiency over 20%

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QPOD-P-89 Large-Area Organic Solar Cell Modules Fabricated by a Doctor Blade Coating Process

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QPOD-P-90 MA1-xGAxPbI3 페로브스카이트 태양전지의 결정립내 구조 제어 효과

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QPOD-P-91 Air-stable $CsPbI_2Br$ Perovskite Solar Cells Introduction of MACl Additives

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QPOD-P-92 금속유기골격체(Metal-organic Frameworks)를 사용한 역구조(p-i-n) 페로브스카이트 태양전지 안정성 향상

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QPOD-P-93 Maximizing Photoluminescence Quantum Efficiency of stacked halide layer via combination of bulk and interface engineering

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QPOD-P-94 광흡수층 상부 고상 계면 처리를 통한 무기 페로브스카이트 태양전지의 안정성 향상에 관한 연구

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QPOD-P-95 Extraction method of mobile ion density for organic-inorganic halide perovskite solar cells

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QPOD-P-96 상온 및 25% 습도 조건에서 가스 퀜칭 기법을 이용한 넓은 밴드갭 페로브스카이트 태양전지의 재현 가능한 제조 방법 개발

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[2)]고려대학교 KU-KIST 그린스쿨 에너지환경대학원, [3)]고려대학교 융합에너지공학과

QPOD-P-97 Spatial and Energy Trap Distribution of Wide-bandgap $MAPbBr_3$ Perovskite Thin Film

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QPOD-P-98 디바이스 구동조건에서의 혼합 양이온 FA 기반 페로브스카이트 태양전지의 열화 메커니즘

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QPOD-P-99 Band-Aligned and Defect-Suppressed Interlayers for High-Efficiency Indoor Organic Photovoltaics (>33%)
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QPOD-P-100 Stable Methylammonium-Free Wide Bandgap Perovskite for Efficient Photovoltaics
*Geon Pyo Hong, Su Geun Ji, **Jin Young Kim
Department of Materials Science and Engineering, Seoul National University

QPOD-P-101 Double layer를 도입한 $CsPbI_3$ perovskite solar cell의 성능 개선
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QPOD-P-102 $Mn(TFSI)_2$을 도판트로 이용한 정공수송층의 즉각적인 계면 처리로 효율적이고 안정적인 무기 페로브스카이트 태양전지 제조
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QPOD-P-103 Improving Interfacial Recombination of Heterojunction Electron Transport Layer via Defect Engineering for Efficient Perovskite Solar Cells Over 23%
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QPOD-P-104 고효율의 단분자 기반의 유기 태양전지 및 탠덤 태양전지를 위한 염소화 전략의 도입
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QPOD-P-105 화학양론적으로 제어된 콜로이드 코발트 황화물 나노 입자에 기초한 페로브스카이트 태양전지 성능 향상
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QPOD-P-106 효율적인 패시베이션을 위한 페로브스카이트 태양전지에서 (α-Methylguanido)acetic Acid의 최적 위치 탐구
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QPOD-P-107 페로브스카이트 태양전지 정공수송층에 사용되는 아민 기반 랜덤 공중합체의 합성
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QPOD-P-108 무기 페로브스카이트 태양전지 안정성 향상을 위한 3차원 양쪽성 이온 도입

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QPOD-P-109 라미네이트된 동질 접합 정공 수송층을 이용한 실내 광전지의 획기적인 성능 향상

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QPOD-P-110 Preparation and Characteristic of $Cu_{2-x}S$ on Nickel thin layer as a counter electrode for quantum dot sensitized solar cells

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QPOD-P-111 친환경 유기태양전지에 적합한 신규 랜덤 공중합체 신규 도너 개발

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Jonnadula Venkata Suman Krishna[2)], 권오훈[3)], **김진영[1,4)], **우한영[2)]
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QPOD-P-112 에탄올 기반의 á-formamidinium lead triiodide 페로브스카이트 층의 친환경 용액 공정

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QPOD-P-113 Understanding the Synergistic Influence of Propylammonium Bromide Additive and Erbium Doped $CsPbI_2Br$ for Highly Stable Inorganic Perovskite Solar Cells

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QPOD-P-114 RF-마그네트론 스퍼터링을 이용하여 증착된 산화주석 박막의 전기적, 광학적 특성 연구

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QPOD-P-115 진공증착한 페로브스카이트 전구체 특성 분석 및 용액 공정을 통한 변환

*이원규[1)], 황재근[1)], 정석현[1)], 김동환[1)], 강윤묵[2)], **이해석[2)]
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QPOD-P-116 페로브스카이트 태양전지의 2차원 광 발광 이미지 분석

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김도형[1)], 정경택[1)], 전용석[2)], **박성은[1)]
[1)]한국에너지기술연구원 태양광연구단, [2)]고려대학교 에너지환경대학원 (그린스쿨)

QPOD-P-117 Metal ion doping and quantum dot passivation approach for stabilizing γ-$CsPb(I_{1-x}Br_x)_3$ inorganic perovskite solar cells

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Chonnam National University

QPOD-P-118 Non-fullerene Acceptors with Alkylthiothiophene Side Chains for Efficient Non-halogenated Solvent Processed Indoor Organic Photovoltaics

Na Gyeong An, *Dohun Yuk, **Jin Young Kim
Ulsan National Institute of Science and Technology (UNIST)

QPOD-P-119 Advances in Tandem Solar Cell : Perovskite/Silicon Triple-Junction with Transparent Conductive Adhesive Lamination Process

*Subin Yu, In Choi, Seo Yeong Lee, **Min Jae Ko
Hanyang University

QPOD-P-120 Understanding the Degradation Effect of Potential-Induced Degradation (PID) in Perovskite Solar Cells

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QPOD-P-121 Optimization of Nickel Oxide Films using vacuum process and oxidation process for p-i-n perovskite solar cells

*Sujin Cho[1)], Jae-Keun Hwang[1)], Dowon Pyun[1)], Seok-Hyun Jeong[1)], Solhee Lee[1)], Wonkyu Lee[1)], Ji-Seong Hwang[1)], Hae-Seok Lee[2)], Donghwan Kim[1)], **Yoonmook Kang[2)]
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QPOD-P-122 Fabrication of Pinhole Free Perovskite Films in Ambient Humidity Condition Using Diethyl Ether as Antisolvent

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QPOD-P-123 실버 나노와이어를 상부 전극으로 한 바코팅 공정의 양면 황화납 양자점 태양전지

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QPOD-P-124 Eliminating bulk and interface traps for realizing efficient and brigh perovskite solar cells

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QPOD-P-125 페로브스카이트 태양전지의 산화주석에 대한 전기적 특성 강화를 위한 염화물 수동태화

*정석현[1)], 이원규[1)], 이솔희[1)], 이상원[1)], 황재근[1)], 이해석[2)], 김동환[1)], **강윤묵[2)]
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QPOD-P-126 Structural modulation of Zn doped Sn-based perovskite solar cells

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QPOD-P-127 페로브스카이트 태양전지의 부동화를 위한 요오드화 페닐트리에틸암모늄 후처리

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QPOD-P-128 루이스 산-염기 부가체를 통한 페로브스카이트 결정립 크기 조절 및 페로브스카이트 태양전지 효율 향상

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QPOD-P-129 Improved Performance and Stability of Organic Solar Cells Enabled by Interface Engineering

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Julius Mwakondo Mwabora[2)], Robinson Juma Musembi[2)]
[1)]Energy Materials Research Center, Korea Research Institute of Chemical Technology (KRICT), [2)]Department of Physics, Faculty of Science and Technology, University of Nairobi (UoN)

QPOD-P-130 Simple approach for an electron extraction layer in an all-vacuum processed n-i-p perovskite solar cell

*·***Beom-Soo Kim[1,2)], Daniel Pérez-del-Rey[1)], Abhyuday Paliwal[1)], Chris Dreessen[1)], Michele Sessolo[1)], **Henk J. Bolink[1)]
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Topic 4. GaP : III-V compound based concentrator and space PV systems

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 오키드(2F)

Gap-P-1 에폭시 접합 기반 Mechanical Stacked III-V/Si 탠덤 태양전지 소자의 상부 InGaP/GaAs 2J 셀 효율 개선

*장승훈[1], 김나영[1], 정철[1], 이욱철[1], 신현범[1], 한승용[2], 김영국[2], 이준신[2], **강호관[1]
[1]한국나노기술원, [2]성균관대학교

Gap-P-2 나노폴리스텔린 구체를 이용하여 성장한 InP III-V 나노로드의 전기적 특성

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Gap-P-3 플라즈마 활성화에 의한 역방향 III-V족 이중 접합 태양전지와 실리콘 웨이퍼의 직접 웨이퍼 접합 공정

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Gap-P-4 See-Through Flexible Photovoltaic Modules of Ultrathin Silicon Solar Microcells Enhanced by Synergistic Luminescent and Reflective Near-Infrared Backplanes

*Whibeom Cho, Shin Hyung Lee, Woonhae Go, **Sung-Min Lee
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Topic 5. MSI : PV module, system and integration

▶ 일 시 : 2023년 3월 30일(목)
▶ 장 소 : 웨스틴조선부산 오키드(2F)
▶ 좌 장 : 황혜미 (한국에너지기술연구원)

MSI-P-1 건축물 태양광에서의 MLPE 인버터 및 스트링 인버터 운전사례 비교 연구
*·**배상순[1)], 홍찬호[2)]
[1)]기후변화대응 에너지전환 협동조합 운영위원회, [2)]유한대학교 전기공학과

MSI-P-4 p-PERC 갈륨 태양전지 모듈 대상 광열화 현상 회복 과정의 화학 반응 동역학 분석
김수민
Gumi Electronics & Information Technology Research Institute

MSI-P-5 Monolithic pattern 구조의 대면적 perovskite 모듈을 위한 RF reactive sputtered-TiO_2 전자 전달층 연구
*김재호, 김문회, 김효정, **양정엽
Department of Physics, Kunsan National University

MSI-P-6 쉉글드 디자인 고출력 양면수광형 단결정 실리콘 태양광 모듈 제작
*이은비[1)], 박민준[2)], 김정훈[1)], **정채환[2)]
[1)]연세대학교 화공생명공학부, [2)]한국생산기술연구원 그린에너지나노연구그룹

MSI-P-7 건물부착형 고경량 유연성 쉉글드 태양광 모듈
*김민섭[1,2)], 윤성민[2)], 박성준[1)], **정채환[2)]
[1)]전남대학교 전기공학과, [2)]한국생산기술연구원 그린에너지나노연구그룹

MSI-P-8 샌드위치 구조의 폴리실라잔 박막과 이를 이용한 박막 봉지 기술
*김다정, **박노창
한국전자기술연구원 신재생에너지연구센터

MSI-P-9 산화 실리콘 나노 박막 기반 태양전지 봉지 기술 개발
*박노창[1)], 김다정[1)], 전경국[2)], 조명기[3)], 김종현[2)], **유기준[3)]
[1)]한국전자기술연구원 신재생에너지연구센터, [2)]아주대학교 분자과학기술학과,
[3)]연세대학교 전기전자공학부

MSI-P-10 2D/3D 이중층 구조를 통한 안정적인 페로브스카이트 태양전지
*최원규, **정재성
한국전자기술연구원

MSI-P-11 ECA를 활용한 Multi-busbar HJT 모듈의 repair 공정에 관한 연구
*전다영, 문지연, 박고등, 오트곤게렐 줄만다크, 남혜령, 권오련, 임현수, **김성현
한국전자기술연구원 신재생에너지연구센터

MSI-P-12 Comparison of the Power Generation of Building Integrated Photovoltaics by Seasonal Change

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**Woo Kyoung Kim
School of Chemical Engineering, Yeungnam University

MSI-P-13 Performance Evaluation of Bifacial and Monofacial PV Modules Depending on Albedo Condition

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MSI-P-14 불소계 고분자를 이용한 태양전지 전면 인쇄 은전극의 내산성 강화 방안

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MSI-P-15 태양광 전기에너지의 직·병렬 혼합 토폴로지로 구성된 일대다중모듈 자기공진 무선전력전송 시스템을 위한 최적화 방안

*이정하[1)], 변철우[2)], 이승법[1)], **오민석[1)]
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MSI-P-16 쌀 재배 농지에서 영농형 태양광발전시스템 최적 설계 방법 연구

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MSI-P-17 수상태양광 이용률 향상 검증을 위한 양면형 모듈 실증시스템 구축 및 분석

*,**이지은, 조현식, 임지연, 김현준
한국수자원공사 K-water연구원

MSI-P-18 탄소중립을 위한 경상남도 에너지자립마을 선도모델 연구

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경상국립대학교 에너지공학과, 미래융복합기술연구소

MSI-P-19 신재생에너지 기반 마을 단위 마이크로그리드 비즈니즈모델 연구

*,**이여름, 박영훈, 손준혁, 이효배, **김광천
한국전기산업진흥회 에너지밸리기업개발원

MSI-P-20 색균형 다중 형광 염료를 포함하는 폴리디메틸실록산 폴리머 및 투명 발광형 태양광 집광장치 응용

*이찬용[1)], 조효빈[1)], 고종원[2)], 김승규[1)], 고요한[3)], 박시은[1)], 강윤묵[1)], 윤용주[1)], **전용석[1)]
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[2)]Department of Materials Science and Engineering, Korea University,
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MSI-P-21 대면적 페로브스카이트 태양광 모듈 응용을 위한 진공 스퍼터 방식으로 제작된 SnO_2 박막 연구

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MSI-P-22 페로브스카이트 태양전지 모듈화 공정 연구

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MSI-P-23 정확한 태양광 발전량 예측을 위한 Extreme Gradient Boosting 모델

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MSI-P-24 랜덤 포레스트 알고리즘 활용한 고정확도 태양광 발전량 예측

*김영언, 응웬 트리 찬 흥, **모드 샤히르 아크탈
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MSI-P-25 물리모델과 기계학습모델을 이용한 태양광 발전성능 추정 기술

*오현규[1,2], 신우균[2], 주영철[2], 배수현[2], 황혜미[2], 강기환[2], **고석환[2], **장효식[1]
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[2]한국에너지기술연구원 재생에너지연구소 태양광연구단

MSI-P-26 출력복원한 에코모듈의 실증모니터링을 통한 I-V Curve 특성 분석

*·**최현석, 정재원, 박상수, 이태훈
한국조명ICT연구원

MSI-P-27 M12 태양전지를 이용한 645Wp급 대면적·고효율 양면형 태양광모듈 개발 및 필드실증

*김지현[1,2], 김주희[2], 김정훈[3], **김창헌[2]
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MSI-P-28 소용량 노후 PV 모듈의 수명예측 및 고장진단 알고리즘 개발을 위한 현장시험 분석

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(재)녹색에너지연구원 태양에너지연구실

MSI-P-29 태양광발전시스템에서 부분 음영에 따른 모듈 단위 마이크로 컨버터 특성 연구

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MSI-P-30 싱글드 모듈 백 시트에서의 빛 반사 분석

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MSI-P-31 고출력 태양광 모듈 제작을 위한 유한요소법 기반 대면적 모듈의 처짐 현상에 관한 연구

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한국생산기술연구원

MSI-P-32 FTO 박리현상을 이용한 태양광 모듈 유리 분리 및 메커니즘 확인

*고종원[1)], 배수현[1)], 강윤묵[2)], 이해석[2)], **김동환[1)]
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MSI-P-33 Bifacial p-PERC 태양광 모듈에서의 PID로 인한 polarization effect 연구

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MSI-P-34 PCM을 적용한 ESS 배터리 함체의 온도관리에 관한 수치해석 연구

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MSI-P-35 N 타입 태양전지의 고전압 열화 (PID) 현상

배수현
한국에너지기술연구원 태양광연구단

MSI-P-36 비닐하우스 사이 공간을 활용한 수직형 영농형 태양광 발전설비 개발

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MSI-P-37 원통형 배터리 모듈에서 셀과 셀 사이 냉각관 삽입 구조에 대한 냉각 성능 해석적 연구

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MSI-P-38 고출력 N-Type HJT 모듈 제작을 위한 저온 Soldering 연구

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Topic 6. ReS : PV reliability and standardization

▶ 일 시 : 2023년 3월 31일(금)

▶ 장 소 : 웨스틴조선부산 오키드(2F)

ReS-P-1 그린허브스테이션 활용을 위한 AI 기반 태양광 발전량 예측 알고리즘 개발

*이민호, 장미금, 정승환, 최지은, **이석호
(재)녹색에너지연구원

ReS-P-2 태양광연계를 위한 재사용 배터리 표준·인증 동향

*김주희[1], 김지현[1,2], **김창헌[1]
[1](재)녹색에너지연구원 태양에너지연구실, [2]전남대학교 광공학협동과정

ReS-P-3 부분음영, 컬러모듈 적용에 따른 시제품 마이크로컨버터 필드실증

*김지현[1,2], 김주희[2], **김창헌[2]
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Topic 7. HPV : Hybrid photovoltaics

- 일 시 : 2023년 3월 30일(목)
- 장 소 : 웨스틴조선부산 오키드(2F)
- 좌 장 : 임효령 (부경대학교)

HPV-P-1 Plasmonic Effect of Au Nanoparticles in InGaN/GaN Multiquantum Wells for Unbiased Solar-Driven Water Splitting

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HPV-P-2 Two-zone Furnace로 합성한 GeSe와 광전기화학적 물분해의 적용

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HPV-P-3 정공 수송층 최적화를 통한 저조도 실내용 페로브스카이트 광전변환 효율 향상

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HPV-P-4 레이저 조사 그래핀 상단에 코팅된 온도 감응성 다차원 혼합 필러 기반 무선, 신뢰성, 유연성을 갖춘 온도 센서 시스템

*김현준[1)], 고광명[2)], **임효령[1)], **좌용호[2)]
[1)]부경대학교, [2)]한양대학교

HPV-P-5 실리콘 웨이퍼 상단에 형성된 나노구조 알루미나 친수성/소수성 특성

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[2)]Department of Biotechnology, Pukyong National University,
[3)]Major of Human Bioconvergence, Pukyong National University

HPV-P-6 A Wide Bandgap Halide Perovskite Based Self-Powered Blue Photodetector with 84.9% of External Quantum Efficiency

*Yeonghun Yun[1)], Gill Sang Han[2)], Sung Woong Yang[1)], Jina Jung[1)], Won Chang Choi[1)], Rajendra Kumar Gunasekaran[1)], **Hyun Suk Jung[2)], **Sangwook Lee[1)]
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HPV-P-7 Establishing a firm electrolyte/metal electrode interface for high-performance composite polymer electrolyte-based all-solid-sate Li-metal batteries

*Hasan Jamal[1)], Firoz Khan[2)], Eunhui Kim[3)], **Jae Hyun Kim[4)]
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HPV-P-8 Nonflammable Deep Eutectic Electrolytes Containing Fluorinated Acetamide Solvent for Lithium-Oxygen or Lithium-ion Batteries

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HPV-P-9 단결정 TiO_2로 보호된 할로겐화물 페로브스카이트 태양전지 기반 광전기화학적 물분해 소자

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HPV-P-10 휘발성 알킬암모늄 염화물을 이용한 페로브스카이트 층의 성장 제어

*박재왕, 김종범, **석상일
Energy Engineering, Ulsan National Institute of Science and Technology

HPV-P-11 High Performance Solar Water Splitting of CdS loaded Hierarchical ZnO-GaN Nanowires on Si for efficient H_2 evolution

*Fawad Tariq, **Sang-Wan Ryu
Department of Physics, Chonnam National University

HPV-P-12 후면전극형 구조 기반의 변형 가능한 결정질 실리콘 소형 태양광 모듈

*박정환, **서관용
울산과학기술원

HPV-P-13 게이트 전압으로 제어 가능한 광 검출기 및 양극성 트랜지스터

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HPV-P-14 Porous Au@g-C_3N_4 전극을 이용한 효과적인 전기화학적 이산화탄소 환원

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HPV-P-15 Low temperature growth of SiO_2 thin film deposited by atomic layer deposition

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HPV-P-16 Colloidal Ni_2P Nanocrystals Encapsulated in Heteroatom-Doped Graphene Nanosheets: A Synergy of 0D@2D Heterostructure Towards Overall Water Splitting

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HPV-P-17 광전기화학적 이산화탄소 환원 효율 향상을 위한 $CuO/g\text{-}C_3N_4$ 전극의 설계 및 제작

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HPV-P-18 고효율 주석 기반 페로브스카이트 태양전지를 위한 박막의 두께 증가 전략

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HPV-P-19 에탄올 산화제를 이용한 ALD 기반 페로브스카이트 패시베이션용 금속 산화물층 연구

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HPV-P-20 In-situ induced oxygen vacancies during rapid synthesis of Ni:FeOOH boosts the water oxidation activity and stability of $BiVO_4$ photoanode

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탄소중립 국제 동향과 우리의 대응

이 상 훈[1)]

한국에너지공단 이사장

NET-ZERO INTERNATIONAL TRENDS AND OUR RESPONSE

Sanghoon Lee[1)]

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Abstract :

국제사회는 2015년 파리협정을 시작으로 2021년 신기후체제를 공식 출범하였고 기후위기 대응을 위한 탄소중립은 역사적인 흐름이자 거스를 수 없는 대세로 인식되고 있다. 현재까지 기후변화협약 198개 회원국 중 97%인 193개국이 탄소중립에 참여하고 있으며 이를 법제화한 국가는 모두 21개국이다.

맥킨지 글로벌 연구소는 매년 9.2조 달러씩 30년간 275조달러를 투자해야 2050 Net-Zero 달성이 가능하다고 보고있으며, 유럽(`30년까지 1조 유로 투자계획 명시), 미국(`25년까지 2조 달러이상 투자), 중국(`50년까지 70~174조 위안 투자) 등 주요국들이 적극적으로 글로벌 기후 위기 대응에 앞장서고 있다.

국제에너지기구(IEA)에서는 에너지 수요 감축 및 탄소중립으로 가는 최우선 정책수단으로 에너지효율향상(37%)을 강조하고 다음으로 재생에너지 보급(32%)을 언급하고 있다. 효율 향상시책으로 제로에너지빌딩 적용, 냉난방 에너지 절감, 전기차 인프라 구축, 화석연료 보일러 금지 등을 제시하고, 재생에너지는 지속적으로 발전단가가 감소하고 있는 태양광과 풍력발전을 제안한다.

한국 수출입은행 태양광산업 동향 보고서에 따르면, 2022년 기준 세계 모듈 생산 용량은 649GW로 전년 대비 29.8%가 증가했고, 글로벌 태양광 설치량은 전년 대비 40% 이상 증가한 260~280GW로 추정되며, 2023년 설치량은 320GW를 전망하며 글로벌 태양광 시장은 지속적인 성장세를 기록할 것을 전망하고 있다.

우리 정부도 2022년 7월 '새정부 에너지정책 방향' 공개를 통해 재생에너지 보급목표를 합리적으로 재설정하고 에너지원별 균형 조정을 추진하겠다고 밝히며 비용 효율적인 재생에너지 보급을 위하여 민간 재생에너지(RE100 기업 등) 투자를 확대하고 계통 부담을 최소화 할 수 있도록 제도를 개선할 예정이다.

이에, 철도 및 도로의 유휴 공공부지, 산업단지 지붕 등을 활용하여 태양광 설치 잠재량을 확대하고 주민이 참여하는 태양광 발전사업에 추가 지원방안을 마련하여 주민과 사업자의 상생협력의 체계와 태양광 수용성 향상에 기여하고 차세대 태양광 기술(탠덤 셀, BIPV 등) 상용화 개발 지원 및 탄소검증제 고도화 등으로 국내 태양광 산업 경쟁력 강화를 위한 다양한 조치를 강구해 나갈 계획이다.

더 높은 효율의 페로브스카이트 태양전지의 제조를 향하여
Our Journey toward the Fabrication of High-Efficiency Perovskite Solar Cells

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Over the past decade, halide perovskite photovoltaic solar cells (PSCs) have attracted worldwide attention due to their unique advantages, such as light weight, flexibility, and application of a solution coating process. Now, a little over 10 years after the birth of the PSC, their power conversion efficiency (PCE) has reached approximately 26%, comparable to silicon solar cells. This rapid increase in PCE was achieved by optimizing the device architecture, the process of depositing a uniform thin film, and the composition of the perovskite material with a suitable bandgap, in addition to the excellent material properties of perovskite materials. One of the critical factors for the deposition of uniform thin films was the introduction of mediators that retard the rapid crystallization between organic cations and PbI2 through solvent engineering or intramolecular exchange processes. Another factor was the realization of a method to stabilize the a-phase of optically active formamidinium lead iodide ($FAPbI_3$) perovskite at room temperature. Furthermore, we reported an atomically coherent interlayer for enhanced charge extraction and transport from perovskite while reducing interfacial defects. Meanwhile, reducing the strain on and inside the grain boundaries and the passivation of defects at grain boundaries will enable the fabrication of PSCs with improved efficiency and stability. In this presentation, I would like to introduce our past journey, recent results, and future strategies for fabricating high-efficiency PSCs.

탄소중립을 위한 수/해상 태양광 발전 시스템의 현황과 미래

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Present and Future of Floating PV Systems for Carbon Neutrality

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Abstract : 지구온난화로 인류의 생존위험은 이산화탄소의 배출에 기인하며, 국내에서 전기에너지 생산의 약 40%를 차지하고 있는 석탄 화력발전을 이용한 전력공급은 대량의 이산화탄소 발생으로 급격한 감소가 예측되고 있다. 전력공급체계의 급격한 변화는 설치비용과 설치시간에서 경쟁력을 갖춰가는 태양광발전은 세계적으로 넓게 확산되고 있다.

본 논문에서는 태양광 발전설비에서 전기에너지 생산량의 중요성에 대하여 설명하고 있으며, 에너지 생산량을 증대하기 위하여 태양광발전설비에서 고려하여야 할 중요한 파라메터를 선정하였다, 또한 현재 사업화가 진행되거나, 진행되기 직전인 주요 태양광 발전 시스템을 다시 한번 검토하였다. 그리고 태양광발전산업에서 최근에 많은 성과를 내는 수상/해상 태양광에 대한 간략한 소개와 자연재해 리스크가 많은 해상태양광 발전 개발 과정과 현황에 대하여 설명하고, 해상태양광 발전 시스템의 위기와 기회에 대한 고려할 점과 향후 수/해상 태양광에서 개발하여야 할 것에 대하여 제안 하였다.

Key words : Carbon Neutrality(탄소중립), PV System(태양광 발전 시스템), Floating PV System(수상 태양광 발전 시스템),Off shore PV System(해상 태양광 발전 시스템)

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실리콘 태양전지 온도에 따른 fill factor 손실 분석

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Fill factor loss analysis depending on temperature of silicon solar cells

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Abstract : Since the temperature of a PV module is not consistent as it was estimated at a standard test condition, the thermal stability of the solar cell parameters determines the temperature dependence of the PV module. Fill factor loss analysis of crystalline silicon solar cell is one of the most efficient methods to diagnose the dominant problem, accurately. In this study, the fill factor analysis method and the double-diode model of a solar cell was applied to analyze the effect of J_{01}, J_{02}, R_s, and R_{sh} on the fill factor in details. The temperature dependence of the parameters was compared through the passivated emitter rear cell (PERC) of the industrial scale solar cells. As a result of analysis, PERC cells showed different temperature dependence for the fill factor loss of the J_{01} and J_{02} as temperatures rose. In addition, we confirmed that fill factor loss from the J_{01} and J_{02} at elevated temperature depends on the initial state of the solar cells. The verification of the fill factor loss analysis was conducted by comparing to the fitting results of the injection dependent-carrier lifetime.

Key words : Fill factor 손실 분석(Fill factor loss analysis), 이중 다이오드 모델(Double diode model), PERC(PERC), 온도 의존도(Temperature dependence), 재결합 전류 밀도(Recombination current density)

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투명히터를 이용한 실리콘 태양전지 및 열전 융합 발전소자 측성 시스템

이용환[1*,**]

Rapid Evaluation System for Silicon Photovoltaic Cell and Thermoelectric Generator Hybrid Devices using Transparent Heater

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Abstract : Photovoltaic cell - thermoelectric generator (PV-TEG) hybrid devices have recently been developed to improve energy harvesting performance, by integrating a TEG device into a heated PV. The ability to rapidly perform performance measurements of the hybrid devices at various temperatures is crucial for both academic research and industrial mass-production, however, an adequate measurement system has not yet been reported. In this work, we demonstrate a novel efficient measurement system suitable for PV-TEG hybrid devices, which employs a large-area (160 mm by 160 mm) transparent heater (TH). The TH can simultaneously transmit solar radiation and effectively heat the PV-TEG hybrid devices. The resulting TH incorporated measurement system enables the rapid measurement of hybrid devices with a larger range of temperatures (e.g., ≤ 80 ℃ for normal measurement systems and ~120 ℃ with our proposed measurement system). In addition, the measurement system exhibits superior reproducibility with a negligible difference in efficiency (< 1%). The new method can accelerate the development of PV-TEG hybrid devices with various temperature conditions and without long waiting times.

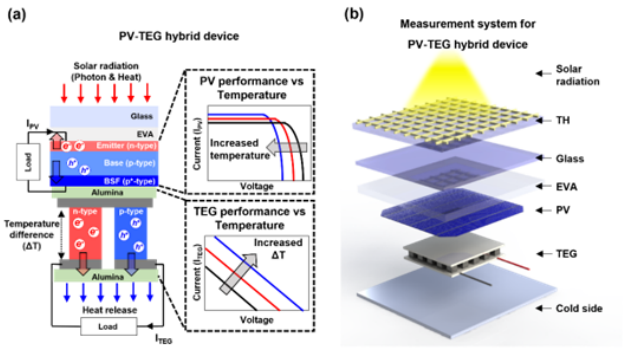


Figure 1. PV-TEG hybrid device. (a) Schematic illustration of a PV-TEG hybrid device and device performance dependency on temperature. (b) A proposed hybrid device measurement system using a large-area TH.

Key words : 평가 시스템(Measurement system), 태양전지(Photovoltaic cell), 열전발전소자(Thermoelectric generator), 융합소자(Hybrid device), 투명히터(Transparent heater)

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고효율 p-TOPCon 태양전지 기술 개발

김도형*, 김용진*, 이상희, 임규현, 박준성, 조윤애, 정경택, 박성은, 강민구, 송희은*

Development of Highly Efficient p-TOPCon Solar Cells

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Abstract : P-type TOPCon (Tunnel oxide passivated contact) solar cells are a promising candidate for the photovoltaic community due to the potential for integration into existing PERC (Passivated emitter and rear cell) technology, leading to reduced investment costs. However, the n-type TOPCon offers relatively more advantages than its p-type counterpart, primarily because of its higher passivation properties resulting from longer bulk lifetime. To further increase the efficiency of p-TOPCon solar cells, it is necessary to improve the passivation quality. This can be achieving by optimizing the processing parameters while forming tunnel oxides and B-doped poly Si layers. It is also crucial to understand the fundamental physical properties of TOPCon layers. This talk will discuss the optimization of passivation quality using a low-pressure chemical vapor deposition method which is strongly dependent on thermal annealing conditions. Additionally, surface defects on the film surface of B-doped poly-Si which are measured by Kelvin probe force microscopy will be revealed. By exploring the surface defects and charge carrier transport properties, it could be possible to elucidate the underlying mechanisms associated with why lower passivation quality in p-TOPCon solar cells has than n-TOPCon counterpart. In this talk, contact resistivity for metalization in p-TOPCon solar cells will be explored. These results highlight the critical importance of tailoring the individual processes to develop highly efficient p-TOPCon solar cells. Therefore, our results and discussions in this talk provide insights into the fundamental physical properties, such as charge carrier behaviors, of passivation layers in p-TOPCon solar cells.

Key words : P-type TOPCon solar cells (p타입 전하선택형 태양전지), B-doped poly Si(보론 도핑 폴리실리콘), passivation (패시베이션), surface defects (표면 결함), charge carrier transport (전하 수송)

한국에너지기술연구원 태양광연구단, Photovoltaic Research Department, Korea Institute of Energy Research

결정질 실리콘 기반의 유연 태양전지 개발

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Development of flexible solar cells based on crystalline silicon

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Abstract : 최근 웨어러블 소자 및 유연 소자의 활용성이 높아짐에 따라 유연 에너지원에 관한 관심이 높아지고 있다. 차세대 유연 에너지원의 하나로 유연 태양전지가 많은 연구가 되고 있으며, 대부분 유기소재 및 박막 필름 기반의 유연 태양전지가 많은 연구를 이루고 있다. 그러나, 유기 및 박막 소재는 안정성 및 에너지 전환효율이 결정징 실리콘 만큼 우수하지 못한 상황이다. 본 발표는 결정질 실리콘을 기반을 유연 태양전지를 개발한 이전 연구를 정리하고, 고효율 유연 태양전지 개발을 위한 전략들을 보고 한다.

Key words : 유연 태양전지 (flexible solar cells), 결정질 실리콘 (crystalline silicon), 실리콘 박막 (thin c-Si film)

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플라즈마 에피탁시 실리콘의 수소 미세구조 연구

*, **김 가현[1], 오 준호[2], 안 정호[2], 모 성인[2], 홍 지은[2]

Hydrogen incorporated microstructure in plasma assisted epitaxial silicon

*, **Ka-Hyun Kim[1], Joon-Ho Oh[2], Jeong-Ho An[2], Sung-In Mo[2], Ji-Eun Hong[2]

Key words : Plasma assisted epitaxial silicon (플라즈마 에피탁시 실리콘), hydrogen microstructure (수소 미세구조), hydrogen (수소), hydrogen exodiffusion (수소방출)

Abstract : Plasma assisted epitaxial silicon (plasma-epi Si) is a new silicon-based material with tailorable microstructure and porosity. While most of research efforts have focused on plasma-epi Si have aimed to suppress the defective interface and improve the material quality for electronic applications, we took a completely different approach to the utilization of plasma-epi Si. Concentration and distribution of the voids can be controlled during growth of plasma-epi Si that enables to realize bottom-up grown porous silicon (pSi) beyond electronic applications. Our result suggests different strategies of plasma-epi Si growth process for different applications. In case of electronic applications, both interconnected defects at initial growth and isolated defects during bulk growth should be suppressed. Targeting bottom-up pSi application, porosity should be intentionally introduced because the porosity tends to be confined at initial stage. Consistent supply of strain during growth should be considered such as by hydrogen plasma treatment or profiles gas flow for bottom-up pSi application.

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고효율 TOPCon 태양전지 구현을 위한 전극화 공정 최적화 및 전극 형성 메커니즘 규명

조윤애[1)*,**], 박준성[1,2)], 김용진[1)], 김도형[1)], 이상희[1)], 정경택[1)], 강민구[1)], 박성은[1)], 송희은[1)], 이해석[2)]

Investigating metal contact formation for the high efficient TOPCon solar cells: optimizing the metalization process and understanding its mechanism

Yunae Cho[1)*,**], June Sung Park[1,2)], Yong Jin Kim[1)], Dohyung Kim[1)], Sang Hee Lee[1)], Kyung Taek Jeong[1)], Min Gu Kang[1)], Sungeun Park[1)], Hae-Seok Lee[2)] Hee-eun Song[1)]

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Abstract :

For the high efficient silicon solar cell, the passivating and metal contact layers should be comprehensively considered. Tunnel oxide passivated contact (TOPCon) structure have been attractive candidate for the high efficiency by the development of passivation layer and metal contact. In the front side of TOPCon solar cell, Ag-Al metallic paste has been usually used to contact with p+ boron emitter with SiNx and Al2O3 passivation layers. The firing profile is the crucial parameter for the high quality of metallization base on the thermal reaction. We investigated the effect of burn-out range and peak temperature on the properties of metallization and resulting solar cell performance. Through the control of burn-out range and peak temperature, the structural and material properties were characterized using by the x-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) measurements in firing profile, which helps to figure out a mechanism of the formation of Ag/Al metal contact. Finally, the comparison of specific contact resistance of metal contact and solar performance suggested the optimal firing profile. We contribute to understanding the firing process and the realization for the high efficient solar cell.

Key words : Silicon solar cell(실리콘 태양전지), Metalization (전극화), firing profile (소성프로파일), peak temperature(최고점 온도)

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고효율 결정질 실리콘 태양전지용 부동태화 접촉 기술

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Passivating Contacts for High-efficiency Crystalline Silicon Solar Cells

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Abstract : Silicon has dominated the solar industry for decades, but the conversion efficiency of Si single-junction solar cells is inherently limited to 29.4%. Breaking this limit requires developing new technologies and transforming them into industrial production. This study focuses on two important concepts enabling highly efficient Si-based solar cells: passivation contacts and tandem technology. The theoretical background of key technologies for contact protection and their potential applications to solar cells are explained in detail. A fundamental limitation of single-junction Si solar cells can be achieved with the introduction of passivation contacts. Upgrading Si to high-bandgap tandem subcells to achieve conversion efficiencies above 30% is a promising approach to improving utilization of the solar spectrum with the potential to produce efficiencies beyond the single-junction Shockley-Queisser limit. Eventually, guidelines for further development of Si photovoltaics emerge clearly, proving that Si will continue to hold an indispensable place in photovoltaics in the long term.

Key words : Crystalline silicon(결정질 실리콘), Solar cell(태양전지), Passivating contact(부동태화 접촉)

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2) 고려대학교

Bottom subcell optimization for high-efficiency III-V//Si tandem solar cells

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Abstract:

This invited talk will focus on the optimization of the bottom subcell of a III-V//Si tandem solar cell to achieve high efficiency. The III-V top subcell is well known for its high efficiency and the bottom Si subcell needs to be tuned and optimized for its application in the tandem architecture to create synergy for better performance of the tandem cell. Silicon-based photovoltaic technology still occupies more than 90% of the total market share. The conversion efficiency of single-junction solar cells is intrinsically constrained to 29.4% as per the Shockley-Queisser (S-Q) limit, which is close to the achieved conversion efficiency today. Conversion efficiencies higher than the S-Q limit have already been achieved in multijunction solar cells. In this category, the III-V//Si tandem solar cell is one of the most promising candidates. In this talk, various strategies for improving the efficiency of the bottom subcell, including surface passivation, texturing, and light management will be discussed. By implementing these techniques, tandem solar cell with conversion efficiencies up to 35.9% for triple junction III -V//Si tandem structure have already been achieved elsewhere. The challenges associated with integration of the two subcells ensuring optimal current matching have also been addressed. Through simulation and experimental results, the effectiveness of these optimization techniques has been demonstrated, which shows they can be used to achieve higher efficiencies. It is also briefly described that the results showing that an efficiency of over 40% can be achieved using novel materials and device architectures. This talk will be of interest to researchers and engineers working on the development of high efficiency solar cells for renewable energy applications, as well as those interested in the optimization of tandem solar cell structures.

Key words: Tandem Solar Cell, III-V on silicon, Top and bottom cells, multijunction, high efficiency[i]

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결정질 실리콘 태양전지 광열화 현상에 관한 계산과학 연구

이태경*,**

Computational Study on Light-induced Degradation of Crystalline Silicon Solar Cells

Tae Kyung Lee*,**

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Abstract : Development of high-performance of crystalline silicon (c-Si) solar cell is important to overcome global crisis of climate change. However, by interacting with oxygen molecules, the performance degradation in c-Si solar cell can occur, known as light-induced degradation (LID). To further improve the performance of solar cell, the understanding of LID mechanism and its control are necessary. In this study, the adsorption behavior of oxygen molecule on the textured silicon surface was investigated by utilizing the molecular simulation. Moreover, the effects of water interaction on the adsorption properties of oxygen on the silicon surface were studied. The computational screening of p-type (*i.e.*, B, Al, Ga, and In) and n-type (*i.e.*, P, As, and Sb) doping elements were performed to achieve the research objective. The silicon-oxygen complex structures (*i.e.*, square and staggered phases) were further explored to investigate the possibility of LID control by doping condition. Overall, in this presentation, I would like to introduce the meaningful finding, which is the doping condition to control the LID phenomenon in c-Si solar cell.

Key words : Crystalline silicon solar cell, Light-induced degradation, Oxygen/Water molecules, Density functional theory calculation

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CIGS 박막태양전지 재료의 전기적 특성 분석을 위한 측방향 광전류법

정중희[1)]

Lateral photocurrent method to characterize the electrical properties of CIGS thin-film solar cell materials

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Abstract : This presentation introduces lateral photocurrent method for characterizing the electrical properties of CIGS thin-film solar cells. First, a semi-empirical formula based on the lateral photocurrent method is introduced to directly measure the sheet resistance of the CdS buffer in the device. Chemical bath-deposited CdS exhibits a particular appearance on glass. Therefore, the electrical properties of the CdS buffer must be measured directly on the device. Second, an approach based on the lateral photocurrent method is introduced to determine the minority carrier diffusion length and back surface recombination rate in CIGS thin-film solar cells. The electrical properties of the light-absorbing layer and the back surface are represented by the minority carrier diffusion length and the back surface recombination velocity.

Key words : Lateral photocurrent method (측방향 광전류법), Sheet resistance (면저항), Minority carrier diffusion length (소수운반자 확산거리), Back surface recombination velocity (후면 재결합속도)

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Tailoring band-gap grading via a hybrid growth method achieving $Sb_2(S,Se)_3$ solar cells with 8% efficiency

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Abstract :

Antimony sulfoselenide ($Sb_2(S,Se)_3$) solar technology has been attracting widespread interest owing to its outstanding photoelectric properties in recent years, however, still facing obstacles such as relatively low power conversion efficiency (PCE). The hydrothermal synthesis method has enabled efficiency of over 10% in the state-of-the-art $Sb_2(S,Se)_3$ solar cells. Nevertheless, the issues resulting from the hydrothermal method, concerning the uneven band-gap grading during the growth process as well as the mass loss during the annealing period, remain unresolved. Here, an effective hybrid growth method, including a pre-hydrothermal deposition and a post-vapor transport deposition, was put forward to address the above issues, by which the Se loss is compensated, and the steep S/Se gradient is also manipulated. As a result, the open-circuit voltage (Voc) and fill factor (FF) of $Sb_2(S,Se)_3$ solar cells (Glass/Fluorine-doped Tin Oxide (FTO)/CdS/$Sb_2(S,Se)_3$/Poly(triaryl amine)(PTAA)/Au) are dramatically improved, achieving a promising efficiency of 8%. The improvement in Voc and FF is ascribed to the tuned band-gap grading of $Sb_2(S,Se)_3$ film fabricated by the hybrid growth method. This study suggests a viable method for enhancing the device performance, shedding new light on the fabrication of high-performance $Sb_2(S,Se)_3$ solar cells.

Key words : $Sb_2(S,Se)_3$, solar cells, band-gap grading

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CIGS 태양전지의 빛 젖음 효과를 통한 광시냅스 소자

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Optical synapse device by light socking effect of CIGS solar cell

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Abstract : 본 연구에서는 Zn(O,S)/Cu(ln,Ga)Se2 p-n 접합의 빛젖음 효과를 이용한 광시냅스 소자에 대하여 연구하였다. 습식 공정으로 합성된 Zn(O,S)/Cu(In,Ga)Se2 구조의 소자는 빛에 노출됨에 따라 광반응이 점차 증가하는 빛젖음 효과가 존재한다. 이러한 빛젖음 효과는 광여기된 전하에 의한 계면결함의 차징스테이트 변화 및 그에 기인한 밴드정렬 변화에 의해 발생한다. 흡수된 빛에 의한 계면결함의 차징상태의 점진적 변화와 그에 수반되는 점진적인 광반응성 변화를 통하여 광시냅스를 구현 가능하다. 실재로 Zn(O,S)/Cu(ln,Ga)Se2 p-n 접합에 400nm 파장의 광펄스를 가하여 광펄스의 간격에 따른 쌍펄스 촉진 현상을 관찰할 수 있으며 광전류 및 광펄스의 빈도에 따라 점진적인 광전류의 증가 (기억과정) 또는 점진적인 광전류의 감소 (망각과정)을 구현할수 있었다. 또한 계면 결함을 제어하여 기억과정과 망각과정이 발생하는 광펄스의 빈도를 제어하여 광시냅스 소자의 장기기억과 단기기억간의 비율을 조절하였다. Zn(O,S)/Cu(ln,Ga)Se2 p-n 접합의 빛젖음 효과에 기인한 광시냅스 특성은 광학메모리 및 이미지 인식에 사용될수 있을것으로 기대된다.

Key words : Light soaking effect(빛젖음 효과), CIGS solarcell (CIGS 태양전지), optcail synapse (광시냅스)

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케스터라이트 태양전지 내 결함 특성

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Defect characteristics in kesterite solar cells

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Abstract : Kesterite solar cells have advantages in resource distribution and economic feasibility, but low efficiency compare to CIGS is a challenge to be solved. The theoretical Shockley–Queisser efficiency limits of CIGS, CZTS, and CZTSe are 32.0%, 32.4%, and 31.6%, respectively.[1,2] Whereas the trap-limit (TL) efficiency limit of CZTS and CZTSe is 20.9% and 20.3%.[3] Also, the best research-cell efficiency of CIGS, CZTS, and CZTSSe is 23.35%, 11%, and 13%, respectively.[4,5] Therefore, it can be seen that the characteristics loss in the CZTSSe absorber is the main cause of low efficiency. Carrier recombination loss can be the main cause of a defect in the absorber. Various defects and defect clusters can exist in CZTSSe, and carrier recombination loss and electron-hole separation can be controlled by suppressing defect formation in the absorber. Precursor design [6,7] and alkali metal doping [7,8] can control defect formation in the absorber. Here we identified the relationship between kesterite solar cell properties and defects. The generated defect showed different characteristics depending on the CZTSSe precursor structure and Na doping. The defects with deep energy level near the space charge region (SCR) is proportional to V_{OC} deficit and inversely proportional to J_{SC} more strongly in CZTSSe than in CIGSe. To improve the efficiency of kesterite solar cells, it is important to suppress the formation of defects with deep energy levels near SCR.

Key words : kestrite solar cell (케스터라이트 태양전지), defect (결함), defect energy level (결함 에너지 준위), defect density (결함 밀도)

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First Principles Investigation of the Maximum Photovoltaic Efficiency Attainable by Imperfect Kesterites

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The Shockley-Queisser (SQ) limit is a useful tool for estimating the efficiency of converting light to electricity in a solar cell, based on only the band gap of the light-absorbing layer. However, very few materials approach this theoretical maximum efficiency. In order to better understand the factors that limit photovoltaic efficiency, we have developed a computational method to predict the maximum efficiency of imperfect solids from first principles. Our approach takes into account the impact of native defects, including their carrier-capture coefficients and associated recombination rates, on the overall conversion efficiency. Using this method, we have determined that Cu2ZnSnSe4 kesterite solar cells have an intrinsic maximum efficiency limit of around 20%, which is significantly lower than the SQ limit of 32%. We have also investigated the effects of atomic substitution and extrinsic doping on efficiency and have identified potential pathways for achieving an enhanced efficiency of 31%. This approach has significant potential to inform the selection of materials for future solar energy technologies.

재결합 방지를 통한 작은 밴드갭 CuInSe2 솔라셀 효율 향상

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CIGS 와 페로브스카이트 탠덤 태양전지에서 하부셀 재료로 적용하기에 이상적인 밴드갭을 갖는 CuInSe2 (CISe) 광흡수체는 Al2O3 패시베이션 로컬 접촉을 사용하여 제조된다. 이러한 밴드갭을 갖는 CISe 셀의 효율은 일반적으로 생성된 전하 캐리어 재결합에 의해 제한되며, 이는 낮은 개방 전압으로 이어진다. CISe 태양전지에 Al2O3 패시베이션 층을 추가하여 소자의 스펙트럼 응답을 1.0 eV까지 유지하면서 개방전압를 향상시키고 소자의 태양광 변환 효율을 향상시켰다. CISe 광흡수층에서 Al2O3 패시베이션 로컬 접촉 효과는 생성된 전하 캐리어 재결합을 최소화하여, CISe 태양전지의 효율을 향상시킨다. Al2O3 패시베이션 국소 접촉은 하부 금속 접촉에서의 전하 캐리어 재결합 억제로 인해 개방전압이 증가하여 태양광 전환 효율이 10.7%에서 12.3%로 증가하였다.

Acknowledgement

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고효율 대면적 초경량·유연 무독성 CIGS 박막 태양전지 기술개발

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Development of highly-efficient and non-toxic CIGS thin-film solar cells on flexible and lightweight substrates

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Abstract : The development of highly-efficient and non-toxic CIGS (copper indium gallium selenide) thin film solar cells on flexible and lightweight substrates has been pursued as a promising solution to the increasing demand for renewable energy sources. In this study, we report a novel approach to address the challenges of traditional CIGS solar cell manufacturing processes, resulting in the development of a solar cell that achieves high electrical conversion efficiency, large area coverage, flexibility, and non-toxicity. To achieve this, we optimized the electrode design, composition, and processing of the CIGS film to develop the large area device. We used a ZnMgO (ZMO) non-toxic buffer layer to replace CdS buffer. We optimized the composition and processing of the CIGS layer, using a three-stage process to improve the morphology and reduce the density of defects in the CIGS film. Additionally, the solar cell was fabricated on a flexible substrate, allowing it to be highly flexible, lightweight. These results provide a solid foundation for the development of innovative solar cell manufacturing techniques and pave the way for the advancement of the solar energy industry.

Key words : CIGS solar cells(CIGS 태양전지), Flexible substrate(유연기판), Large area(대면적), non-toxic(무독성)

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CZTSSe 태양전지의 저조도 효율향상을 위한 2종 양이온 동시 치환을 통한 결함제어 연구

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Study on defect control through double cation substitution to improve low-illumination efficiency of CZTSSe solar cell

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Abstract : With the growing need for cost-effective and sustainable Internet of things (IoT) technology, kesterites-based solar cells are proving their worth. We report the fabrication of an efficient CZTSSe absorber layer with improved V_{oc} loss and their possible application test for indoor photovoltaic application. The double cation incorporation (co-doping) approach is employed with Ag and Ge to achieve this. The devices fabricated and tested under standard illumination (1 sun) and low light intensity conditions showed enhanced device performance and lower V_{oc} loss after co-doping. Under indoor light conditions, the V_{oc} of 290 mV with white LED (WLED) and 310 mV with fluorescent lamp (FL-4000K) was achieved at the lowest intensity of 400 lux, while it shows >350 mV at 1200 lux under FL-4000K for the CZTSSe:Ag-Ge device. The V_{oc} recovery of >60% under all intensity conditions and >70% at 1200 lux with WLED and FL-4000K were also achieved. Morever the CZTSSe:Ag-Ge device showed a device efficiency of 4.95% and 5.85% under WLED and FL-4000K at 1200 lux. The prototype device also demonstrated successful test results under indoor conditions. These achievements are attributed to enhanced carrier density, reduced density of defects, and low carrier recombinations.

Key words : Kesterit(케스터라이트), Solar cell(태양전지), Cation subsitition(양이온 치환)

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유기태양전지용 비플러렌 억셉터 소재 개발

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Development of non-fullerene acceptors for OPV

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Abstract : Polymer solar cells (PSCs) have attracted great attention as next-generation wearable power generators due to their merits of light-weight, low cost, and potential stretchability. One of the most successful advances in improving the power conversion efficiency (PCE) of PSCs has been recently achieved with the advent of non-fullerene small molecule acceptors (NFSMAs). A highly fused backbone structure of the NFSMAs incorporated with strong dye molecules allow to a high absorption coefficient compared to conventional fullerene-based acceptors, leading to the drastic improvement of the light absorption and the PCE of PSCs to 17-18%. Despite recent successes of the NFSMA-based PSCs, morphological instability and sharp domain interfaces caused by strong crystalline and high diffusion properties of the NFSMA can limit long-term stability and mechanical reliability for their practical applications. In this regard, all-polymer solar cells (all-PSCs)—consisting of a polymer donor (P_D) and a polymer acceptor (P_A)—are a particularly attractive class of the PSCs due to their excellent morphological stability and mechanical robotness . Here, we report a new series of NFSMA-based P_A materials containing the same building blocks of P_D to enhance the molecular compatibility between P_A/P_D, achieving high mechanical robustness and efficiency of all-PSCs.

Key words : OPV(유기태양전지), non-fullerene acceptor(비플러렌 억셉터), Stability(안정성)

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Charge transfer dynamic in non-fullerene organic solar cells

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Abstract : In spite of differences in charge dynamics between organic solar cells (OSCs) based on fullerene acceptors and organic solar cells (OSCs) based on non-fullerene acceptors (NFAs), some analyses such as energy loss and charge transfer (CT) level still follow the conventional method used for fullerene-based OSCs. In the conventional fullerene-based OSCs, in which the excited electrons from the donor are transferred to the acceptor, the electron charge transfer state ($^{e}E_{CT}$) that electrons pass through has a great influence on the device performance. In the bulk-heterojunction (BHJ) system based on low band-gap NFAs, however, the electron density excited in the acceptor itself is already high, thus $^{e}E_{CT}$ created near the lowest unoccupied molecular orbital (LUMO) levels of donor and acceptor has little influence on energy loss (V_{OC} loss) and device performance. Rather, a hole transfer state ($^{h}E_{CT}$) from the acceptor to the donor has a greater influence on the device performance. Here, we suggest a simple method to determine the exact $^{h}E_{CT}$ level by deconvolution of EL spectrum of BHJ blend (EL_B). In general, the onset part of the external quantum efficiency (EQE) of the BHJ blend with NFA is formed solely by the contribution of the acceptor itself. In an EL measurement, electrons are injected directly into the acceptor LUMO and holes are initially injected into the HOMO of the donor and then transferred to the acceptor through $^{h}E_{CT}$. Thus, EL_B has information related to both the singlet recombination of the acceptor and the radiative recombination via $^{h}E_{CT}$. Through the deconvolution of EL_B, we have clearly decided which part of the broad EL_B spectrum should be used to apply the Marcus theory. Accurate determination of $^{h}E_{CT}$ is expected to be of great help in fine-tuning the energy level of donor polymers and NFAs by understanding the charge transfer mechanism clearly.

Key words : Organic solar cells, Non-fullerene acceptor, Energy loss, Hole transfer state

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Liquid-State Dithiocarbonate-based Polymeric Additives with Monodispersity rendering Perovskite Solar Cells with Exceptionally- High Certified Photocurrent and Fill Factor

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Abstract : Dithiocarbonate-based non-hygroscopic polymers with a glass transition temperature (Tg) and polydispersity index (PDI) of approximately 4 °C and 1, respectively, are synthesized through living cationic ring-opening polymerization. These liquid-state polymers are characterized by monodispersity based on the low Tg and PDI, rendering remarkable miscibility with the perovskite precursors without aggregation. Accordingly, these polymers are added to perovskite solar cells (PSCs) to enhance their power conversion efficiency (PCE). The PCE of reference PSCs increases from 19.70 to 23.52% after direct addition of the synthesized polymer. Such efficiency improvement is attributed to the considerable increases in short-circuit current density (JSC) and fill factor (FF), resulting from the augmented size and defect passivation of perovskite crystals induced by added polymers. In fact, PCE and JSC of the devices measured in our laboratory and the certification center are the highest among the reported polymer-added PSCs, thanks to the great miscibility of the new polymers leading to the large amount addition which enables more thorough passivation among the grain boundaries. The improvement in open-circuit voltage falls short as compared to that in JSC and FF, ascribed to the relatively moderate interaction strength between perovskite materials and dithiocarbonate groups.

Key words : sulfur-containing polymer, ring-opening polymerization, polymeric additives, perovskite solar cells, polymer passivation

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페로브스카이트 내 전하 이동 현상 규명

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Charge carrier dynamics in perovskite thin films

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Abstract : Herein, in order to accurately estimate carrier mobility, we employed transient photo-conductive (TPC). We can reveal the free carrier density of both photoexcitation before and after in perovskite film, for photo-conductivity measurement probed apply a small DC bias in electrode. When illuminated pulse laser on perovskite film, high amount charge was temporarily generated, which as function of time decays due to carrier recombination. Therefore a common method to determine transient conductivity is indicated at t=0, and it is increased with excitation density. However, photo-carrier mobility was decreased above certain excitation density, high excitation density caused the possibility of recombination due to the collision between electron and hole. Thus, for accurate calculation of carrier mobility employed photoconductivity at the highest free charge carrier density (t=peak). The excitation density versus carrier mobility shows that when carrier mobility was calculated at t=0, above certain excitation density shows sub-linear, and when carrier mobility was calculated at t=peak carrier mobility linear. The linear of excitation density versus carrier mobility shows constant calculated carrier mobility despite the high excitation density.

Key words : Perovskite(페로브스카이트), mobility(전하이동도), optoelectronics(광전자 분광학)

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양자점 적외선 검출기 트랩 제어 방법

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Various Trap Passivation Strategy for infrared QD Photodetectors

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Abstract :

The infrared region of the electromagnetic spectrum has many promising applications, including LiDAR, optical communication, telecommunications, thermography, bioimaging, photovoltaics, and night visions. However, the high cost of epitaxial III-V semiconductors and fabrication processes have limited the widespread adoption of infrared technology beyond the silicon absorption range. Colloidal quantum dots, specifically lead chalcogenide QDs, are a promising alternative for infrared detection due to their tunable bandgap and compatibility with conventional Si ROIC in device fabrication, leading to reduced fabrication costs. However, incorporating lead chalcogenide QDs into photodetectors faces challenges due to the high density of surface defects caused by QDs' large surface-to-volume ratio.

In this work, we present various methods for improving the performance of infrared photodetectors, focusing on reducing trap density via surface treatment of QDs using thermal annealing, chemical, and electrochemical treatment. We developed a chemical treatment method that reduces trap states while maintaining existing ligands, and found optimal conditions for thermal annealing to reduce surface traps without sintering QDs by atomic diffusion. We evaluate the effects of these treatments on device performance and trap characterization, improving bandwidth and responsivity compared to reference devices. Additionally, we present our findings on the interfacial effect of QD devices and the performance of PbS QD array detectors.

Key words : Quantum dots(양자점), Photodetector(광검출기), SWIR(단파적외선), Trap(트랩)

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물분자의 수소이온이동을 매개로한 알킬암모니움의 안정성 유도와 금속할라이드 페로브스카이트 결정 성장과의 관계

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Water molecule mediated proton transfer stabilization of alkylammonium cation in metal halide perovskite thin film

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Abstract : The alkylammonium cations in metal halide perovskite crystals are easily occurred deprotonation process due to unexpectedly dissolved water molecules in precursor. Hydroxide network of water molecules have high affinity with meta-stable proton of alkylammonium cations and leads deprotonation process and produced hydrogen defects in metal halide perovskite crystals. This condition is leading to produce the separation of crystal phase in a perovskite film. However, ionized halide in the perovskite precursor is rearrangmented protons from hydroxide of water molecules and stabilize to hydrophilic side of alkylamine in the hydrogen rearrangement via ionic halide. Using ionic halide added metal halide perovskite precursors, we can obtaine fine perovskite thin film as nearby single-phased crystal for example, tetragonal of methylammonium lead tri-iodide and cubic formamidinium lead tri-iodide crystals. In addition, the protonated alkylammonium as cationc molecules are leading to strengthen compressive strain via enhancing Mulliken charges between hydrogens of alkylammoniums and halide in crystals. The annealed these fine crystal thin films are resulted to obtain high performance solar cell device. In this work, we are proposed a way for minimization of hydrogen defects in metal halide crystals and this principle will be applied in most metal halide perovskite materials. I will talk the precise mechanism of protonation process of alkylammonium cation in the model precursor of methylammonium lead tri-iodide and ionized iodide addition.

Key words : Fine alkylammonium metal tri-halide (경화된 알킬암모니움 금속할라이드), Local crystal changes (국소결정변화), Proton transfer mechanism (프로톤 이동 메커니즘), Proton defects (프로톤 결함)

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SnO2 전자전달층을 적용한 고효율 페로브스카이트 태양전지 제조 및 대면적 응용연구

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탄소중립이페로브스카이트 태양전지는 현재 최고 22.1%의 광변환효율을 보여주고 있다. 그러나 페로브스카이트 태양전지는 0.1cm^2 크기 전후의 소면적에서 많은 연구가 이뤄지고 있어, 향후 상용화를 위한 대면적 응용연구에는 아직까지 이렇다 할 좋은 결과들을 보여주고 있지 못하는 실정이다. 본 연구에서는 특수한 열처리 방식을 도입하여 20%이상의 광변환효율을 보이는 기존 0.1cm^2급 크기의 제조방식을 1cm^2급 이상의 대면적으로 응용·확대하였을 경우에도 효율이 크게 떨어지지 않고 18%이상의 고효율을 유지할 수 있는 방법을 제시하고자 한다. 또한,

페로브스카이트(Perovskite) 태양전지는 최근 몇 년간 높은 효율과 낮은 생산 비용으로 인해 태양전지 기술 분야에서 주목을 받고 있는 기술이다. 2050 탄소중립 실현을 위해 태양광 발전이 핵심 에너지원으로 역할을 해야만 하는 상황에서 그 중요도가 더욱 높아지고 있다.

그러나 현재의 페로브스카이트 태양전지 기술은 아직 상용화에는 이르지 못하며, 그 주요 원인이 대면적화(Scaling up)와 안정성에 대한 문제이다. 본 연구에서는 SnO2 소재의 전자전달층을 이용하여 안정성과 대면적화 문제를 개선하고자 한다. 특히 어닐링 조건에 따른 최적화를 통해 25cm^2급 이상의 대면적으로 확대할 수 있는 연구방법을 제시하고 이를 통해 향후 페로브스카이트 태양전지 상용화 가능성을 더욱 높이고자 한다

KIER 페로브스카이트 기반 탠덤 태양전지 연구 현황

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Research activities on perovskite-based tandem solar cells at KIER

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Abstract : 2050 탄소중립 실현을 위한 무탄소 전원으로서 태양광 발전의 중요성이 그 어느 때보다 강조되고 있다. 국토면적이 제한된 우리나라에서 태양광 발전 비율을 효과적으로 증대시키기 위해서는 초고효율 태양전지 개발이 필수적이며, 기존 실리콘 태양전지로 대표되는 단일접합의 이론 한계 효율을 돌파하기 위한 방법으로 탠덤 기술이 게임 체인저로서 대두되고 있다. 특히 고효율 구현 가능성과 더불어 밴드갭 튜닝 및 저온 공정이 가능한 페로브스카이트 태양전지 기술의 출현은 탠덤 태양전지 연구의 촉진제가 되어 현재 전 세계에서 초격자 기술 선점을 위한 무한 경쟁이 벌어지고 있다. KIER도 이와 같은 추세에 발맞춰 기 보유한 결정질 실리콘 및 유연 CIGS 박막 태양전지 기술과 페로브스카이트 태양전지 기술을 접목한 다양한 구조 (양면 수광형 페로브스카이트/실리콘 탠덤 태양전지 및 유연 페로브스카이트/CIGS 탠덤 태양전지)의 탠덤 태양전지 개발을 수행중이다. 본 발표에서는 최근 KIER에서 이뤄진 nip 및 pin 구조 투광형 페로브스카이트 상부셀의 고효율화/안정성 확보 연구 내용을 소개하고자 한다. 더불어 이를 양면수광형 실리콘 하부셀 및 유연 CIGS계 하부셀에 적용한 탠덤 태양전지 연구 내용도 공유하고자 한다.

Key words : tandem solar cells(탠덤 태양전지), perovskite/Si tandem(페로브스카이트/실리콘 탠덤), perovskite/CIGS tandem(페로브스카이트/CIGS 탠덤)

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Design Strategy of Colloidal Quantum Dot Heterostructure for Downshifting Layer

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Abstract : The luminescent downshifting (LDS) layer, which can down-convert the high-energy solar photons to low-energy visible ones, enables enhancing both the performance and aesthetic points of photovoltaic modules. For efficient PVs with an LDS layer, fluorophors should have high photoluminescence quantum yield, a small spectral overlap between absorption and emission, and high photostability. Here, I present the colored PV modules with LDS layers of InP/ZnSeS quantum dots (QDs). Sophisticatedly designed InP/ZnSeS QDs decrease the sacrificed photons and enhanced the absorption ability in the UV regions. Also, ligand engineering improves the photochemical stability of LDS layers after the damp heat test. This novel fluorophor will contribute to the realization of efficient and appealing colored PV modules.

Key words : Colloidal Quantum Dot, Heterostructure, Downshifting Layer

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Effects of Optical Interference on Quantum Dot Solar Cells

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The influence of optical interference for optimizing structure of the colloidal quantum dot thin-film solar cells should be carefully considered for further efficiency boost because of the insufficient absorption of the active layer. In this study, fringe patterns of absorption spectra are effectively removed via introducing the jagged interface between the zinc oxide thin-film and lead sulfide colloidal quantum dot thin-film, where the refractive index difference has the maximum value in a typical colloidal quantum dot solar cell device (ITO/ZnO/PbS/Au). As a result, despite of rich trap states in jagged zinc oxide, the short circuit current density of solar cells with rough interface continuously increases as the thickness of the colloidal quantum dot layer increased, while the increase in short circuit current density of solar cells with flat interface is limited by optical interference. The behavior of current density in the devices with varying interfaces is further verified by electrical and optical calculation through one dimensional modeling. Under optimized condition, the colloidal quantum dot thin-film solar cell using jagged interface architecture shows a power conversion efficiency of 13.1% for modeling and 11.1% for experiment. This study suggests that the optical interference on absorption exert considerable impact to ideal optimization of colloidal quantum dot thin-film solar cells architecture.

순간 고전압에 의한 Perovksite 태양전지 열화

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Degradation of Perovskite solar cell under Instantaneous Kilovolt Stress

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Abstract

Perovskite 태양전지의 효율은 다양한 연구를 통해 현재 상용화되어 있는 실리콘 태양전지와 유사한 수준까지 도달하였으며, Tandem 이나 유연소자 적용을 통해 시장에 진입하고자 한다. 하지만 Perovskite 태양전지의 낮은 신뢰성은 상용화에 있어서 가장 어려운 부분이다. 튼튼한 결정 구조 형성, surface passivation, 수분과 산소에 대한 차단막 층 도입 등을 통해 산소와 물에 대한 신뢰성은 상당부분 해결되었으나, 아직 전기적 Stress에 대한 연구가 부족한 상황이다. 특히 기존 전력망과 연결되어 전기를 공급해야 하는 태양전지의 특성상 순간 높은 전압에 노출될 가능성이 매우 높아 이상전압에서 열화에 대한 연구가 필요한 상황이다.

본 연구에서는 정전기 방전 (electro-static discharge), 계통에서 발생하는 써지 전압 (Surge Voltgae), 낙뢰 등의 비정상적인 상황으로 발생할 수 있는 순간 고전압 (수 kV, 수십 ns 이내)에서 Perovksite 태양전지의 특성 변화를 체계적으로 분석하였다. Perovskite 태양전지에 1 kV 이상의 고전압을 20 ns 인가한 경우 Perovskite 태양전지는 Diode의 특성을 완전히 잃어버리고, 효율이 1% 이하로 저하되는 특성이 나타난다. 특히 광으로 인해 생성된 전자가 Diffusion을 통해 상대 전극으로 빠져나가는 통로가 완전히 파괴되어 정상적인 효율이 나오지 않게 된다. 기존의 산소와 수분에 의해 천천히 저하되던 열화와 달리 높은 전압이 인가되자마자 바로 파괴되는 현상이 발생한다. 박막 분석법을 통해 분석한 결과 수간 고전압에 의해 주로 파괴된 부분은 Perovskite 층과 전자수송층, 혹은 Perovskite 측과 정공 수송층의 계면이라는 것을 알 수 있었다. 따라서 순간 고전압에 저항성이 높은 태양전지 구현을 위해서는 적절한 계면 처리가 도입되어야 할 것으로 예상된다.

Key words : Perovskite solar cell(페로브스카이트 태양전지), Electrical stress(전기적 충격), Reliability (신뢰성), 순간 고전압 (Instantaneous Kilovolt Stress)

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Defect engineering of metal-halide perovskites for next-generation optoelectronic devices

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Metal-halide perovskites have emerged as a highly promising material for next-generation optoelectronic devices such as light-emitting diodes (LEDs) and solar cells. Over the past decade, significant progress has been made in terms of device performance, but the issue of internal defects still poses a challenge for their practical application. Defects in perovskites can result in quenching of charge carriers via non-radiative recombination channels, leading to degraded optoelectronic performance. Besides, the defects migrate to lead to peculiar electronic and optical behavior of the devices such as current-voltage hysteresis and luminance overshooting, which may seriously impact the stability of the perovskite optoelectronic devices accelerating their degradation. To address these challenges, various strategies using different classes of materials have been proposed and investigated. In this talk, we will discuss various approaches for defect passivation in metal-halide perovskites, ranging from the use of organic chemical reagents to the incorporation of low-dimensional perovskites into the 3D structure. Our results demonstrate the effectiveness of these strategies in suppressing the formation and migration of defects, leading to improved optoelectronic characteristics and operational stability in LEDs and solar cells.

[1] ″Proton-transfer-induced 3D/2D hybrid perovskites suppress ion migration and reduce luminance overshoot″ **H. Kim**†, J. S. Kim†, J.-M. Heo†, M. Pei, I.-H. Park, Z. Liu, H. J. Yun, M.-H. Park, S.-H. Jeong, Y.-H. Kim, J.-W. Park, E. Oveisi, S. Nagane, A. Sadhanala, L. Zhang, J. J. Kweon, S. K. Lee, H. Yang, H. M. Jang, R. H. Friend, K. P. Loh, M. K. Nazeeruddin, N.-G. Park, and T.-W. Lee*, *Nat. Commun*., 11, 3378 (2020)

[2] ″Employing 2D-perovskite as an electron blocking layer in highly efficient (18.5%) perovskite solar cells with printable low temperature carbon electrode″ S. Zouhair†, S.-M. Yoo†, D. Bogachuk, J. P. Herterich, J. Lim, H. Kanda, B. Son, H. J. Yun, U. Würfel, A. Chahboun, M. K. Nazeeruddin, A. Hinsch, L. Wagner*, and **H. Kim***
Adv. Energy Mater., 2200837 (2022)

[3] ″Self-Crystallized Multifunctional 2D Perovskite for Efficient and Stable Perovskite Solar Cells″ **H. Kim**, M. Pei, Y. Lee, A. A. Sutanto, S. Paek, V. I. E. Queloz, A. J. Huckaba, K. T. Cho, H. J. Yun, H. Yang, and M. K. Nazeeruddin* *Adv. Funct. Mater.*, 30, 1910620 (2020)

[4] ″Phase-Pure Quasi-2D Perovskite by Protonation of Neutral Amine″ M. Dessimoz, S.-M. Yoo, H. Kanda, C. Igci, **H. Kim***, and M. K. Nazeeruddin* *J. Phys. Chem. Lett.* 12, 11323 (2021)

Universal perovskite nanocrystal ink for optoelectronic devices

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Abstract : Semiconducting lead halide perovskite nanocrystals (PNCs) are regarded as promising candidates for next-generation optoelectronic devices due to their solution processability and outstanding optoelectronic properties. While the field of light-emitting diodes (LEDs) and photovoltaics (PVs), two prime examples of optoelectronic devices, has recently seen a multitude of efforts toward high-performance PNC-based devices, realizing both devices with high efficiencies and stabilities through a single PNC processing strategy has remained a challenge. In this work, diphenylpropylammonium (DPAI) surface ligands, found through a judicious ab-initio-based ligand search, are shown to provide a solution to this problem. The universal PNC ink with DPAI ligands presented here, prepared through a solution-phase ligand-exchange process, simultaneously allows single-step processed LED and PV devices with peak electroluminescence external quantum efficiency of 17.00% and power conversion efficiency of 14.92% (stabilized output 14.00%), respectively. It is revealed that a careful design of the aromatic rings such as in DPAI is the decisive factor in bestowing such high performances, ease of solution processing, and improved phase stability up to 120 days. This work illustrates the power of ligand design in producing PNC ink formulations for high-throughput production of optoelectronic devices; it also paves a path for “dual-mode” devices with both PV and LED functionalities.

Key words : **perovskite nanocrystals**, photovoltaics, surface ligands, ligand exchange

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Realizing defect-less perovskite QDs by surface passivation and alkali metal doping for opto-electronic applications

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Abstract: Perovskite QDs have been considered as light-absorbing materials for next generation solar cell due to their outstanding opto-electrical properties. However, unfortunately, poor structural stability is weakness of perovskite QDs and must be solved. The perovskite QDs with highly structural stability were realized by introducing surface passivation and alkali metal doping. These methods significantly enhanced structural stabilities of perovskite QDs by minimizing ligand dissociation and defect generation.

대면적 고기계적 내구성 태양전지를 위한 유기소재 및 소자 기술 개발

손해정[1)]**

Development of organic materials and devices for large-area and mechanically stable polymer photovoltaics.

Hae Jung Son[1)]**

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Abstract : Organic photovoltaics have received a lot of research interests since they give an opportunity to realize light energy conversion devices, which are lightweight and mechanically stable. Such advantages potentially allow Organic photovoltaics to be applied as power suppliers for wearable devices, electronic-skins and so on. To further develop organic photovoltaics from lab-scale researches into industrial applications, it is important to develop polymer materials and devices to form high performance p-n junction at a large area. We also need to understand molecular behaviors under mechanical stresses and degradation mechanism of the p-n junction, and develop novel methods for improving its mechanical stability. In this presentation, I will introduce developments of novel organic materials and methods for realize size-scalable p-n junction and stretchable energy devices. We successfully demonstrated high performance and stretchable photovoltaic devices at large area and reveal the relationship of organic materials and photovoltaic properties.

Key words : Organic photovoltaics (유기태양전지), Large-area (대면적), Stretchable device (스트레처블 디바이스, p-n junction, (p-n 접합)

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고효율 페로브스카이트 태양전지를 위한 고 결정 페로브스카이트 제작 방법

김기환[1)]**

Method for fabricating high-crystalline perovskite for high-efficiency perovskite solar cells

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Abstract :
One of the most effective methods to achieve high-performance perovskite solar cells has been to include additives that serve as dopants, crystallization agents, or passivate defect sites. Cl-based additives are among the most prevalent in literature, yet their exact role is still uncertain. In this work, we systematically study the function of methylammonium chloride (MACl) additive in formamidinium lead iodide (FAPbI3)-based perovskite. Using density functional theory, we provide a theoretical framework for understanding the interaction of MACl with a perovskite. We show that MACl successfully induces an intermediate to the pure FAPbI3 a-phase without annealing. The formation energy is related to the amount of incorporated MACl. By tuning the incorporation of MACl, the perovskite film quality can be significantly improved, exhibiting a 63 increase in grain size, a 33 increase in phase crystallinity, and a 4.33 increase in photoluminescence lifetime. The optimized solar cells achieved a certified efficiency of 23.48%.Put Abstract here

Key words : solar cells, perovskite, high crystal, additive, seed layer

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유기전해질을 Dual-side Passivation 층으로 도입한 고효율 고안정성 페로브스카이트 태양전지

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Efficient and Stable Perovskite Solar Cells by introducing Organic Electrolytes as Dual-side Passivation Layer

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Abstract :
Interface engineering at the interface between the perovskite layer and the charge transport layer (CTL), or CTL and metal electrodes, is critical for demonstrating the efficient and stable perovskite solar cells (PSCs). Herein, we demonstrate the efficient and stable PSCs by introducing the organic electrolytes (OEs) as a "dual-side passivation layer" in both p-i-n and n-i-p configuration of PSCs. Firstly, a newly synthesized bathocuproine (BCP)-based nonconjugated polyelectrolyte (poly-BCP) is introduced between the tin oxide (SnO2) CTL and the perovskite layer in the n-i-p configuration. Poly-BCP effectively passivate oxygen-vacancy defects of the SnO2 side and simultaneously scavenges ionic defects of perovskite side, suppressing both bulk and interfacial nonradiative recombination in PSCs. As a result, the modified PSCs exhibited a high power conversion efficiency (PCE) of 24.4% and a high open-circuit voltage of 1.21 V. Furthermore, the non-encapsulated PSCs show excellent long-term stability by retaining 93% of the initial PCE after 700 h under continuous 1-sun irradiation in nitrogen atmosphere conditions. Secondly, amine-functionalized small molecule electrolytes (SMEs) are introduced as passivation layer between the PCBM CTL and metal electrode (here, Cu) in the p-i-n configuration. A strong coordination bond of Cu—N forms at the Cu/SMEs interface, leading to the layer-layer growth mode for the dense formation of Cu electrodes with a strong adhesion to the CTL. Thus, this modified electrode prevents the ingress of moisture into the PSCs, resulting in outstanding moisture stability; the efficiency of non-encapsulated PSCs retains 90% of the initial PCE after 200 days of exposure to atmospheric air (25 ℃, relative humidity [RH] ~20-40%). Under harsher conditions (e.g., 25 ℃/RH65%, 25 ℃/RH85% and immersion in water) for a considerable time period, the modified PSCs manifest relatively no degradation compared with the pristine PSCs.

Key words : Perovskite Solar Cells(페로브스카이트 태양전지), Stability(안정성), Organic Electrolytes(유기전해질), Passivation Layer(패시베이션 층)

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유기, 주석 기반 태양전지의 소재 및 소자기술

송창은[1)]**

Materials and Device Engineering for Organic and Sn-based Perovskite Solar Cells

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Abstract : The development of high-performance organic and lead-free perovskite solar cells is crucial for addressing the concern of evironmental pollution from the toxic element Pb and Cd. In recent years, organic and tin-based perovskite solar cells have emerged as a promising candidate for eco-friendly photovoltaic technology for future applications. Here in, I present the latest research results of solution-processed organic and tin-based perovskite photovoltaics in our group. We hope that this approach may alleviate limiting factors for the commercialization of emerging photovoltaics based on organic and lead-free perovskite materials.

Key words : organic solar cells(유기태양전지), Sn-based perovskite solar cells(주석 기반 태양전지), photoactive morphology(광활성층 모폴로지), compositional engineering(조성 엔지니어링), additive processing (첨가제 공정)

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마이크로 프리즘 배열이 집적된 유연 GaAs 태양광 모듈

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MICRO-PRISM ARRAY INTEGRATED FLEXIBLE GAAS PHOTOVOLTAIC MODULE

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Abstract : 유연 GaAs 태양광 모듈을 LAB(Laser-Assisted Bonding) 공정과 HU(Hybrid Underfill) 재료 기술을 적용하여 개발하였다. 유연한 기판 위에 HU를 인쇄하고 두께 30μm 정도 얇은 GaAs 태양전지를 20×18로 배열한 후 LAB 공정을 적용하여 태양전지와 기판을 접합하였다. 태양전지 상부 전극에 와이어 본딩 공정을 적용한 다음 EVA와 전면 시트를 진공 라미네이션하였다.

HU는 솔더 파우더와 고분자 수지로 구성되어 있으며, LAB 공정 중 짧은 레이저 조사 시간에 기판과 태양전지의 전극을 전기적, 기계적으로 접합시키는 특성을 갖고 있다. 접착 공정 후경화 공정을 통해 경화된다. HU는 일반 솔더 페이스트 사용시 발생하는 기화 현상이 없기 때문에 그로 인해 발생하는 기포가 없고, 플럭스 잔류물에 의한 부식현상이 발생하지 않는다는 장점이 있다. LAB 공정은 980nm의 근적외선 레이저를 사용하며 태양전지에 흡수되어 태양전지 배열 아래 접합부의 온도를 높여 HU를 활성화시킨다. 기판의 온도를 태양광 전지보다 상대적으로 낮게 유지하여 LAB 접합 공정에서 발생하는 모듈의 휨을 상대적으로 줄여 공정의 안정성을 높이며 동시에 모듈의 신뢰성을 높인다. MPA(Micro-prism array)을 태양광 모듈에 집적하여 집광 효과를 얻을 수 있었다 MPA는 셀 사이에 입사되는 빛을 활성 셀로 굴절시켜 모듈의 출력을 증가시킨다. MPA를 모듈에 집적함으로써 전류가 상대적으로 약 5% 증가하였다. 셀 대 모듈 손실은 약 3%로 측정되어 모듈 제조 공정이 안정적임을 확인하였다. 곡률 반경은 최소 3 mm로 확인되었으며, 열 사이클 신뢰성 시험도 통과하였다.

Key words : 유연 GaAs 태양광 모듈, Laser-Assisted Bonding, Hybrid Underfill, 마이크로 프리즘 배열, 곡률 반경

Key word(주요용어) : Flexible GaAs Module, Laser-Assisted Bonding, Hybrid Underfill, Micro-prism array, radius of curvature

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본딩기술을 이용한 저가형 고효율 InGaP/GaAs 이중접합 태양전지 개발

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Development of low-cost, high-efficiency InGaP/GaAs double junction solar cells using bonding technology

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Abstract : 3-5족 화합물 태양전지는 현재 세계최고의 효율을 보유하고 있다. 미국의 NREL은 2022년 1sun AM1.5G 환경하에서 39.5%의 3중접합 태양전지 효율을 발표하였다. 3-5족 화합물 태양전지는 결정구조를 갖고 있는 적층형구조로 50년이상의 신뢰성을 확보한 안정된 태양전지이며, 우주기반 태양광 발전에 주축을 이루는 태양전지로 지구상의 기상조건의 악화에도 에너지를 공급할 수 있는 신재생에너지원이다. 이렇게 장점이 많음에도 불구하고 지상발전에서 적용범위가 적은 이유는 제작비용이 고가라는 점이다. 이러한 문제점을 극복하기 위해서 주로 연구된 대표기술은 기판재활용 기술과 실리콘과 결합된 3-5족/실리콘 태양전지 기술이다. 이 기술들은 본딩기술을 기반으로 이루어진다. 본 발표를 통해 그동안 연구되었던 국내외 3-5족 태양전지 관련 본딩 기술 개발동향과 본 연구소에서 연구했던 결과들에 대하여 발표하고자 한다.

Key words : bonding technology(본딩기술), High efficiency(고효율), Solar cell(태양전지), Low cost(저가형)

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InAlAs/GaAs 응력기반 슈퍼레티스 결함 필터 MBE 성장을 이용한 모노리식 GaAs/실리콘 탠덤 태양전지

정대환[*, **], 김연화, 메이 마다랑, 주은교

Monolithic MBE growth of GaAs/Si tandem solar cell using InAlAs/GaAs strained layer superlattices dislocation filter layer

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Abstract : Monolithic integration of III-V/Si tandem solar cells are promising because they can surpass the single junciton silicon cell efficiency of ~27% with relatively low manufacturing cost. Here, we demonstrate the first domestic GaAs/Silicon tandem solar cell with optically transparent InAlAs/GaAs strained lyaer superlattices dislocation filter layer. The cells were measured by LIV, shown 7.24% 1-Sun efficiency in J-V curve after as-grown samples were fabricated with standard wet etching, and electron beam deposition. The tandem cell is current-limited by the Si-subcell and incorporating a 3rd cell on top of the middle GaAs cell will increase the power conversion efficiency further. According to the results, we believe that an optimized GaAs on Si tandem solar cell with InAlAs/GaAs dislocation filter layers is a promising step to realize further cost-effective and high performance monolithic triple junction on Si solar cell.

Key words : Tandem solar cell (탠덤 태양전지), III-V/Si (35족/실리콘), MBE (분자빔 성장)

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내화특성이 향상된 강판일체형 컬러 태양광 모듈의 신뢰성 향상에 대한 연구

김영수[1)]*, 김아롱[2)], 탁성주[3)]

A Study on the reliable PV module using color steel plate substrate to secure fire safety

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Abstract : 건물 부문은 산업, 운송 분야에 이어 우리나라에서 세 번째로 많은 온실가스를 배출하고 있는 부문이다. 이에 따라 정부에서도 탄소 중립 실현을 위해 건물일체형 태양광(BIPV) 산업 활성화 대책을 발표하는 등 BIPV 제품 보급과 산업 발전을 위한 다양한 노력을 기울이고 있다. 최근 잇따른 건물 화재 사고로 인한 인명피해로 BIPV 제품에 대해서도 일반 건축물 외장재의 내화 특성을 요구하고 있어 내화 특성이 강화된 BIPV 제품의 개발이 시급한 상황이다. 이에 기존 유리 또는 폴리머로 이뤄져 있던 후면소재를 강판으로 대체한 강판일체형 모듈이 각광을 받고 있으며 glass를 사용한 모듈 대비 경량화도 가능해 BIPV 확산에 큰 기여를 할 것으로 기대되고 있다. 그러나 강판과 기존 모듈 소재들과의 조합, 적합성 및 모듈 장기 신뢰성에 대한 트랙 레코드가 부족한 상황으로 이에 대한 검증이 필요한 상황이다. 본 연구에서는 3원계 고내식 합금도금강판을 base plate로 적용한 강판일체형 BIPV 모듈의 신뢰성 향상을 위한 평가 결과를 소개하고 기존 BIPV 모듈과의 비교분석을 통한 모듈 안전성, 화재 안전성, 경량화 가능성에 대해 논의하고자 한다.

Key words : BIPV (건물일체형태양전지), color (컬러), steel plate (강판), fire safety(화재 안전성), c-Si solar cell (결정계 실리콘 태양전지)

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수직입면형 BIPV의 신규 화재시험방법 구성방안에 대한 연구

박계원*

Proposal on the new reaction-to-fire test method of vertically oriented BIPV

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Abstract : 건축수직 입면형 BIPV는 탄소중립 2050등 건축물 에너지 절감 정책의 일환으로 인해 널리 시공되는 추세로, 화재안전에 대해서는 KS C 8577에 의한 수평 화염전파 모드에 의한 화재평가로 검증받고 있으나 화염의 방향성이 현실적으로 반영되지 않는 한계를 내포하고 있다. 더불어 2022년부터 국토교통부 고시에 의거 건축외장재는 소재에 대한 성능시험(KS F ISO 5660-1, KS F 2271)에 부가하여 2층 규모의 시편에 대한 실물시험 검증 성능시험(KS F 8414)이 적용되도록 적시되어 있는 상황으로, 수직입면형 BIPV는 KS C 8577, KS F ISO 5660-1, KS F 2271, KS F 8414 등 4종류의 화재안전성 평가를 통과해야 한다. 반면에 수직입면형 BIPV이 내포하고 있는 화재위험성을 반영한 시험방법은 현재 국가표준 및 법령상 부재한 상황으로, 본 연구에서는 합리적인 화재시험방법의 도출을 위해 중공층 효과가 반영된 시험편의 배열 및 시험셋업 등의 구성방안을 검토하였다. 시험편에 위해를 가할 수 있는 임계열량을 설정하고 해당 가열원으로 공급되는 버너의 열출력을 산출하였으며, 수직화염확산성을 반영할 수 있는 시험편의 결합방법과 덕트내 흡입 유량의 산정 등에 대한 상세 시험방법의 도출을 시도하였다.
이를 통해 본 논문에서는 현재 일반적으로 유통되고 있는 BIPV의 연소성능 분석을 통해 성능수준을 파악하고 시편제작 시 기술적 한계여부 및 시험방법상의 현실적 위험성 반영여부 등을 검토하여 현 국토부 고시의 적합성을 검토하고자 한다. 더 나아가 건물 외장재로서 시공되는 수직 입면형 BIPV가 내포하는 수직방향의 화재위험성이 적절히 반영되면서, BIPV 시스템 특이성(에너지 효율을 상승시키기 위해 BIPV 결합모듈 내 중공층 레이어 반영 여부 등)이 파악될 수 있는 합리적인 화재성능시험방법을 제안하여 궁극적으로 BIPV 산업계의 기술개발 발전에 기여코자 한다.

Key words : Building Integrated PhotoVoltaic(건축일체형태양광), Reaction-to-fire performance(연소성능), fire safety(화재안전), facade materials(외장재), air cavity(중공층)

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건물 태양광 시스템 표준 현황 및 인증기준

류의환[1)]*, 김덕성[2)], 김규진[3)]**

Standard and Certification for Building Integrated Photovoltaic

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Abstract : 건물태양광 시스템은 주택, 상업건물, 공장, 연구시설 등에 설치될 수 있어 산업에서 다양하게 활용되고 있는 외장재를 태양광과 통합을 한다는 장점으로 사업성 및 사업 확장성이 우수하다고 판단된다. 현재 건물일체형 태양광 모듈 관련 국제표준 동향을 살펴보면 IEC에서는 IEC TC 82 WG2 소속의 Project Team에서 EN 50583을 바탕으로 커튼월(IEC 62985), 지붕재 표준 등을 참고하여 건물태양광 시스템 표준인 IEC 63092를 제정하였다. IEC 63092는 전기요구사항 및 건축적 요구사항(기계적 저항성 및 안정성, 화재시 안전, 위생/보건 및 환경, 사용시의 안전, 방음, 에너지 절약 및 열보유, 천연자원의 지속 가능성)을 적용형태별로 분류하여 그에 따르는 검증을 진행하도록 하고 있다. 국내에서는 2017년부터 건물일체형 태양광 모듈에 대하여 KS C 8577표준 시험을 통한 KS 인증 제도가 시행되고 있다. KS C 8577은 결정질,박막 모듈에 대한 평가가 모두 가능하며 총 22가지 시험항목이 있다. 모듈의 발전성능을 평가하기 위한 최대출력결정 시험, 전기적 안전성을 평가하기 위한 충격전압시험, 절연시험 등, 내구성을 평가하기 위한 고온고습, 온도사이클, 자외선 시험, 내화성을 평가하기 위한 내화시험, 구조성능을 평가하기 위한 고온저항, 구슬낙하 시험이 있다.

Key words : BIPV(건물일체형 태양광 모듈), 표준(Standard), 인증(Certification)

후기 : 본 연구는 2020년도 산업통상자원부의 재원으로 한국에너지기술평가원(KETEP)의 지원을 받아 수행한 연구과제입니다. (과제번호 : 20203040010330)

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Nanomaterials for energy and environmental applications

Dong Han Seo

Energy Materials & Devices Track

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Controlling the physical and chemical properties of the nanomaterials are essential for fabricating high performing energy storage devices especially in the field of supercapacitors and applying them in environmental applications. In this talk, it covers the synthesis and applications of diverse carbon-based nanomaterials synthesized by thermal & plasma assisted approaches and how composite structures can be formed with metal oxide nanostructures. Especially, the graphene-based materials and the graphene/metal oxide composite materials synthesis and their application in supercapacitors will be covered in details. Moreover, new emerging research areas in terms of materials synthesis & modification and future research direction related to the energy storage devices will be provided.

저비용 에너지 소자를 위한 균열기반 박막 분리 기술

이용환[1*,**]

Crack-Assisted Layer Transfer Method for Cost-Effective Energy Device Applications

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Abstract : Monocrystalline semiconductors-based solar energy conversion devices have attracted huge interest due to its high efficiency compared with other materials. However, the monocrystalline semiconductor-based devices have limited to only high-end applications due to the high cost of the monocrystalline semiconductor substrates such as gallium arsenide (GaAs) and indium phosphide (InP).

In this work, we show a cost-effective method for producing monocrystalline III-V compound semiconductor thin films via a facile cracking method. The sub 20 μm-thick large-area monocrystalline InP thin films was exfoliated from 350 μm-thick InP substrate via crack-assisted layer transfer method. We confirmed that the material quality (e.g., minority carrier lifetime) of the exfoliated InP thin films remains identical to that of the unprocessed commercial InP substrates. In addition, the approaches enable to produce InP thin films with micro-scale periodic grating structure on the fracture surface by controlling crack propagation direction in InP donor substrate. The dimensions of the periodic grating structure can be controlled by modification of the process parameters of the controlled cracking method. Finally, we propose a new approach for energy bandgap engineering in InP thin films which is further analyzed using computer-aided simulations. By adopting the grating structure of InP thin film, we show that periodically localized stress can be formed on InP thin film with a stress-inducing thin layer. This enables the control of strain as well as energy bandgap in InP thin films. Due to the stress concentration effect, the energy bandgap in InP thin film can be shifted up to 25 meV. In addition, we also present cost-effective photoelectrochemical (PEC) cells using the exfoliated monocrystalline semiconductor thin films for cost-effectively hydrogen fuel generation.

We believe that our proposed facile crack-assisted layer transfer method, which does not require any sophisticated equipment and complex fabrication process, shows a promising way to reduce the cost of monocrystalline silicon and III-V compound semiconductor. In addition, it can be used to realize cost-effective high-performance solar energy conversion devices as well as various (opto)electronic applications.

Key words : 결정질 반도체(monocrystalline semiconductor), 균열(cracking), 박형 웨이퍼(thin wafer), 광전기화학전지(photoelectrochemical cell), 물분해(water-splitting)

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광전기화학 수소생산을 위한 반도체 나노물질 기반 광전극 설계

윤정호[1)]*

Design of semiconducting nanomaterial-based photoelectrodes for photoelectrochemial (PEC) hydrogen production

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Abstract : Since Fujishima's research on Electrochemical Photolysis of Water using Nanomaterial-based Photoelectrodes in 1972, photoelectrochemical (PEC) properties of semiconducting nanomaterials have been attracting a great attention with the expectation of clean, renewable, and sustainable technologies in energy and environmental fields. The novel PEC properties shed new insights on emerging solar-driven research areas, including solar-to-hydrogen conversion by water splitting and solar-to-electricity conversion by solar cells, and environmental remediation by advanced oxidation process (AOP), and their hybrid system. In particular, semiconducting nanomaterials hold the keys for efficient solar energy harvesting and conversion processes like photocatalysis and PEC reactions. In this talk, we will give a brief overview of our recent progress in designing semiconducting nanomaterials for PEC energy conversion including solar hydrogen generation, bi-functional PEC system for waste-to-hydrogen, and a tandem system integrating PEC and perovskite solar cells. In more details, we have been focusing on a few aspects:

1) photocatalysis mechanism, light harvesting, charge separation and transfer and surface reaction engineering of low-cost metal oxide based semiconductors including modified TiO_2 and $BiVO_4$ as efficient photoelectrodes;

2) Solar hydrogen production using bi-functional PEC system and PEC-PV (perovskite solar cells) tandem system.

The resultant semiconducting nanomaterial systems exhibited efficient PEC performance, which underpins sustainable development of solar-energy conversion application.

Key words : solar-to-hydrogen conversion (태양광수소변환), photoelectrochemical reaction (광전기화학반응), semiconducting nanomaterials (반도체나노물질)

1) 경희대학교 환경학 및 환경공학과 대기환경에너지융합연구실

수로형적합 태양광 국·내외 현황 및 적용기술 개발

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Development of Domestic and international status and Application Technology for Solar System of Canal Type

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Abstract 재생에너지 3020 이행을 위해 농촌지역에 10GW 태양광 설치 필요하다. 탄소 배출 없는 에너지 공급의 중심인 태양광 분야 설치 확대가 농촌지역을 중심으로 확대되고 있으나, 민원, 환경문제, 지역조례에 의한 설치 제한으로 태양광의 설치 가용면적이 제한 되었다. 재생에너지 3020, 그린뉴딜, 탄소중립을 이행하기 위해서 유휴 공간 활용과 더불어 추가적인 토지확보 없이 기존의 시설물을 활용하는 재생에너지 설치가 필요하며, 이에 따른 기준이나 제도 마련을 위해서는 수로·하천 루프탑형 태양광의 실제 요구조건을 해결하도록 기술개발이 요구된다.

영농 지역에서는 IoT 기술 등의 4차 산업형 스마트팜 보급·확산이 급격히 진행됨에 따라, 예상되는 전력 수요 대응 및 영농생산 활동에 영향을 주지 않고 유휴부지 활용성이 높은 새로운 형태의 수로적합 태양광 발전 시스템 구축 모델 개발이 필요하다.

수로적합형 태양광 기술은 국산 양면·투광형 모듈 인증 제품을 활용한 수로적합 태양광, 안정성(태풍/강풍/홍수/폭설/한파, 화재 및 감전 등 전기안전) 확보가 가능한 구조물 설계·분석 및 설치기술, 기존 수로 상부에 일정 간격으로 설치되어, 수로 내 환경(수온, 수변생물, 토질 증) 저해 요소가 거의 없는 투광형 태양광발전시스템 설치, 수로 환경(수로폭, 구조, 수위), 설치방향(정남향 혹은 동서향), 배치(간격), 루프탑 높이에 대한 발전량 분석을 통한 시스템 최적 설계, 수로적합 태양광발전설비 및 전력공급, 모니터링, 디지털 O&M 등의 태양광 에너지 통합 시스템 구축을 통한 원활한 운영기술 확보가 요구된다.



그림 1. 인도 2MW 수로형 태양광



그림 2. 아치형 프로토 타입 수로태양광

육지 면적의 70%가 산지인 국내 환경에서 수로 루프탑 태양광시스템은 농수로, 하천 등의 유휴부지 활용, 보급 잠재량 개선 및 탄소 중립 기여할 것으로 판단된다. 투광형 양면 태양광 모듈을 활용, 고출력 확보, 경제성과 주민수용성 확보할 수 있는 기술로 향후 시장 진입성 및 사업성을 것으로 예상된다. 수로적합 루프탑형 태양광 발전은 지구온난화로 인한 기후위기에 대응하고 탄소중립을 위한 보급잠재량을 개선하는데 유효 할 것으로 판단된다.

Key words : Cannel(수로), Digital O&M(디지털 유지관리), Monitoring System(모니터링 시스템)★

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2023년도 한국태양광발전학회 춘계학술대회(2023.03.30~31)

태양광 플랫폼 기반 스마트 O&M 플랫폼 구축 사업 현황

박대현*
엔라이튼*

Abstract

태양광발전시스템에 대한 제조업체들의 기술이 발전함에 따라 태양광 패널의 발전효율이 상향 평준화 되고 있으며, 태양광 발전시스템 O&M을 통한 발전 효율성 향상 또한 중요해지고 있는 추세이다. 현재 태양광 발전시스템 O&M은 노동집약적 구조로 대규모 자원을 기반으로만 발전량 보증의 형태로 계약이 이루어지고 있다. 이러한 노동집약적 구조의 태양광 O&M 산업은 디지털화를 통한 기술적 진보가 시급한 분야로 볼 수 있으며, 기존 O&M 발전량 예측 솔루션은 예측오차 및 예측을 위한 데이터 네트워크 비용의 문제로 활용의 문제가 있다. 이에 소규모 태양광 자원을 대상으로 예측오차 및 데이터 네트워크 비용 문제를 해결하면서 사업자의 지출 부담을 줄일 수 있는 방식으로의 플랫폼 기반 태양광 스마트 O&M 서비스를 제안한다.

영농형 태양광 발전시스템의 경제성 있는 구조물의 연구

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A study on economical structures for agrivoltaic solar power generation systems

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Abstract

Climate change and carbon neutrality are attracting attention around the world, and according to the Paris Agreement, which came into effect in November 2016, the Korean government is also presenting policies suitable for this, and is carrying out strategies to reduce greenhouse gases and implement carbon neutrality.

Solar energy is a representative eco-friendly renewable energy, and recently, solar sharing, which enables crop cultivation and solar power generation by installing solar modules on top of farmland, is attracting attention. This is to enable solar power generation and crop growth at the same time by using solar energy. Solar sharing is an agrivoltaic solar power generation system that combines solar power generation and agriculture in a method proposed by Nagashima of Japan.

An agrivoltaic power generation system needs a structure to support the solar cell module generating solar power from the top. This structure has a problem in that the structure and construction cost are high because it must have a structure to withstand fixed load and snow load, wind load and earthquake, and also requires a height and span distance that do not affect the operation of agricultural machinery.

We compared various types of structures and calculated the cost using the most used frame structure in Korea as an example. In order to lower the construction cost out of the total cost, it is necessary to review the structure of the structure and the plan to shorten the construction period. Therefore, in this study, in order to solve these problems, research was conducted on the development of parts to reduce the number of parts used and the structure of structures that can shorten the construction period.

Key words : Structure(구조물),Agrivoltaic(영농형),Solar sharing(영농형태양광)

태양전지 개발 방향 및 필드에서의 제품 성능 분석

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Photovoltaic R&D direction and the analysis on the product performance in field

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Abstract : Photovoltaics (PV) is one of the renewable energies and the portion in the market is continuously increasing recently. The current main product is the crystalline mono product in PV market and there have been many activities to increase (1) the cell efficiency by developing the cell structures such as tunnel oxide passivated contact (TOPCON) solar cell, perovskite solar cell and tandem solar cell and (2) the module power by using big wafer size such as M10 (182 × 182 mm2) or M12(210 × 210 mm2) or using bifacial cell or using multi busbar cell such as 12 busbar to enhance fill factor (FF) or half cells to reduce power loss or module materials which has better optical performances such as higher transmittance at the glass and the front encapsulant and higher reflectance at the rear white encapsulant or white backsheet. In PV industry, not only above activites, but also cost reduction activities have been implemented to reduce the product cost, for example, using less consumption on the cell pastes, thinner wafer and cheap or thinner module materials on glass or encapsulant materials.

Above R&D activities in PV industry have focused on the above activities, however, there is another parameter to consider during R&D activities. It is the energy yield which can show how many electrical power can be generated during the specific time in field. This parameter can be affected by the cell and module design, and the system design. Recently, the above activities to increase the product power or to decrease the cost is found to affect the energy yield. This energy yield is hard to predict with the standard test condition (STC) during the product development.

This presentation shows some activities and examples which can predict the energy yield, and finally show the direction on PV R&D direction.

Key words : Crystalline photovoltaic (결정계 태양광), cell efficiency(셀효율), module power(모듈 출력), cost (비용), energy yield(이용률)

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재 제조 태양광모듈의 내구성능 평가 및 분류 기준 제안

김경수[1)]*

Development of Qualification Test Method And Classifying Technique for ECO-PV Module

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Abstract : 태양전지모듈은 최소 20년 이상 외부 환경의 변화에 안정적으로 전기에너지를 공급하는 태양광시스템의 기본 구성품이다. 그러나 제조 및 시스템 운전에 따른 불량 및 노후화가 급속이 진행되어 교체가 필요한 경우가 종종 발생하기도 한다. 또한 급속한 태양광모듈 제조 소재, 사이즈 및 출력 변경 등으로 적절한 동일 모듈로 교체가 어려운 경우도 있다.
본 발표에서는 태양전지 및 다이오드 및 케이블 등의 일정 부분의 재공정을 통하여 기존 모듈을 재사용할 수 있도록 하는 에코모듈 공정에 대하여 소개를 하며 사회적 및 경제적으로 유익한 재사용 모듈의 안정성을 평가할 수 있는 내구성능 평가 방법에 대한 연구 내용을 소개하고자한다. 또한 다양한 불량 및 고장 유형에서 에코모듈 공정에 투입 가능한 판단 기준 또한 제시하고자 한다. 내구성은 평가는 크게 3가지 카테고리로 분류하였으며 반 자동화 장치 및 소프트웨어 개발을 통하여 에코모듈의 통합적인 데이터화를 한 내용을 공유하고자한다. 시장에서 안정적으로 이런 에코모듈의 안정적인 정착을 바라며 본 내용에 대하여 학술대회를 통해 연구내용을 나누고자 한다.

Key words : PV Module(PV모듈), Solar Cell(태양전지), IEC TC82, Standard(표준), Reliability(신뢰성), Solar Energy(태양에너지) , Certificate(인증)

Reference:
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IEC TC82 WG2 태양광모듈 국제표준화동향과 국내 태양광표준인증로드맵

신정현[1)]*, 최현동[2)], 김승주[3)], 조성대[4)], 황수현[5)], 전무이[6)], 이승재[7)], 황재옥[8)]

IEC TC82 WG2 PV module international standardization trend and domestic PV standard certification road map

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Abstract : IEC TC82 WG2는 태양광모듈의 국제표준 제·개정을 선도하는 표준화기구이다. 이 표준화 기구에서는 지속적인 회의와 실증시험, 측정실험, 교차검증을 통하여 태양광모듈의 성능, 안전성, 신뢰성에 대한 새로운 시험평가 방법을 지속적으로 연구하고 이를 국제표준화 한다. IEC TC82 WG2에서 제정된 태양광모듈 표준은 태양광모듈의 연구, 제조, 거래, 설치에서 핵심적인 기준점이 된다. 이러한 국제 표준에 각 국가별로 특화된 지리적, 기술적, 산업적 여건을 고려한 National difference가 일부 반영될 수 있으나, 큰 틀에서는 IEC 표준을 크게 벗어나지 않는다.

IEC TC82 WG2의 태양광모듈 표준을 주도하는 것은 태양광산업계의 경쟁력을 향상시키는 핵심요소이기에, 미국, 독일, 유럽, 일본, 중국, 한국 등 의 태양광표준전문가 들이 지속적으로 참여하여 표준을 논의하고 있다. 현재 활발히 논의되고 있는 표준으로는 양면형태양광소자, 태양광모듈성능 및 안전성, 에너지등급, 부품소자, 재시험요건, 고온환경태양광모듈, 페로브스타이트텐덤측정표준 등이 있다. 본 연구에서는 이러한 IEC TC82 WG2의 최신 동향을 알아보고 분석하여 국제표준경쟁력 강화를 위한 방법을 모색하고자 한다.

또한 IEC TC82 WG2의 동향에서 나아가서 국내 태양광산업생태계에 특화된 국가태양광표준인증로드맵을 수립하기 위한 제반 연구와 진행사항을 함께 소개하고 각계 각층의 다양한 태양광 전문가들로부터 의견을 수렴하고자 한다.

Key words : IEC TC82 WG2(태양광모듈국제표준화기구), Testing and evaluation(시험평가), Certification(인증), Standardization(표준화), Roadmap(로드맵)

후 기 :
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1), 2), 3), 4), 5), 6), 7), 8) 한국기계전기전자시험연구원, Korea Testing Certification institute

태양열 에너지 저장소재 및 열전변환 소자

류학기[1)]*

Solar heat energy storage materials and thermoelectric conversion devices

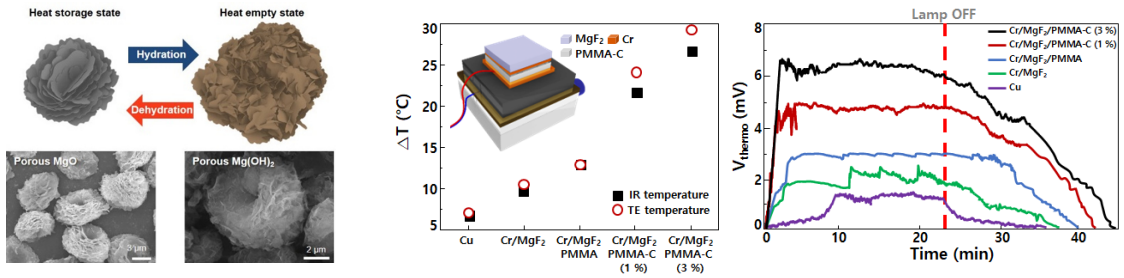
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Abstract : Continuous industrial development has increased the demand of energy. Inevitably, the development of energy sources is steadily progressing using various methods. Rather than establishing a new energy source, a system for storing waste heat generated by the industry has now been accepted as a useful strategy.

i) Among such systems, the hydration and dehydration reactions of $MgO/Mg(OH)_2$ are eco-friendly, have relatively low toxicity and risk, and have a large reserves. Therefore, it is a promising candidate for a heat storage system. In this study, ultra-high porous particles were used to maximize the heat storage efficiency of pure MgO. Due to its large surface area, the heat storage rate was 90.3% of the theoretical value and the reaction rate was very high. In addition, as structural collapse, likely to be caused by volume changes between reactions, is blocked as the porous region is filled and emptied, the cycle stability is secured. Ultra-high porous MgO micro-particles can be used to build eco-friendly heat storage systems.

ii) Moreover, a facile strategy for a hybrid photothermal structure that can efficiently manage solar heat is reported. The hybrid photothermal structure consists of a Cr/MgF_2 multilayer structure absorber and a poly(methyl methacrylate) (PMMA)-graphene heat reservoir that prevents the absorbed heat from being lost through radiation or convection. It exhibits a quite high light absorption of approximately 80 % over a wavelength range of $0.5 - 2.5\ \mu m$. The thermal conductivity and thermal diffusivity are improved by about 47 % according to the addition of graphene to PMMA, effectively transferring the stored heat to a place where it can be used efficiently. When the hybrid photothermal structure was applied to the hot zone of a thermoelectric generator device, the output voltage is improved by 2.74 times compared to the device with only the light absorber. In addition, the difference between the high and low temperatures reached up to approximately 27 K.



Key words : Solar Heat Storage (태양열 저장), Ultra-high porosity (초다공성), MgO (산화 마그네슘), PMMA-carbon composite (PMMA-carbon 복합체), heat reservoir (열저장), Thermoelectric device (열전소자)

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Electrochemical exfoliation of optoelectronically-active 2D materials

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Abstract : Two-dimensional (2D) nanomaterials have been received a great attention as potential building blocks for use in fundamental elements of (opto)electronic applications due to their diverse and remarkable electronic and optical properties. However, such fundamental demonstrations cannot be directly applied to practical applications because of scalable synthesis of high quality nanomaterials and their proper assembly. In this presentation, I will demonstrate wafer-scale van der Waals assembly of 2D materials, which are exfoliated via a molecular intercalation-assisted electrochemical exfoliation method. The resulting materials with distinct electronic properties including metal, semiconductor, and insulator, can be assembled into various (opto)electronic devices such as transistors, diodes, logic gates, and photodetectors. Also, such solution-based approach further enables inkjet printing-based device fabrications without a conventional lithography.

Key words : solution process(용액공정), 2D materials(2차원소재), electrochemical exfoliation(전기화학박리), electronics(전자소자), optoelectronics(광전자소자)

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Ultra-flexible and skin-compatible organic optoelectronic devices

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Ultra-flexible organic electronic devices have provided unprecedented advantages for bio-medical applications, with the development of the Internet of Things. In addition, the combination of facile and cost-effective processing accessibility of organic materials has triggered the rapid development of flexible electronic materials and devices. As a next-generation human-friendly wearable devices and sensors, the enhancement of electronic functions and mechanical stability should be further studied. In this presentation, I would like to review recent advances and remaining challenges in the field of ultra-flexible organic electronics for bio-medical applications. The preliminary results, including appropriate material selection and structure engineering, will be discussed to build skin-compatible energy harvester and sensors, while preserving their photonic/electrical performances under external mechanical stresses. We anticipate that our results will inspire more studies that assist in expanding the practical applications and potential of ultra-flexible electronics in wearables, primary healthcare, and medical and humanoid systems.



Figure 1. Ultra-flexible organic electronics on skin and tissue surface

Key words : Ultra-flexible electronics, Organic photovoltaics, Physiological sensors, Skin electronics

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Si 기반 광전극을 이용한 광전기화학적 물분해 수소 생산 최적화 연구

이민서[1], 김준[2], 김지혜[1], 장윤정[1],** 김진영[2]*,**

Systematic Engineering of Photoelectrochemical Cell toward Practical Hydrogen Production from Water Splitting using Silicon-based Photocathodes: from Catalyst to Cell Structure

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Abstract : Advances in solar-driven hydrogen production technologies are urgently needed to increase the performance and reduce the cost of photoelectrochemical (PEC) conversion and utilization of hydrogen. Metal/Semiconductor-based electrodes and polymer-based membranes are the core components to produce the PEC reaction and rapid progress in their development has increased their efficiencies and lifetime. Recently, PEC research and application activities gradually focus on exploring rational design and construction of cell structure for the promotion of cell performance and efficient hydrogen generation. The nanometer and micrometer scale interfaces in the membrane-electrode assembled layers are crucial for the scalable and sustainable PEC processes. In this talk, our recent results from these activities will be presented.

Key words : Photoelectrochemical(광전기학), Hydrogen production(수소생산)

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2) 한국과학기술연구원

반도체 물질의 엑시톤-광자 상호작용 연구

조창희[1)*]

Study on exciton-photon interaction in semiconductors

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Abstract : Nanophotonic materials/devices are stimulating the intense activity in the area of photonics due to their unique ability of tailoring the optoelectronic properties based on light-matter interactions. In particular, controlling the optical emission, transmission, and absorption properties of materials with engineered structures has been of great importance for understanding the underlying physics and designing new optoelectronic devices. In this talk, we will discuss the light-matter interactions in artificially designed nanophotonic devices which can tune the optical properties of semiconducting materials. By properly designing the devices, we can control the degree of coupling strength between the light and matter, providing a way to realize ultrafast light emitters, very low-threshold lasers, and coherent phases of matter depending on the coupling strength.

Key words : **Exciton**(엑시톤), Photon(광자), Semiconductor(반도체)

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Synthesis and Property control of N-doped Graphene Quantum Dots for Energy Applications

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Abstract : The emerging carbon-based quantum dots have been attracting attention because of their tremendous potential for optoelectronic and biomedical applications, which is due to their unique and size-tunable optical properties, their ability to be functionalized, and their biocompatibility. Here, we reported a facile one-step synthesis of the nitrogen-doped high-crystallinity GQDs (N-GQDs) from poly-acrylonitrile (PAN)-based CFs using the solvo-thermal cutting method. Interestingly, the optical properties of N-GQDs can be simply controlled by varying the heat treatment temperature of the CFs with different N contents.[1] We also proposed the facile one-step synthesis of highly fluorescent and amphiphilic N-GQDs using a fumaronitrile precursor. An interesting property of the prepared GQDs is their near pH neutral dispersibility without refinement, which stands in contrast to reported methods. This finding indicates that our approach could lead to low-cost and efficient processability that is scalable and environmentally friendly.[2]

Recently, we report an efficient and scalable production of chemically tailored N-GQDs with high uniformity and crystallinity via a simple one-step solvent catalytic reaction for the thermolytic self-assembly of molecular precursors. We find that the graphitization of N-containing precursors during the formation of N-GQDs can be modulated by intermolecular interaction with solvent molecules, the mechanism of wh ich is evidenced by theoretical calculations and various spectroscopic analyses. Given with the excellent visible-light photoresponse and photocatalytic activity of N-GQDs, it is expected that the proposed approach will promote the practical utilization of GQDs for various applications in the near future.[3]

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Key words : PAN fiber, Hydrothermal cutting, N-doped graphene quantum dots, One-step synthesis, Solvent-catalytic reaction, High-crystalline

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광전기화학 물분해용 분자 잉크 기반 신흥 칼코겐 광흡수층

양우석[1)*]

Molecular-Ink-Derived Emerging Chalcogenide Light Absorbers for Photoelectrochemical Water Splitting

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Abstract : To accelerate the deployment of solar H_2, cost must be reduced while maintaining reasonable efficiency for the realization of solar H_2 production at a commercial scale. The most important building blocks in photoelectrochemical (PEC) water splitting systems in terms of cost and performance are light-absorbing semiconductors. Therefore, it is of significant importance that searching low-cost semiconductors for PEC water splitting as well as the development of cost-effective fabrication routes.

In this talk, I will present recent advances in low-cost chalcogenide semiconductor materials for PEC water splitting. Particularly, molecular-ink-based routes, including hydrazine, thiol-amine and organochalcogen-based system, for the preparation of emerging chalcogenide light absorbers will be highlighted. Strengths and weaknesses of various chalcogenide light absorbers, such as Sb_2Se_3, SnS, Cu_2S, Cu_3BiS_3 will be critically discussed with material-specified strategies for enhancing the performance.

Key words : Water splitting (물분해), Molecular ink (분자 잉크), Solution processing (용액 공정), Chalcogenide (칼코겐화합물)

1) 성균관대학교 화학공학/고분자공학부

Contact-Resistance-Free, Millimeter-Scale Gas Sensor Compatible with Surface Mount Process: Towards Wearable Flexible Electronics

Hyo-Ryoung Lim

Major of Human Biocovergence, Division of Smart Healthcare, College of Information Technology and Convergence, Pukyong National University

With increasing demands for continuous air monitoring, recent advances in flexible, miniaturized electronics and nanostructured materials have paved the way for a lightweight, hand-held, and wearable gas sensor system. The state-of-the-art nanoengineered surface hold the promise of innovation; however, the majority of the studies rely on flexible, two-dimensional substrates coated with the gas-reactive nanomaterials, which increase the likelihood of electrical failure at the contact sites under bending. Here, we introduce a contact-resistance-free surface mount chip as a gas sensor platform coated with branched nanowire networks, exhibiting great sensing capabilities as well as low signal-to-noise ratios (SNR) at bent configurations. The low-cost, side-polished capacitors inherently embed three-dimensional interdigitated electrodes (IDEs) inside, exhibiting high compatibility with existing surface mount technologies (SMT). We exploit chemical conversion coatings of branched, p-type tellurium nanowires with a robust, high surface-area-to-volume ratio, doped with graphene for enhanced responses. The platform exemplifies nitrogen dioxide (NO_2) gas sensing capabilities with high sensitivity (> 20%) at time-weighted average (TWA) limit. Overall, our design approaches provide robust contact at nano-, micro-, and millimeter scales, useful in future wearable and flexible electronics.

미래 모빌리티용 방열 세라믹 소재기술 연구현황

최종진[1)*], 안철우[1)], 차현애[1)], 문영국[1)], 김정환[1)], 한병동[1)]

Research Status of Heat Dissipation Ceramic Materials for Future Mobility

Jong-Jin Choi[1)*], Cheol-Woo Ahn[1)], Hyun-Ae Cha[1)], Young Kook Moon[1)], Jung-Hwan Kim[1)], Byung-Dong Hahn[1)]

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Abstract :

최근 첨단산업의 급속한 발전과 함께 전자부품의 소형화 및 다기능화 추세로 인해서 전자제품의 열관리가 갈수록 어려워지고 있다. 전자부품의 열관리 성능의 향상을 위해서 점점 더 우수한 특성의 방열 소재를 필요로 하고 있으나, 사용에 충분한 절연 특성을 가지는 세라믹 소재 중 가장 우수한 방열 성능을 보이는 것으로 알려져 있는 질화물 소재는 비싼 가격으로 인하여 그 적용이 매우 제한적인 실정이다. 특히 급속히 수요가 증가하고 있는 전기자동차의 배터리 패키지 및 전장부품의 경우 이러한 발열 이슈가 더욱 심각해 지고 있어 기존에 사용되고 있는 알루미나 중심의 산화물 방열소재를 보다 고특성의 소재로 대체하고자 하는 요구가 크게 증가하고 있다.

이러한 이유로 저가 산화물 방열 소재의 방열 특성 향상 연구가 요구되고 있으며, 최근 한국재료연구원에서는 저가 고품질 산화물 방열 신소재를 개발하여 한국재료연구원의 연구소 기업인 SOULMATERIAL을 통해 상용화를 시도하고 있다. 한국재료연구원에서 개발된 소재는 저온소결이 가능하면서 열전도 특성은 향상된 신소재로서 가격 경쟁력이 있는 저가 고품질 산화물 방열 소재이다. 본 발표에서는 본 연구원에서 개발한 방열 소재의 열특성 분석과 함께, 첨가제의 첨가가 고품질 산화물 방열 소재의 소결온도와 열전도 특성에 미치는 영향에 대해 소개한다.

Key words : 방열(heat dissipation), 절연(insulation), 세라믹(ceramic), 산화물(oxide), 미래 모빌리티(future mobility)

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바이오/나노재료의 스마트한 디자인을 통한 센서 기반 플랫폼 개발

이준민

Smart design of bio/nanomaterials for developing sensor-based platforms

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Abstract : An organ-on-a-chip, volved from tissue engineering and microfluidics and associated microfabrication techniques, is a 3-D microfluidic-based cell culture platform that supports living human tissues and cells to simulates the activities, mechanics, and physiological response of organ systems. Tissue engineering enables establishing a minimally functional unit that contains multifaceted cellular and extracellular cues to recapitulate certain aspects of human physiology in a controlled manner rather than building a whole living organ. In addition, the microengineering techniques in organ-on-a-chip platforms combined with electrochemical sensors allow the use of flow-associated shear stress or mechanical strain and integration of multiple sensing units for monitoring of molecules secreted by cells and automatic systems for controlling dosing and dilution of multiple drugs in circulating media. In this regard, it is critical to understand the interface between biomaterials and cells because cells in contact with biomaterials can sense microenvironmental cues such as mechanical properties, matrix protein, and external stimuli as well as respond to subtle changes of these cues to eventually control cell phenotypes and fate decisions. Here I will present several nano-biomaterial-based model systems and sensor-based platforms where cells could be guided through multiple biophysical, mechanical, and biochemical signals to regulate cell fate decision (e.g., cardiomyocyte maturation) and even target tumors (e.g., cardiotoxicity-related drug delivery using a heart-breast cancer-on-a-chip platform). These studies reveal the importance of the precise synchronization of microenvironment parameters existed in engineered biomaterials during cellular decision making, which could be potentially employed for the development of biomedical engineering approaches especially for disease modeling and regenerative therapies.

Key words : Nanomaterials (나노재료), Biomaterials (생체재료), Hydrogels (하이드로젤), Tissue Engineering (조직공학)

1) 포항공과대학교 신소재공학과

Laser-based Selective Reaction for Synthesis of Nanomaterial and its Sensor Application

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Transition-metal dichalcogenide (TMD) heterostructures have garnered significant interest in the fields of physics, chemistry, and practical applications due to their tunable properties, including band offset, carrier density, and polarity. However, the complexity of existing synthesis processes has impeded the large-scale integration of heterostructure device arrays, thus hindering the realization of their full potential.

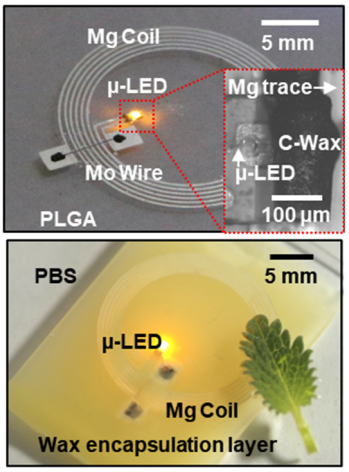
To address this issue, we propose a novel laser-based selective photothermal reaction method for the structure-controllable synthesis of TMDs, such as MoS_2 and WS_2. Our approach enables precise control of MoS_2 microstructure, including thickness, shape, and interspacing, resulting in a well-aligned patterned MoS_2 structure. Moreover, we confirmed that the MoS_2/WSe_2 heterojunction with a sharp interface between vertical layers could be realized using a pulsed laser annealing system. Through experimental and theoretical studies, the underlying principles of selective synthesis was established. As a proof of concept, we demonstrated the behavior of a MoS_2-based optoelectric sensor, a skin-attachable motion sensor in this study.

Composite materials for transient electronics

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Bioresorbable encapsulation, substrate, and conductive material are critically important in the development of an emerging class of biodegradable electronic devices and implants whose key characteristic is to dismember in a controlled fashion after stable operation, over extended time periods. In this presentation, conductive nanoparticle doped in transient materials, such as natural wax, silk, and pulp are investigated as a possible candidate toward transient electrodes. The demonstration of these materials includes a functional bioresorbable electronic system that can be chemically degraded or mechanically scattered in aquatic environments.



이차원 단결정 금속나노시트의 합성과 응용

김태욱[1)]**

Two-Dimensional Single-Crystalline Copper Nanosheets: Synthesis and Applications

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Abstract : Among the various metallic materials, copper is promising because it is inexpensive, abundant, and highly conductive. Synthetic methods and growth mechanisms to form various morphologies of Cu nanostructures and their use in various engineering applications have been intensively studied. In contrast to other novel metals with fcc crystalline structures (e.g., Au or Ag), due to the difficulty reducing Cu ions to Cu atomic clusters in aqueous solvent systems and their poor resistance to oxidation upon exposure to air, complicated synthetic strategies are employed to grow anisotropic metallic structures. It is well known that the growth of anisotropic metallic nanocrystals is possible through a slow reduction process, which provides a better chance to overcome the thermodynamically favored reaction toward the formation of truncated nanocubes or multiple twinned particles due to their intrinsically higher energy compared with other isotropic shapes. The sophisticated controls on kinetics of nucleation and growth is required. In this reason, there have been few reports on growth of Cu NPLs and their practical applications, compare to Cu NWs. Although these experimental approaches provide fundamental information on the crystal growth of Cu NSs and the possibility of using Cu NSs in practical applications, it remains a great challenge to achieve the well-defined, simple, eco-friendly and dimension-controlled synthesis of Cu NSs, especially their large-size growth, up to tens of microns, for potential electronic ink applications. Here, we demonstrate a simple method for the dimensional control of Cu nanocrystals from NWs (1D) to NSs (2D) by adding iodine (I) as an additive in the well-known synthesis of Cu NWs. The combination of the additive (iodine (I)), mild reductant (glucose), stabilizer (hexadecylamine, HDA) and reaction time allowed us to grow large single-crystalline two-dimensional Cu NSs with the edge lengths up to 30 μm. We report hierarchical porous Cu film via assembly of single-crystalline, nanometer-thick, and micrometer-long copper nanosheets and their use in EMI shielding. Layer-by-layer assembly of Cu nanosheets enabled formation of a hierarchically-structured porous Cu film with features such as multi-layer stacking; 2D networking; and a layered, sheet-like void architecture. The hierarchical-structured porous Cu foil exhibited outstanding EMI shielding performance compared to the same thickness of dense copper and other materials, exhibiting EMI shielding effectiveness (SE) values of 100 and 60.7dB at thicknesses of 15 and 1.6 μm, respectively. In addition, the EMI SE of the hierarchical porous Cu film was maintained up to 18 months under ambient conditions at room temperature and showed negligible changes after thermal annealing at 200°C for 1 hr. These findings suggest that Cu nanosheets and their layer-by-layer assembly are one of the promising EMI shielding technologies for practical electronic applications.

Key words : Metal nanosheet(금속나노시트), Dimension control(차원제어), copper nanocrystal(구리나노입자), Porous copper film (다공성구리필름)

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미세구조와 전자 및 정공 선택형 poly-Si/SiO_x TOPCon의 전하수송 메커니즘간의 상관관계 연구

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Correlations between microstructure and carrier transport for Poly-Si/SiO_x structured electron and hole selective tunnel oxide passivating contacts

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Abstract : Stack of heavily doped poly-Si and SiO_x tunnel oxide forms tunnel oxide passivating contact (TOPCon), which is getting spotlight to realize high-efficiency crystalline Si solar cells. Specifically, in orger to further increase efficiency of c-Si solar cells, realization of c-Si solar cells with both contacts having TOPCon structures are needed. In this regard, lack of understanding on distinct characteristics in carrier transport mechanisms and related microstructural evolutions between electron and hole contacts is one of the hurdles. In this paper, we study on correlations between microstructural evolution and resulting carrier transport mechanism of electron and hole contacts which consist of doped poly-Si and SiO_x tunnel oxide. Generrally, it is known that electron contacts exhibit higher passivation quality compared to hole contacts. We find that passivation properties and carrier transport mechanisms are both strongly affected by microstructural evolution of both doped poly-Si and SiOx tunnel oxide. Based on different carrier transport mechanisms observed for electron and hole contacts, we suggest design rules for hole contacts, which needed to be designed in a different way compared to electron contacts.

Key words : Crystalline silicon solar cells (결정질 실리콘 태양전지), carrier selective passivating contacts (전하선택형 패시베이팅 접촉), polycrystalline silicon (다결정 실리콘), tunnel oxide (터널 산화막), carrier transport (전하수송), microstructure (미세구조)

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p-n 접합을 이용한 고효율 결정질 실리콘 광음극

진원주[1], 서관용[1]*

High efficiency crystalline silicon photocathode using a p-n junction

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Abstract :

In this prensentation, we introduce a high-efficiency crystalline silicon (c-Si) photoelectrode, which has a p-n junction. Comparing with the c-Si/electrolyte hetero-junction photoelectrode, the c-Si p-n junction photoelectrode would exhibit a higher applied bias photon efficiency (ABPE) due to its high built-in electric field. Moreover, unlike conventional photocatalysts, we applied additional catalyst in the opposite side to the incident light direction and thus it allows us to maximize light absorption without considering the transmittance of the catalysts. In addition, the catalyst plays a role of passivation to prevent corrosion of c-Si in an electrolyte environment, enabling the realization of a highly stable photoelectrode. As a result, our photoelectrode showed an ABPE of 10.1% when used as a photocathode and an ABPE of 4.1% when used as a photoanode. Furthermore, it maintained a high stability, with an efficiency of over 98% after more than 1000 hours of operation.

Key words : Crystalline silicon (결정질 실리콘), p-n junction (p-n 접합), Photoelectrochemical cell(광전기화학 전지), Water splitting(물 분해)

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증착 온도에 따른 SiN_x layer의 수소 함량 및 결합 구조 특성 분석

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Analysis of Hydrogen Content and Bonding Structure of SiN_x Layer by Deposition Temperature

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Abstract : SiN_x layer는 태양전지에서 여러 주요한 기능을 담당한다. 주로 반사 방지막의 역할을 수행하며 뿐만 아니라 내부에 포함된 수소가 태양전지의 재결합을 막는 passivation을 한다. 그러나 소성 이나 열처리 공정 등의 고온 공정에서 SiN_x layer 내부에 포함된 수소가 외부로 방출되며 기공, 즉 blister가 발생하게 되는데 이러한 이유로 SiN_x layer의 특성이 저하거나 구성이 변화될 수 있으므로 공정 시 이를 유의하여야 한다. 본 연구에서는 공정 시 온도의 변화에 따라 SiN_x layer의 결합구조와 박막이 가지는 특성의 변화를 분석하고 그러한 변화가 blister의 분포에 의해 영향을 받는지에 대한 분석을 하고자하였다. SiN_x layer 증착을 위해 PECVD (Plasma enhanced chemical vapor deposition)를 이용해 n-poly TOPCon의 후면구조에 350 ℃ ~ 530 ℃의 범위에서 각 조건별로 SiN_x layer를 증착하였다. 그리고 각 온도 별로 준비한 sample을 소성 전과 소성 후로 분류하여 각 조건의 sample을 FT-IR (Fourier transform infrared), exo-diffusion, OM (optical microscopy)을 통해 결합 구조, 수소 함유량, blister의 분포를 파악하였다. 그리고 QSSPC (Quasi-Steady-State PhotoConductance measurement)를 이용하여 박막이 가지는 passivation 특성을 분석하였다. 추가적으로 전극 공정을 진행하여 각 조건에서 SiN_x layer가 가지는 전극의 접촉 비저항을 비교하여 blister와 접촉 비저항의 상관관계를 파악하고자 하였다.

Key words : SiN_x layer(질화막), blister(블리스터), passivation (패시베이션), specific contact resistivity (접촉 저항)

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습식 표면처리 기술을 통한 고효율, 대면적 투명 결정질 실리콘 태양전지 개발

박정환[1], 이강민[1], 서관용[1]*

Development of High-effciency and Enlarged Transparent Crystalline Silicon Solar Cells via Wet Chemical Surface Treatment

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Abstract : Transparent crystalline silicon (c-Si) solar cells are promising candidates for the commercialization of transparent solar cells thanks to high efficiency and long-term stability. The transparent c-Si solar cell was fabricated by forming a microhole structure using deep reactive ion etching (DRIE). However, DRIE used to fabricate the c-Si microhole structure inevitably generates silicon sidewall surface damage, enhancing surface recombination and limiting the power conversion efficiency (PCE) of the solar cell. Here, we apply wet chemical surface treatment to c-Si microhole using isotropic wet chemical etching technique to conformally remove the sidewall damage. As a result, the transparent c-Si solar cell with the wet chemical surface treatment exhibited an open-circuit voltage (V_{oc}) increase of 90 mV compared with the transparent solar cell without the surface treatment. Whereby, the champion device showed a PCE of 14.5% (current density (J_{sc}) = 28.9 mA/cm^2,V_{oc} = 638 mV, and fill factor (FF) =78.8%) at an average visible transmittance of 20% and cell size of 25 cm^2). Furthermore, isotropic wet chemical etching systematically can control the microhole diameter at the etching rate (9.5 μm/min) while removing the sidewall damage of the microhole. As the microhole diameter increased, the light transmittance at the visible wavelength of 400-800 nm could be tuned from 10% to 70% using one master transparent c-Si substrate. Notably, the proposed wet chemical surface treatment satisfies the three development factors of 1) high PCE, 2) scaling up, and 3) easy light transmittance tuning of c-Si TPVs.

Key words : Transparent Solar Cells (투명 태양전지), Crystalline silicon(결정질 실리콘), Surface Treatment(표면처리), Transmittance Control (투과도 제어), Neutral Color (중성색), Wet-Chemical Etching (습식 식각)

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기생흡수 저감을 위한 top contact-free 페로브스카이트/실리콘 탠덤 태양전지 구현

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Demonstration of Top Contact-Free Perovskite/Silicon Tandem Solar Cells for Minimizing Parasitic Absorption

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Abstract :

단일접합 태양전지의 이론한계효율을 극복하기 위한 방안으로, 다중접합 태양전지에 대한 연구가 활발하게 이루어지고 있다. 2-terminal (2-T) 탠덤 태양전지는 서로 다른 2개의 광흡수층이 적층되어있는 구조로, 전기적으로 직렬연결되어있기 때문에 소자의 전류밀도가 광전 특성에 큰 영향을 끼친다. 하지만 광흡수층 외에 캐리어 생성에 기여하지 않는 여러 층들 (전하수송층, 버퍼층, 투명전극 등)도 함께 수직 방향으로 적층되어있어 불가피한 기생흡수가 발생하며, 이는 소자의 전류밀도를 제한하게 된다. 본 연구에서는 기존 2-T 탠덤 태양전지에서 발생하는 기생흡수를 최소화하고자, 상부 태양전지의 상단에 존재하는 층들을 상부 태양전지와 하부 태양전지의 사이에 중간전극 (quasi-interdigitated intermediate electrode) 형태로 재배치함으로써 광흡수를 극대화할 수 있는 탠덤 구조를 제시하고 이를 최초로 구현하였다. 이 때, 중간전극은 TiO2와 그 위에 honeycomb 형태로 패터닝된 Ni/NiOx shell을 포함하며, SiOx를 통해 두 층간의 전기적 연결을 차단하였다. Ni/NiOx shell 제작은 포토리소그래피와 산화 공정을 포함하며, 약 10 nm 가량의 NiOx가 형성되었음을 확인하였다. 최종 탠덤 소자는 1.54 V의 개방전압과 4.23%의 효율을 보였으며, 추가 분석과 함께 앞으로의 개선 방향에 대하여 논의하였다.

Key words : Tandem solar cells(탠덤 태양전지), Quasi-interdigitated intermediate electrode(중간전극), Parasitic absorption(기생흡수), Ni oxidation(Ni 산화)

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Controlling the light trapping capability of microwire solar cells via microsphere lithography

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Abstract:

Silicon microwires have been widely investigated for realizing the high-efficiency silicon solar cells thanks to the outstanding light absorption property and the formation of the radial junction. To realize the high-efficiency microwire based radial junction solar cells, it is necessary to control the microwires structure such as diameter, spacing, and length of the microwires. Here, we introduced a novel fabrication process of microwires through a microsphere lithography process. The microsphere lithography using polystyrene beads enables to control spacing and dimension of microwires for the enhanced light absorption. The fabricated tapered microwires (TMW) via the microsphere lithography process exhibit outstanding light absorption of 97% at the entire wavelength region (300-1100 nm) even without anti-reflection film layer. To experimentally demonstrate the TMW arrays with a nanometer-scale spacing of 200 nm, which cannot be realized by conventional photo-lithography, we utilized a soft lithography method based on polystyrene beads for patterning a c-Si wafer. The solar cells based on optimized TMW arrays exhibited a current density of 42.5 mA/cm^2 and power conversion efficiency of 20.5%, which exceed those of the previously reported microwire-based radial junction solar cells. Therefore, we expect the proposed soft lithography process for the microwires will be a versatile platform for the high-efficiency radial junction solar cells.

Keywords: : tapered microwire array, microsphere lithography, nanoscale spacing control, radial junction solar cells, crystalline silicon solar cells

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Monolithic 페로브스카이트/실리콘 탠덤 소자의 구조별 바텀 실리콘 태양전지 최적화 방향

송호영[1)]*, 이상원[2)], 강윤묵[3)], 김동환[1)], 이해석[3)]**

Direction for optimizing bottom Silicon solar cells by structure in monolithic Perovskite/Silicon tandem devices

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Abstract :
In this study, we demonstrate numerical modeling to analyze and optimize the effects of optical and electrical properties in 2 terminal monolithic Perovskite/Silicon tandem structure using the Sunsolve and Quokka programs. First, based on the recently reported high-efficiency 2 terminal Perovskite/Silicon tandem system, we provide properties for each layer to minimize optical loss using optical simulation. After the top perovskite and the recombination layer were fixed using this, the bottom Silicon was largely divided into homojunction (PERC, TOPCon structure) and heterojunction (HIT structure), and an electrical simulation was conducted for each structure. Especially the characteristics of Si bottom cell were identified according to the bulk properties (bulk lifetime, resistivity) and passivation quality. Through the optimized results of the optical and electrical simulations, we were able to evaluate the potential efficiency limit and propose a method for improving the cell performance for each bottom cell structure in the tandem devices.

Key words : 2 terminal monolithic Perovskite/Silicon tandem (2단자 페로브/실리콘 탠덤), each bottom Silicon solar cell structure (각 바텀 실리콘 태양전지 구조별), numerical modeling (수치 모델링)

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산업용 CVD의 실시간 모니터링을 위한 PSG 박막 성장의 잔류가스 분석방법

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Residual Gas Analysis methoed of PSG Layer Growth for In-Situ Monitoring of Industrial-Scale CVD

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Abstract : 태양전지 제조 산업에서는 대량의 박막 생산을 위해 chemical vapor deposition (CVD) 기법을 선택한다. 이러한 CVD 기법은 챔버 안에서 화학반응에 매우 민감하기 때문에 공정 수율의 향상을 위해 주기적인 유지보수로 돌발적인 고장이나 불량을 방지하여 장비의 안정적인 상태를 유지한다. 최근 Industry 4.0 전략의 도래와 함께 주목받는 핵심 기술 중 하나는 predictive maintenance (PdM) 이다. PdM은 downtime 또는 주기적인 유지보수 방법과 다르게 돌발적으로 발생하는 비정상 상태의 특성화를 통해 정상 상태에서 비정상 상태로 진행되는 과정을 예측하여 매우 효율적이고 적시에 적절한 유지보수 전략이다. Residual gas analyzer (RGA) 는 PdM 전략을 위해 CVD 공정에 적용하기 적합한 분석법 중 하나이다.

본 논문은 low pressure CVD (LPCVD) 기법을 사용하는 industrial-scale 장비에서 phosphosilicate glass (PSG) 박막 증착 공정 시 RGA를 이용하여 'chemically sensitive' CVD 공정 제어 방법을 제안한다. 여기서 PSG 박막은 오늘날 passivated emitter and rear contact (PERC)태양전지의 emitter 형성을 위해 주로 사용되는 박막 물질이다. RGA 측정은 PSG 박막 증착 시 반응 가스의 공급량에 따른 박막 두께 변화를 분석했다. 그 결과, 반응 가스 공급량 변화에 따라 reaction rate의 변화는 거의 없었지만 total reaction이 변화는 것이 확인 되었다. 그리고 RGA 결과를 통해 gas flow rate 계산하여 반응 가스의 부분압에 따른 박막 성장률을 실시간으로 예측할 수 있음을 실험적으로 구현했다. 박막 성장을 실시간 모니터링하고, 예측하는 것은 박막의 대량생산과정에서 Closed Loop 시스템의 제어를 통해 더 나은 재현성과 품질관리를 가능하게 하여 PdM 전략 수립에 도움이 되고, 더 나아가 smart factory 구현에 큰 기여를 할 것으로 예상된다.

Key words : Predictive Maintenance(예측 유지보수), Chemical Vapor Deposition(화학 기상 증착), PhosphoSilicate Glass(인도핑 실리카 글래스), Residual Gas Analyzer(잔류가스분석기)

터널옥사이드와 도핑된 폴리실리콘 사이에 intrinsic poly-Si 박막을 삽입하여 TOPCon 태양전지의 패시베이션 특성 향상

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Improved SiO_x/poly-Si passivated contacts via inserting intrinsic poly-Si layer

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Abstract :

Tunnel oxide passivated contact (TOPCon) solar cells have gained significant attention due to their high efficiency. The chemical passivation through the tunnel oxide layer and field effect through the doped polysilicon layer are the key factors that enable TOPCon solar cells to achieve high efficiency. However, the passivation quality (iVoc, lifetime) of TOPCon solar cells degrades due to auger recombination caused by excessive P in-diffusion from doped poly-Si to c-Si during the high-temperature process of depositing doped polysilicon.

In this research, we aimed to reduce the auger recombination in TOPCon solar cells by controlling the doping profile in crystalline silicon with an intrinsic polysilicon layer of different thicknesses between tunnel oxide and doped poly-Si layer. The intrinsic polysilicon layer (9 nm, 18 nm, and 27 nm) was inserted between the tunnel oxide (1.5 nm or less) and the doped polysilicon layer. The experiment was conducted in-situ from the tunnel oxide to the doped polysilicon layer through PECVD, and heat treatment was carried out for 30 minutes by changing the temperature (810-890°C) in the furnace.

Our results indicate that the thickness of the intrinsic polysilicon layer has a significant impact on the passivation quality of TOPCon solar cells. We observed that when the thickness of the intrinsic polysilicon layer was 18 nm or more, there was less degradation of the passivation quality at a relatively high temperature. Moreover, the structure with intrinsic polysilicon can efficiently control the doping profile in crystalline silicon.

In conclusion, our research demonstrates that the incorporation of an intrinsic polysilicon layer of sufficient thickness can improve the passivation quality of TOPCon solar cells, enabling them to achieve higher efficiencies at heat process. Our findings provide valuable insights for the development of efficient and cost-effective TOPCon solar cells.

Key words : Tunnel oxide passivated contact (탑콘 태양전지 내의 폴리 실리콘 특성), Passivation quality (패시베이션 특성), Auger recombination (오제 재결합), Doping profile (도핑 프로파일)

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기상증착된 고효율 SnS_xSe_{1-x} 박막태양전지를 위한 Se/(S+Se) 조성비 최적화

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The Se/(S+Se) Compositional Ratio Optimization Towards Highly Efficient Vapor-Transport-Deposited SnS_xSe_{1-x} Thin-film Solar Cells

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Abstract : In this work, the tin chalcogenide based mixed-phase SnS_xSe_{1-x} ($0<x<1$) thin films were synthesized by using the vapor-transport-deposition (VTD) method. The tin sulfide (SnS) and tin selenide (SnSe) is considered promising binary chalcogenide absorber materials due to their advantageous properties such as p-type conductivity, bandgap (1.2-1.4 eV), high optical absorption coefficient, and ~32% of theoretical efficiency for the application in the highly efficient thin-film solar cells (TFSCs). By taking advantage of different bandgaps of the SnS and SnSe, the SnS_xSe_{1-x} thin films can be prepared with various bandgaps by changing the Se/(S+Se) ratio. Therefore, SnS_xSe_{1-x} thin films were deposited using a mixture of SnS and SnSe powders as the evaporation source in the VTD. Energy-dispersive X-ray spectroscopy (EDS) analysis confirmed the formation of homogeneously and uniformly distributed ternary SnS_xSe_{1-x} alloys, and it was possible to tune the Se/(S+Se) ratio within the SnS_xSe_{1-x} by varying the SnS to SnSe powder ratio. The corresponding X-ray diffraction patterns revealed that the 2θ values of the characteristic (111) peak of the orthorhombic structure shifted toward the lower angle as the Se-content increased owing to the expansion of the lattice constant due to the larger-sized Se atoms. The S-rich SnS_xSe_{1-x} devices exhibited superior V_{oc}, while the Se-rich devices displayed superior J_{sc}. The device with the optimum Se/(S+Se) ratio showed intermediate V_{oc} and J_{sc} values but maximum device performance. The highest power conversion efficiency of 3.75% was achieved for the optimized $SnS_{0.70}Se_{0.30}$ absorber layer, and this value is significantly higher than those of pure SnS or SnSe devices.

Key words : Thin film solar cells(박막태양전지), Tin Chalcogenides(주석 칼코지나이드), SnS_xSe_{1-x}, vapor transport deposion(기상증착법)

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비정질 TiO_2 패시베이팅 컨택 도입을 통해 계면 특성이 강화된 초박막 CIGS 태양전지 개발

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Abstract : $Cu(In,Ga)(S,Se)_2$ (CIGS) ultrathin solar cells (UTSCs) have received much research attention because of their superior potential for industrial-scale production and various photovoltaic applications. For CIGS UTSCs to achieve high efficiency, rear-interface passivation is important because it has larger influence on thinner absorbers. Conventional passivation layers (e.g., Al_2O_3, SiO_2, and HfO_2) inevitably require nanoscale contact openings for electrical conduction, the complex processing of which severely hinders scale-up production. In this presentation, we show that amorphous TiO_2 layers act as a passivating contact, which not only passivates defective rear-interfaces but also provides excellent electrical conduction for solution-processed CIGS UTSCs. The amorphous nature of TiO_2 layers plays a decisive role in achieving ohmic conduction over the entire area without any contact openings. The holes in the absorbers easily move into amorphous TiO_2 layers, even in the presence of large valence band offset (2.6 eV), suggesting that the defect states within the band gap of the TiO_2 layers act as hole conduction pathways. The detailed analysis data and device performance statistics will be discussed in detail.

Key words : Amorphous TiO_2 (비정질 TiO_2), Passivating contact (패시베이팅 컨택), Chalcopyrite (칼코파이라이트), Ultrathin solar cell (초박막 태양전지), Defect states (결함 준위)

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폴리이미드 코팅된 유리기판을 이용한 ITO 후면전극 기반 유연 CIGS 박막 태양전지 모듈

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Flexible CIGS thin films monolithic-integrated solar modules using ITO back contact on Polyimide-coated glass substrate

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Abstract : 폴리이미드 기판을 이용한 CIGS 박막태양전지는 가볍고 유연성이 우수하여 건물, 창호, 휴대용 기기 등 다양한 응용 분야에서 성장잠재력이 높다. 그러나, 폴리이미드는 CIGS 공정에 따른 열변형으로 구성박막층의 박리 및 균열이 쉽게 발생하여 공정의 난이도가 매우 높다. 대표적으로 CIGS 태양전지의 후면전극으로 사용되는 Mo은 폴리이미드와의 열팽창 계수 차이로 균열이 쉽게 발생하며 유연 CIGS 태양전지의 기계적 안정성을 감소시킨다. 또한, 단일집적모듈 구현을 위한 후면전극 절연공정(P1 스크라이빙)시 비정상적 가공형상이 자주 발현되어 모듈 성능이 열화될 가능성이 높다. 따라서, 본 연구에서는 유연 CIGS 태양전지 제조의 안정성을 향상시킬 목적으로, 폴리이미드를 스핀코팅한 유리기판을 적용하고 ITO 후면전극으로 대체한 CIGS 태양전지 모듈기술을 개발하였다. 폴리이미드 필름 대신 폴리이미드/유리 기판을 적용함으로써 CIGS 태양전지 제조공정 난이도를 낮출 뿐만 아니라 내구성이 뛰어난 CIGS 태양전지 구현이 가능하고, 폴리이미드/유리기판을 분리함으로써 유연 태양전지를 구현할 수 있었다. ITO/CIGS 셀 제작시 계면에서 형성되는 고저항 GaOx 문제 해결을 위한 계면구조 최적화를 통해 셀효율을 17.3%로 향상시킬 수 있었다. 또한, 단일집적모듈 구조 구현을 위해 레이저를 이용한 P1, P2, P3 가공 기술을 개발하였다. ITO 후면전극은 Mo 전극에 비해 수월성 높은 가공이 가능하였으며, 이를 기반으로 유리기판 수준의 cell-to-module (CTM) 성능을 확보할 수 있었다. 40.14cm^2 크기의 면적에서 단일집적모듈 효율 14.94%을 구현했다. 제작된 CIGS 태양전지는 폴리이미드/유리기판을 분리하여 유연 태양전지를 구현했으며, 분리된 태양전지의 효율 감소는 3% 이하로 유연 태양전지 구현 가능성을 보여줬다. 이러한 결과는 태양전지의 고효율 구현 가능성을 보여주며, 안정적인 공정이 가능해 유연 태양전지 산업에서 높은 경쟁력을 가진다.

Key words : CIGS, 유연태양전지, 폴리이미드, 후면전극, ITO

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반투광형 및 양면수광형 광전변환을 위한 초박막 $CuInSe_2$ 광흡수층 최적 성장조건 연구

안진기[1,2)*], 김동렬[1)], 조아라[1,3)], 이아름[1)], 이상민[1)], 안승규[1)], 정인영[1)], 조준식[1,3)], 김태완[2)], 박주형[1,3)**]

Study on the optimal growth condition of $CuInSe_2$ ultrathin absorber layer for semitransparent and bifacial power conversion

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Abstract : 투명전극을 사용한 반투광형 태양전지는 양면 수광을 통한 효율적인 전력생산뿐만 아니라 안정성이나 건축 미학적 관점에서도 우수하여 다양한 생활밀착형 에너지원으로서 응용 및 활용이 가능하다. 본 연구에서는 반투광형 태양전지기술 중 $Cu(In,Ga)Se_2$(CIGS) 태양전지에서 Ga을 제외시킨 300 nm 두께의 $CuInSe_2$(CISe) 광흡수층을 single stage co-evaporation 방식을 통하여 처음으로 양면수광형 semitransparent ultrathin(STUT) CISe 태양전지를 제작하였다. CISe 광흡수층은 밴드갭이 약 1.0 eV이고 광흡수계수가 높은 장점이 있으며, Ga의 배제로 인하여 광흡수층의 결정성이 높아 전류밀도도 상대적으로 높다. STUT CISe 태양전지를 위한 광흡수층의 최적 성장조건을 연구하기 위해서, 증착 온도와 NaF post-deposition treatment(PDT) 시간을 조정하였다. 첫번째로, 증착 온도를 다양하게 변화시킴에 따라 CISe 흡수층의 구조적 및 형상적인 변화를 관찰하였고, 기판온도가 증가할수록 흡수층 내의 결정질 크기가 점점 커지는 것을 확인하였다. 두번째로, 최적의 증착 온도에서 NaF PDT 시간을 조정하면서 태양전지 성능을 조사하였다. NaF PDT 공정이 없는 경우와 대비하여, NaF PDT 공정을 한 경우 단락전류밀도는 비슷하지만 개방전압과 충진율이 상당하게 증가한 것을 확인하였다. 이렇게 도출된 최적의 성장조건에서 STUT CISe 태양전지의 효율은 6.36%를 보였다. 또한, 최적의 성장조건에서 제작된 STUT CISe 태양전지를 전후면 동시 광조사 조건(전면 1.0 sun 고정, 후면 0.0~1.0 sun 조사)을 조성하여, 양면(호환)효율을 측정하여 서로 비교하였다. 전면 광조사 1.0 sun 조건을 고정하고 후면에서 알베도 효과를 고려한 0.2 sun과 0.3 sun을 광조사한 조건에서, STUT CISe 태양전지는 점차 전류밀도가 증가하면서 6.91%와 7.14%의 향상된 양면(호환)효율을 보였다. 그러므로, STUT CISe 태양전지는 반투광형 태양전지뿐만 아니라 향후 응용될 양면수광형 적층형 태양전지의 하부층으로서도 상당한 잠재력을 가지고 있는 것을 확인하였다.

Key words : $CuInSe_2$($CuInSe_2$), Semitransparent ultrathin(반투광형 초박막), Optimal growth condition(최적 성장조건), Bifacial power conversion(양면수광)

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국부 접촉 Al_2O_3 후면 패시베이션 층을 갖는 Cu(In,Ga)Se_2 태양전지의 Ga 그레이딩 효과에 대한 시뮬레이션 분석

김준용[1)]*, 성시준[2)], 김대환[2)], 도윤선[1)]**

Simulation analysis on Ga grading effect in Cu(In,Ga)Se_2 solar cells with local contact Al_2O_3 rear passivation layer

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Abstract : Local contact aluminum oxide (Al_2O_3) rear passivation layer has been investigated to realize highly efficient thin film Cu(In,Ga)Se2 (CIGS) solar cells. This passivation layer can improve the open-circuit voltage (V_{OC}) and short-circuit current density (J_{SC}) due to the suppression of carrier recombination and higher reflection. For further improvements in performance, the energy band in the CIGS absorber layer can be engineered by controlling the Ga grading. However, there are limitations to experimentally finding the optimal [Ga]/([Ga]+[In]) (GGI) distribution in the absorber layer. In this paper, studies on the Ga grading effect in CIGS solar cells with local contact Al_2O_3 rear passivation layer to improve their performance are reported. To identify the Ga grading effect in the absorber layer, we performed two-dimensional optical and electrical simulations. As the GGI increased from 0.19 to 0.61, the band gap increased from 1.09 to 1.4, reducing the amount of light absorbed at infrared wavelengths. This decreased the number of electron/hole pairs in the absorber layer, lowering the J_{SC}. On the other hand, the V_{OC} was improved due to larger quasi-Fermi level splitting as the band gap increased. As the slope of the rear-graded GGI increased, the V_{OC} was improved due to a stronger electric field. The J_{SC} and fill factor (FF) increased and then decreased, showing maximum values at a rear maximum GGI of 0.3. At a rear maximum GGI of 0.42, the maximum efficiency was achieved. In addition, the performance variation of the solar cells according to the slope of the front-graded GGI was investigated. Our results provide guidelines for designing the GGI distribution in the CIGS absorber layer with a local contact Al_2O_3 rear passivation layer.

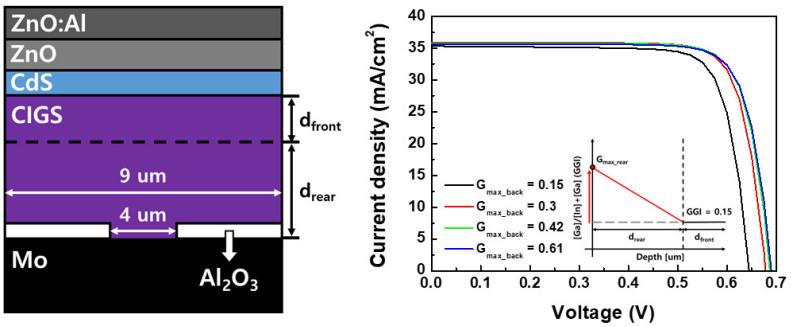


Fig 1. Simulation result according to GGI rear grading in a CIGS with a local contact Al_2O_3 rear passivation layer

Key words : CIGS(CIGS), Rear passivation(후면 패시베이션), Ga grading effect(Ga 그레이딩 효과)

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Improvement of charge loss at Cu(In,Ga)Se_2/CdS interface by tuning band gap grading

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Abstract : Efficiency of flexible Cu(In,Ga)Se_2 (CIGS) has been boosted by the optimized alkali incorporation and controlling interface properties. Especially, controlling conduction band offset (CBO) is crucial for effective charge carrier transport at the absorber/buffer interface. In this study, three flexible CIGS thin film solar cells with various band gap grading in absorber layer to investigate the optoelectronic properties at the interface. Mo-coated polyimide (PI) film was used for flexible substrate, and ratio of Ga was controlled to form graded band gap. Admittance spectroscopy (AS) results showed that the high band gap grading sample had the highest activation energy among the samples in high-frequency range. Herein, the samples were mechanically etched to reveal their layer structure and investigate the interface characteristics directly. Micro-photoluminescence spectrum were obtained from the etched surface and it revealed that the activation energy was originated from electron-defect interaction. Furtheremore, Kelvin probe force microscopy (KPFM) was conducted on revealed interface to probe the work function difference at the interface. The work function difference at the CIGS/CdS interface was the lowest in the high band gap graded CIGS sample indicating the presence of small band offset. On the other hand, low band gap graded CIGS sample showed the large work function difference acting as a charge barrier which resulted in charge loss. In conclusion, low conduction band offset contributed to the improved carrier transport a the interface in the high band gap graded CIGS though it had a higher interface defect level. [1]

[1] Ha Kyung Park et al., ACS Applied Meterials & Interfaces, 47 (2021) 34697-34705

Key words : Flexible Cu(In,Ga)Se_2 (CIGS) thin film solar cells (유연 CIGS 계 박막 태양전지), band gap grading (밴드갭 그레이딩), conduction band offset (전도띠 오프셋), Kelvin probe force microscopy (켈빈 탐침 힘 현미경)

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알칼리 후열처리 공정이 $Cu(In,Ga)Se_2$ 광흡수층의 전기적 비저항 특성 및 단일집적모듈의 션트손실에 미치는 영향

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The effect of alkali post-deposition treatment on the electrical resistivity of $Cu(In,Ga)Se_2$ absorbers and the shunt loss of monolithically-integrated solar module

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Abstract : CIGS 박막태양전지는 높은 광 발전효율, 우수한 안정성 및 경량 유연판 적합성 덕분에 창호, 벽, 지붕을 활용한 건물형 태양전지(BIPV)로 활용 가능성이 매우 높다. 이러한 대면적 공간 활용을 위해서는 CIGS 박막태양전지 셀 단위 기술 개발뿐만 아니라 대면적을 다수의 소면적 셀로 분할하여 직렬연결 시킨(후면전극 분할:P1 가공, 전면-후면전극 연결:P2 가공, 전면전극 분할:P3 가공) 단일집적모듈 기술개발이 중요하다. 모듈 구조 특징상 Cell-to-Module(CTM) 손실이 발생하는데, 대부분 패터닝 및 TCO 흡수 증가에 따른 광전류 손실, 패터닝에 따른 전기적 션트손실이 주된 원인으로 거론된다. 한편, 이러한 단일집적구조는 P1 가공영역에 광 흡수층이 존재하므로 광흡수층의 전기 비저항에 따라 누설전류가 발생할 수 있는데, CIGS 광흡 수층은 공정조건에 따라 비저항이 크게 달라진다. 따라서, 고효율 셀 공정 기술 개발 시 CIGS 비저항에 미치는 공정변수의 영향에 대한 분석이 모듈 기술 개발에서 필수적이다. 최근 CIGS고효율화를 위한 방법으로서 Na, K, Rb, Cs 알칼리 후열처리 공정(PDT)이 활발히 연구되고 있다. 이에 달칼리 후열처리 공정, 특히 NaF, 및 KF PDT가 단일집적모듈 성능에 미치는 영향을 분석하였다. 이를 위해 NaF PDT, NaF+KF PDT 공정으로 셀과 단일집적모듈을 제조하여 효율을 측정하였고, 모듈 제조 중 P1 가공선을 가로질러 저항을 측정하여 CIGS 광 흡수층의 저항(P1 저항)을 비교하였다. 본 실험에서 PDT 처리에 따른 셀 효율과 모듈 효율은 다음과 같다. NaF PDT 셀 효율은 17.1%, Voc 0.704V, Jsc 33.1㎃/㎠, FF 73.6%이고, NaF+KF 셀 효율은 18.2%, 0.713V, 33.5㎃/㎠, FF 76.3%로 KF 추가를 통한 Voc가 9mV, FF2.7%가 증가한 것을 확인하였다. NaF PDT 모듈 효율은 11.0%, Voc 0.671V, FF 56.6%(션트저항 135.8Ω㎠)이고, NaF+KF 모듈 효율은 13.5%, Voc 0.693V, Jsc 27.3㎃/㎠, FF 70.9%(션트저항 1,265Ω㎠)로 NaF 모듈의 경우 션트가 발생하였지만, NaF+KF 모듈은 션트가 없었다. 각 CIGS 광흡수층의 P1 저항은 NaF PDT에서 168Ω㎠, NaF+KF PDT에서 3,375Ω㎠으로 측정되어 KF PDT가 CIGS저항을 증진시켰다. PDT 따른 캐리어 수는 유사한 수준이지만 이동도에서 NaF: 4.47㎠/Vs, NaF+KF: 0.06㎠/Vs로 감소하는 것을 확인했다. 이는 CIGS Grain 높이가 2㎛인 대비 P1 폭이 약 50㎛로 수평 방향 이동거리가 25배 증가한 환경에서 KF 추가로 인한 수평 방향의 저항이 증가한 것으로 판단되며, Grain boundary 내의 전기전도도가 낮은 2^{nd} phase가 형성되었기 때문에 이동도가 낮아졌다고 해석된다. 최종적으로 NaF+KF PDT조합을 통해 Voc와 FF 개선과 동시에 CTM도 NaF PDT 35.6%에서 NaF+KF PDT 25.8%로 감소시킬 수 있었다.

Key words : $Cu(In,Ga)Se_2$(CIGS 박막태양전지), Alkali Ion PDT(알칼리 이온 후열처리), Monolithic-Integrated Module(단일집적모듈)

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쯔비터 이온 작용기를 가진 이온 포획층을 활용한 고효율 역구조 페로브스카이트 태양전지

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Efficient Inverted Perovskite Solar Cell Adopting Zwitterionic Ion-capturing Layer

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Key words : conjugated polyelectroytes, perovskites, defect passivation, solar cells

Abstract : Organic-inorganic hybrid perovskite solar cells (PeSCs) have seen a steep rise in power conversion efficiency (PCE) in recent decades and commercialization is just around the corner with achieving over 25.5%. However, high-performance PeSCs are still far from commercialization due to their poor thermal and light stability in general. After the degradation of perovskite by heat or light, iodides migrate to the silver cathode which damage the performance of the device in turn. In this study, we dramatically increased the thermal and light stability of PeSCs by introducing additional ion capturing layer between electron transport layer and cathode, which is capable of inhibiting migration of the ions. Unlike the former materials that merely block ion migration, a zwitterionic conjugated small molecule (C-ZI) could be directly bound to iodide and silver ions owing to their sulfonate and ammonium functional group. The ion capturing ability is investigated by UV-Vis absorption spectroscopy, X-ray photoelectron spectroscopy, energy dispersive X-ray spectroscopy, and time-of-flight secondary ion mass spectrometry. With adoption of C-ZI as a ion-capturing layer, PeSCs achieved a PCE of 23.3% and maintained stable PCE for 1500 hours at 85 ^{o}C heat and for 500 hours at maximum power point.

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Strain engineering of SnO_2 electron transport layer for stable and efficient perovskite solar cells

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Abstract : Perovskite solar cells (PSCs) are being close to commercialization because of high power conversion efficiency exceeding 25%. Although halide perovskite is known to be defect tolerant, bulk and surface defects are still responsible for the loss of open-circuit voltage (V_{oc}). Specifically, interfacial defect can cause detrimental effect on both efficiency and stability. In this study, we report on an effective way to reduce defects on the surface of SnO_2 thin film and tensile strain within the interface between electron transport layer and perovskite layer by post-treatment using functional molecule. Tensile strain was released by post-treatement as confirmed by grazing-incidence X-ray diffraction (GI-XRD). D-spacing of the (100) plane of the control perovskite layer was gradually increased with decreasing thickness, indicative of tensile strain, which was, however, less pronounced after introduction of functional molecule onto the SnO_2 film. Steady-state photoluminescence intensity of the traget sample was 1.76 times higher than that of the control one, suggesting a decrease in non-radiative recombination. Carrier life time of the bulk perovskite was also enhanced by the post-treatment, leading to an improved V_{oc}. As a result, power conversion efficiency (PCE) was increased from 22.57% to 23.86% according to a quasi-steady-state (QSS) measurement due mainly to the improvement of V_{oc} from 1.17 to 1.19 V and fill factor (FF) from 77.8% to 79.8%. Moreover, 95% of initial PCE was observed after 600 hours for the target device, which was much higher than that of the control one.

Key words : perovskite solar cell (페로브스카이트 태양전지), surface modification of SnO_2 (주석산화물 표면처리), strain engineering (스트레인 엔지니어링), tensile strain (이완 스트레인), stability (안정성)

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Green Solvent Based Air-Processed Highly Efficient Organic Solar Cells with Power Conversion Efficiency of 17.38%

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Abstract

Power conversion efficiencies (PCEs) of glove-box (GB) processed, two-component, single-junction organic solar cells (OSCs) have recently exceeded 18%. However, their mass-scale manufacture using roll-to-roll coating techniques is impracticable if they must be fabricated in an air-free environment. From a commercialization perspective, efficient air-processed OSCs are of much greater interest than GB-processed devices. Herein, we report that controlling the crystallinity of non-fullerene acceptors plays a key role in determining the properties of blend films. Notably, Y6-hu (a Y6-derivative) exhibited a higher degree of crystallinity when processed in air. Air-processed OSCs showed an outstanding PCE of 17.38%, which, to the best of our knowledge, is the highest PCE yet reported for two-component-based OSCs processed in air using halogen-free solvents. Moreover, opaque large-area OSC sub-modules with PCEs of 12.44%, and red-green-blue colored semi-transparent OSC sub-modules with PCEs of over 10% were demonstrated. By understanding how morphological features relate to the charge-generation dynamics of air-processed OSCs, a new window is opened for the fabrication of efficient and stable air-processable organic electronics.

용액 공정으로 만든 PbS 버퍼 층 도입으로 안정성이 향상된 페로브스카이트 태양전지

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Highly stable perovskite solar cells with PbS buffer layer formed by solution process

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Abstract :
페로브스카이트 태양전지를 상용화하기 위해서는 열과 습도, 빛에 대한 안정성 확보가 필요하다. 그러나 페로브스카이트는 공기 중의 수분에 노출되면 쉽게 분해된다는 단점을 가지며 페로브스카이트 내 아이오딘 이온은 이동성이 높아 열이나 빛에 노출되었을 때 다른 층으로 이동 후 금속 전극과 반응하여 부식시키므로 태양전지의 안정성을 떨어뜨린다. 따라서 이러한 열화를 막아 안정성을 높이기 위해서는 페로브스카이트 표면에 수분이나 산소의 침입 또는 아이오딘 이온이나 금속 원자의 확산을 막을 버퍼 층을 형성시키는 것이 필요하다. 또한 버퍼 층은 무기물로 구현하는 것이 소자 장기안정성 확보를 위해 유리하다. LiF 소재와 같이 기존에 활용되는 무기 버퍼층은 1 nm 이하로 아주 얇은 박막을 진공증착으로 형성하기 때문에 공정 비용이나 용이성 측면에서 단점이 존재한다. 이 연구에서는 Na_2S 용액을 간단히 페로브스카이트 표면에 스핀 코팅한 후 열처리함으로써 PbS 버퍼 층을 형성시켰다. 표면에 형성된 PbS는 물에 녹지 않기 때문에 페로브스카이트층을 수분으로부터 보호해주며, 용액공정으로 형성된 버퍼 층은 매우 얇으면서도 견고하게 페로브스카이트 표면을 부동태화시킴으로써 이온 이동을 효과적으로 억제하였다. 그 결과 PbS 버퍼 층을 도입한 태양전지는 광안정성 실험에서 350시간 후에도 초기효율을 유지했다. 또한 별도의 봉지 없이 85℃의 열안정성 실험에서 1000시간 후에도 초기효율의 75% 이상, 36.4%RH 습도에서의 안정성 실험에서는 100시간 후에도 초기효율의 95%를 유지했다. 용액에 포함된 Na^+ 이온은 페로브스카이트층 내부로 침투하여 결함 부동태화를 유도하며, 형성된 PbS 버퍼 층은 전자 유입을 차단하면서 정공 전달을 원활하게 하는 정공 전달층으로의 역할이 가능함을 보였다. 그 결과 페로브스카이트와 정공 수송 층 사이에서 정공 전달 효율 증가를 통해 태양전지 소자의 광전변환 효율을 향상시키는 것을 확인하였다.

Key words : perovskite solar cells(페로브스카이트 태양전지), stability(안정성), inorganic buffer layer(무기물 버퍼층), PbS(황화납), solution process(용액 공정)

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QPOD-O-5

Bending Fracture Behavior Depending on Composition of Halide Perovskite Films

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Flexible perovskite solar cells (PSCs) have received attention owing to lightweight and bendable characteristics. Mechanical property of the perovskite film is important in determining bendability. In this report, we have investigated dependence of bending facture behavior on composition of halide perovskite films on flexible polymer substrate. Lead-based $APbX_3$ perovskites with different A-site cations and X-site anions of $(FAPbI_3)_{1-x}(CsPbBr_3)_x$, $(FAPbI_3)_{1-x}(MAPbBr_3)_x$, $FA_{1-x}Cs_xPbI_3$, and $FA_{1-x}MA_xPbI_3$ were studied, where FA and MA stand for formamidinium and methylammonium. Fracture energy (Γ) and the fracture toughness (K_{IC}) were estimated from the crack density (ρ) - the bending strain (ε_a) relation according to Hsueh and Yanaka model. Surface morphology was found to have significant influence on bending fracture behavior. The highest fracture energy of 186.2 J/m^2 along with fracture toughness of 3.559 MPa·(m$^{1/2}$) were observed from $(FAPbI_3)_{0.75}(CsPbBr_3)_{0.25}$ due to highly enhanced wrinkled morphology, which was higher than those of the pure $FAPbI_3$. The significant enhancement of Γ and K_{IC} in the wrinkled morphology is beneficial to flexible PSCs by improving mechanical stability against fractures against bending motions.

Low-dose TEM study on the microstructure of $GA_xMA_{1-x}PbI_3$ perovskites

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Abstract : Halide perovskites (HPs) have attracted significant attention for their high property tunability by compositional controls, which suggests promising applications in various optoelectronics. Especially, it has been reported that incorporation of Guanidinium (GA^+) in $MAPbI_3$ perovskites effectively enhances power conversion efficiency as well as the structural stability of solar cells. But its intragrain lattice structure has never been studied due to its extreme weakness on the electron beam. In this study, with delicately controlled low-dose transmission electron microscopy (TEM) techniques, microstructure of $GA_xMA_{1-x}PbI_3$ perovskites was investigated. First, using in-situ electron irradiation selected-area electron diffraction analysis, we determined a critical electron dose of 50 e·Å-2 that allows for microstructural imaging while minimizing structural damage. Second, we observed the variation of fraction and structrual features of ferroelastic $\{112\}_t$ twins and $\{111\}_c$ nanotwins versus GA incorporation ratio. Lastly, substantial strain distribution in atomic-scale was observed in the GA 20% by high-resolution TEM. These results on the microstructural change induced by the giant organic cation in HPs will provide a more comprehensive understanding of the enhancement of device performance.

Key words : Halide perovskites, Low-dose, TEM, Microstructure, and Planar defect

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페로브스카이트 간 열압착 접합 공정을 이용해 향상된 성능과 장기 안정성을 확보한 페로브스카이트 태양전지

정희윤[1)*], 오은성[2)], 김동준[2)], 심홍재[3)], 이원종[4)], 윤순길[1)], 임종철[4)], 윤재성[3,5)], 김택수[2)], 양태열[1,6)**]

Enhanced Performance and Long-Term Stability in Perovskite Solar Cells Fabricated by Thermocomopression Bonding between Perovskite Layers

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Abstract : Organic-inorganic perovskite solar cells (PSCs) have attracted the PV community due to high power conversion efficiency (PCE) and low-cost process applicable to the fabrication of flexible and semi-transparent devices, but still suffer from poor stability. In order to ensure long-term stability of PSCs by blocking extrinsic degradation factors such as oxygen and moisture, effective encapsulation technology is indispensable. Laminated PSCs not only can be fabricated as flexible and transparent devices but also can be encapsulated without a separate process. Although various processes to fabricate the laminated PSCs have been suggested, there has never been a systematic study on material properties and device characteristics in the laminated PSCs according to process conditions. In this study, bulk and interfacial properties of laminated perovskite and device characteristic of laminated PSCs are extensively investigated. Comparing the interfacial adhesion energy measured by double cantilever beam tests and the PCE values of the laminated PSCs according to the lamination process method, it is confirmed that thermocompression bonding between perovskite layers is the best lamination method. Because perovskite has soft mechanical characteristics and active atomic migration nature, perovskite layers can be firmly combined into one layer when heat or pressure is forced. In comparison with control perovskite which is prepared by general spin-coating process, the laminated perovskite has larger grains and smoother, denser interfaces, thereby not only reducing defect and trap density but also suppressing ion migration and phase segregation under illumination. In addition, laminated perovskite shows enhanced stability against water. The laminated semi-transparent PSC with a wide-bandgap perovskite (E_g~1.67 eV) exhibits superior long-term stability over 3000 hours in a shelf-test at 85 ℃ with a PCE of 17.24%.

Key words : Semitransparent perovskite solar cell(반투명 페로브스카이트 태양전지), Thermocompression bonding (열압착 접합), Stability(안정성), Interfacial characteristics (계면 특성)

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Surface manipulation of lead halide perovskite quantum dots and enhanced deposition processability

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$CsPbI_3$ perovskite quantum dots (PQDs) have attracted large attention as photo-active layers of optoelectronic applications. Particularly, the PQDs have been employed in solar cells by replacing insulating ligands such as oleate and oleylammonium with short ligands through multiple-step layer-by-layer (LbL) deposition process based on solid-state ligand exchanges (SSLE). Previous SSLE methods using $Pb(NO_3)_2$ in methyl acetate (MeOAc) and formamidinium iodide (FAI) in ethyl acetate (EtOAc) solutions have issues of byproducts such as acid and alcohol, and of low device stability. Instead, by using sodium acetate in MeOAc and phenethylammonium iodide (PEAI) in EtOAc solutions in LbL deposition process, the performance and stability of PQD solar cell devices were enhanced. Furthermore, to enhance deposition processability of PQD photovoltaic absorbers, we prepared colloidal PQD ink dispersed in chlorobenzene via solution-phase ligand exchange (SPLE) using PEAI agents. The SPLE-PQDs passivated with PEAI showed a low amount of insulating ligands and an improved photoluminescence quantum yield. The $CsPbI_3$ PQD solar cells fabricated via single-step deposition process using the SPLE-PQD ink and phenethylammonium acetate (PEAOAc)-based SSLE exhibited a power conversion efficiency of 13.7% with a more facile manufacturing process.

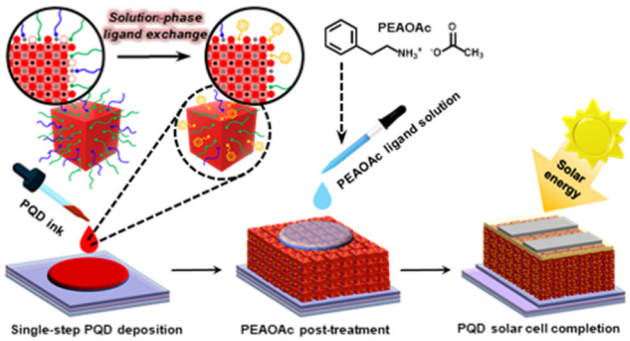


Figure 1. Schematic representation of the fabrication of $CsPbI_3$-PQD solar cells via single-step PQD deposition process using the SPLE-PQD ink and the PEAOAc post-treatment.

Table 1. Photovoltaic parameters of the solar cell measured under AM 1.5 G simulated light

	V_{OC} (V)	J_{SC} (mA/cm^2)	*FF*	*PCE* (%)
Control device	1.25	13.9	69.9	12.1
SPLE-PQD device	1.24	15.4	71.3	13.7

스퍼터링 및 이온교환법을 통한 요철구조 실리콘 기판 위 균일한 wide-bandgap 페로브스카이트 박막 증착

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Fabrication of Wide-Bandgap Perovskite on Textured Silicon Surface using Sputtering and Ion-Exchange Method

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Abstract : This study aims to fabricate high-efficiency silicon/perovskite tandem solar cells by depositing conformal perovskite films on textured silicon surfaces. While the dry deposition process has been used to maintain the pyramid shape of the textured silicon surface, it poses a challenge in controlling the composition of mixed perovskite. In this work, we present a sequential process using sputtering and dry conversion to deposit a conformal $MAPbI_3$ perovskite film, which is subsequently treated in an IPA solvent containing Br to form a mixed composition perovskite film of $MAPbI_{3-x}Br_x$. By analyzing the surface morphology and depth profile, we demonstrate the control of composition ratio of Br. Finally, we fabricate perovskite solar cells and successfully deposit the mixed composition perovskite films conformally on a large-area textured silicon surface. This study provides insights for the development of textured silicon-based silicon/perovskite tandem solar cells with high power conversion efficiency.

Key words : Perovskite solar cells(페로브스카이트 태양전지), Silicon/perovskite tandem solar cells(실리콘/페로브스카이트 텐덤 태양전지), Sputtering(스퍼터링), Dry process(건식 공정), Ion-exchange method(이온교환법)

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건물일체형태양광(BIPV) 시스템의 SHGC 성능 분석

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Solar Heat Gain Coefficient Analysis of Building Integrated Photovoltaics

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Abstract : 건물 외피에 PV 모듈을 일체화하는 건물일체형태양광(BIPV; Building Integrated Photovoltaics) 발전시스템은 제로에너지건축물(ZEB; Zero Energy Buildings) 달성을 위한 핵심기술로서 활발히 연구 및 보급되고 있다. 국내에서는 커튼월 건물의 외피마감재로서 주로 투광형(G/G; Glass to Glass) BIPV 모듈이 적용되고 있으며, 건자재로서 요구되는 단열성능을 만족하기 위해 복층화 형태로 구성되고 있다. 투광형 BIPV 시스템은 건물의 단열성 측면에서 열관류율(U-value) 뿐만 아니라, 태양열 취득률(SHGC; Solar Heat Gain Coefficient)도 고려되어야 한다. 이는 투광형 BIPV 시스템의 SHGC 성능에 따라 전체 시스템의 발전특성과 실내열전달에 영향을 주며, 결과적으로 건물의 에너지성능이 달라지기 때문이다. 특히, 투광형 BIPV 시스템의 발전유무(MPPT; Maximum Power Point Tracking, OC; Open Circuit)에 따라 SHGC 성능 값이 다르게 나타날 수 있으며, 이에 대한 명확한 분석이 요구되며, 기존 유리나 창호시스템의 SHGC 성능평가와는 달리, 투광형 BIPV 시스템의 발전조건도 고려되어야 된다. 그러나 아직까지 투광형 BIPV 시스템의 SHGC 성능평가법 및 성능분석에 관한 연구는 미진한 실정이다. 이에 본 연구에서는 투광형 BIPV 시스템의 SHGC 성능평가법에 대해 고찰하고, 기존 관련 연구를 토대로 투광형 BIPV 시스템의 SHGC 성능을 평가하였다.

Key words : Building integrated photovoltaics(건물일체형태양광), Solar heat gain coefficient(태양열취득률), Performance evaluation methods(성능평가법), Thermal peroperties(열특성)

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분산 브래그 반사경-확산기 구조를 이용한 건물 일체형 태양전지의 다양한 색상 구현

김용기[1)]*, 신명훈[1)]**, 최수원[2)], 권정대[2)]**

Realization of various colors for building-integrated photovoltaic using a distributed Bragg reflector-diffuser structure

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Abstract : 분산 브래그 반사경(DBR)과 확산기(diffuser)가 결합된 투명 전극 구조를 이용하여, 건물 일체형 태양전지(BIPV)의 다양한 색상을 구현하였다. 태양전지의 활성층으로 수소화된 비정질 실리콘(a-Si:H)이 사용됐으며, DBR-diffuser 투명 전극은 인듐 주석 산화물(ITO)과 Al이 도핑된 산화아연(AZO)의 다층 박막 구조로 이루어져 있다. DBR-diffuser 투명 전극에 대해 유한 차분 시간 영역 방식(FDTD)의 광학 시뮬레이션을 진행하여, 태양전지의 다양한 색상 구현을 위한 설계 조건을 분석하였다. ITO와 AZO의 두께를 조절하는 것만으로도, 청색, 녹색 및 적색의 색상 구현이 가능함을 확인하였으며, 8쌍의 DBR만으로 선명한 색상을 구현할 수 있었다. 또한, DBR과 결합된 diffuser 구조는 컬러 노이즈를 23% 억제하는 것으로 확인됐다. 본 연구의 DBR-diffuser 투명 전극은 BIPV용 태양전지의 색 품질 향상에 기여하며, 다양한 소재의 여러 태양전지 및 모듈에 폭넓게 적용할 수 있을 것으로 기대된다.

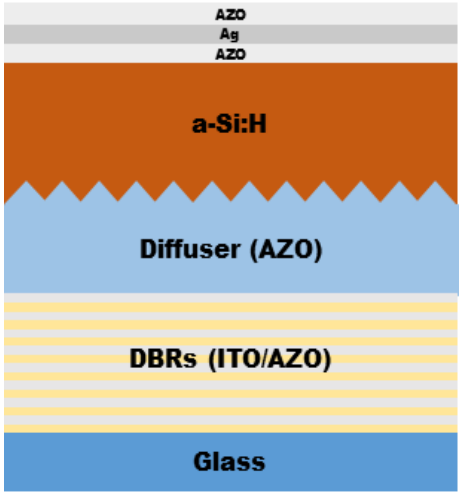


그림 1. DBR-diffuser 투명 전극 구조가 적용된 a-Si:H 태양전지의 모식도

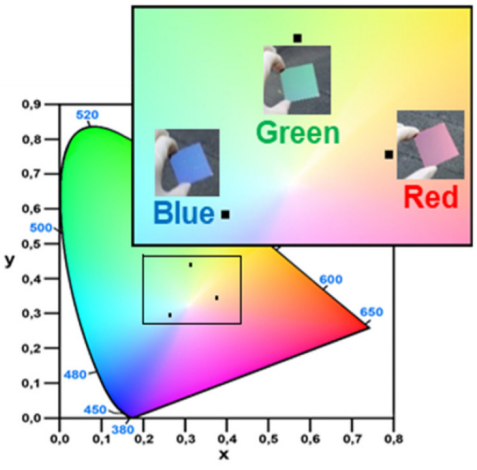


그림 2. 다양한 색상의 a-Si:H 태양전지 및 색 좌표(CIE 1931)

Key words : Building-integrated photovoltaic (건물 일체형 태양전지), Distributed Bragg reflector (분산 브래그 반사경), Colored transparent solar cell (색상이 있는 투광형 태양전지)

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고장 I-V 곡선과 딥러닝을 이용한 태양광 고장 진단 기술

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PV fault diagnosis tecnnology using fault I-V curves and Deep Learning

*Woogyun Shin[1], *Soohyun Bae[1], *Gihwan Kang[1], *Youngchul Ju[1], *Hyemi Hwang[1], **Sukwhan Ko[1]

Key words : 고장 I-V 곡선(Fault I-V curves), 딥러닝(Deep-Learning), 데이터 전처리(Data preprocessing), 혼동 행렬(Confusion matrix), 고장 진단(Fault diagnosis)

Abstract : 탄소 중립, RE100을 달성하기 위해 각 국에서는 신재생에너지원을 이용한 발전시스템을 구축하고 있다. 그 중 태양광은 가장 많이 설치되어 활용되는 발전원으로써, 2021년 기준 전 세계 태양광 누적 설치량은 약 940 GW, 국내 태양광 누적 설치량은 약 21 GW 이다. 태양광의 설치가 급격히 증가함에 따라 태양광 발전소의 성능과 고장을 진단할 수 있는 O&M 기술에 대한 수요가 다시금 증가하고 있다. 태양광의 성능과 고장을 진단하는 방법은 여러 가지가 있지만, I-V 곡선을 측정하는 방법이 성능 측면에서 가장 정확한 기법이라고 볼 수 있다. 본 연구에서는 태양광 스트링의 고장 I-V 곡선과 딥러닝 기술을 이용하여 태양광의 고장을 진단하는 연구를 진행하였다. 딥러닝 학습 데이터는 태양광 발전소 및 시뮬레이션을 이용하여 생성하였으며, 생성된 데이터의 학습을 위해 데이터 정규화 방법을 적용하였다. 정규화 된 데이터의 고장 원인에 따라 Labeling 하였고, 전이 학습을 통해 태양광 고장 진단을 딥러닝을 훈련하였다. 훈련된 신경망은 검증/시험 데이터를 이용하여 혼동 행렬로 평가하였다.

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1선 지락 위치 검출을 위한 반 전압법 기반 태양광 시스템 개발

홍순일[1)]*, 이용규[1)], 최의성[1)]**

Development of a Solar Power System for 1-Line Fault Detection Using Reverse Voltage Method

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Abstract : Solar power generation systems are becoming increasingly important as a means of energy production, and are experiencing steady growth in demand. However, various faults can occur in solar systems, and there is a need for technical research to address these issues. In particular, one of the most common problems in solar systems is a 1-line fault, which can lead to decreased performance or even shutdown of the entire system. Therefore, a quick and accurate response to this problem is required. In this study, we applied the reverse voltage method to detect 1-line faults in solar power systems.

The reverse voltage method is a suitable technique for locating 1-line faults by using the current deviation of the solar panel. This method involves measuring the voltage of the solar string by dividing it into + to F.G and - to F.G voltages, and the relationship between the open circuit voltage of the module and the reverse voltage difference can be used to identify the location of the 1-line fault.

In this study, we developed a technology to detect 1-line faults in solar power systems by applying the reverse voltage method. Experimental results confirmed that the location of the 1-line fault could be quickly determined. These results are expected to contribute to solving the problem of 1-line faults in solar systems and ensure stable operation.

Key words : Photovoltaic(태양광 발전), 1-line fault(1선 지락), 반 전압법(Half Voltage method)

1) (주)네오에너지커넥터

독립지주식 영농병행 태양광의 발전량 및 고부가가치 작물의 경제성 분석

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Analysis of the economic feasibility of power generation and high value-added crops of solar power combined with independent pillar type agrophotovoltiac system

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Abstract : 농촌의 고령화현상은 지속적으로 심화되고 있으며 통계청에 따르면 `20년 대비 고령인구(65세 이상) 비율은 46.8%로 4.5% 증가하였고, 농가인구는 2,215천명으로 4.3%감소하였다. 이러한 현상이 지속됨에 따라 생산성이 떨어지고, 수익이 줄어들면서 우리나라의 성장 잠재력을 크게 위축시킬 수 있는 방아쇠 역할을 하고 있다. 이에 따른 농업환경의 악화와 위기에 처한 농가문제에 대한 해결을 위해서는 청년 농업인을 육성해야 한다. 청년 농업인 육성을 위해서는 다양한 수요를 충족시켜야 하며, 특히 이는 투자 대비 수익성이 낮기 때문이다. 이러한 농가 소득의 보전과 지속가능한 농업을 위한 방안으로는 영농형 태양광은 이를 뒷받침 할 수 있는 해결책으로 제시되고 있다. 우리나라의 전체 농가의 절반은 쌀 농가로써 `22년 통계청에 따르면 전국 평균 쌀의 10a당 생산량은 518kg, 평균가 2,289원을 계산했을 때 1,185,702원으로 경영비를 제외하면 소득은 그리 많지 않은 편이다. 따라서 본 연구에서는 고부가가치 작물인 블루베리를 적용한 20kW급 독립지주식 영농형 태양광 개발 모델의 발전량과 블루베리 생육 평가 분석자료를 바탕으로 99.9kW급(600평, 20a)모델에 적용하였을 때의 경제성 분석을 수행하였다. 분석결과, 고부가가치 작물인 블루베리의 착과수를 바탕으로 한 20a당 평균 수입은 2,501만 7000원으로 산출 되었으며, 전력생산을 통한 순이익은 9,872,000원으로 분석 되었다.

Key words : Agrophotovoltaci(영농형 태양광), Pillar type(지주식), Blueberry(블루베리)

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수직형 태양광 시스템의 최대 출력을 위한 설치 방법 모색

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Finding the installation methods for maximum output of vertical photovoltaics system[c]

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Abstract : 지구 온난화가 심각해지면서 태양광 패널의 설치가 매년 증가하고 있으며 태양광 관련 기술 또한 많은 발전을 이루고 있다. 하지만 태양광 패널의 경우 많은 면적을 차지하기 때문에 문제가 되고 있고 수직형 태양광의 경우 이 문제를 최소화할 수 있는 기술이다. 또한 수직형 태양광의 경우 전력 생산이 가장 적은 아침과 저녁에 많은 전기를 생산하기 때문에 전력 프로파일면에서도 훌륭하다. 수직형 태양광의 경우 일반 설치 각도와 다른 출력 양상이 나타나게 되기 때문에 본 연구 향할 때와 서쪽을 향할 때의 출력 양상이 다르게 나올 것이고, 셀의 종류에 따라서도 다른 양상이 나올 것으로 예상하였다. 따라서 샘플의 경우 2가지 셀 타입 (bifacial p-PERC, bifacial n-Topcon)으로 진행하였고에서는 최대의 출력을 낼 수 있는 구조를 찾기 위한 분석을 진행하였다. 양면형 태양광이기 때문에 셀의 전면이 동쪽으로 셀의 전면 후면이 각각 동서 방향으로 향하게 하여 총 4가지 샘플로 실험 구성하였다. 실제 field에 설치한 후에 나온 출력 양상을 비교하여 최적의 설치 방법을 결정하였다.

Key words : 수직형 태양광, 태양광 시스템, bifacial p-PERC, bifacial n-Topcon

태양광연계 ESS용 재사용 배터리 분류 표준화 연구

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Study on Classification Standardization of Reused Batteries Energy Storage System for Phorovoltaics

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Abstract : 우리나라는 친환경 정책에 따라 ’21년 유엔에 제출한 NDC(국가탄소감축계획)는 ’30년까지 신재생에너지 발전 비중을 30.2%로 제출하였다. 하지만 제 10차 전력수급기본계획(’22. 12.)에 따르면 신재생에너지 발전량 비중은목표를 ’30년도 기준 21.6%로 설정하였다. 이는 기존 목표에 미치지 못 하는 설정이지만 신재생 발전 비중을 높여야 한다는 것은 모두가 공감하는 사실이다. 이에 따라 늘어나게 될 태양광발전소는 전력생산 및 수요피크를 경험하게 될 것이고 이에 대한 대비로서 에너지저장장치(ESS)와의 연계를 육성하지 않을 수 없다. 최근 급격히 늘어나는 전기차 보급에 따라 발생되는 ’32년 기준 10만개의 폐 배터리가 발생할 것으로 예측되는 가운데 배터리 재사용 산업이 주목 받고 있다. 본 발표에서는 태양광에 연계될 재사용 배터리 ESS의 성능 및 안정성에 대한 국내외 분류 체계 및 표준화에 대한 보고한다.

Key words : PV Plant(태양광발전소), ESS(에너지저장장치), Reused Battery(재사용 배터리), Standardization(표준화)

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MoO_x 국부접합을 사용한 정공선택형 구조를 적용한 후면 접합 실리콘 태양전지의 특성

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Properties of rear emitter passivating contact silicon solar cells with hole-selective structure using MoO_x local contact

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Abstract : 본 연구에서는 몰리브덴 산화물(MoO_x)을 사용하여 캐리어 선택적 접촉을 가지는 후면 접합 패시베이션 접촉 실리콘 태양 전지의 제조 및 특성에 대해 보고하였다. 이 구조는 전면 도핑 공정 없이 캐리어를 효과적으로 수집할 수 있어 690 mV 이상의 높은 가중 개방 전압을 얻을 수 있다.

패시베이션 후 다양한 온도에서 실리콘 질화막과 알루미늄산화막 캡핑층으로 수소화 어닐링 공정을 수행하여 태양전지의 가중 개방 전압 특성을 더욱 향상시켰다. 또한 MoO_x 필름의 일함수가 태양 전지의 가중 개방 전압 특성에 큰 영향을 미친다는 것을 발견했다. 그 결과 MoO_x 필름의 일함수가 5 eV 이하일 때 전류-전압 특성이 낮아지고 일함수가 높을수록 향상되는 것으로 나타났다. 또한 전면 패시베이션 영역과 MoO_x 접합 영역 및 일함수 변화를 통한 단락전류 밀도, 개방전압, 충진율, 변환효율에 대하여 시뮬레이션 하였고 일함수의 개선이 가장 큰 손실의 원인으로 파악되었다. 시뮬레이션 결과 변환 효율이 21.8 % 까지 개선이 이루어질 것으로 보이며, 이러한 연구 결과는 후면 접합 패시베이션 접촉 실리콘 태양 전지를 위한 캐리어 선택적 접촉으로서 MoO_x의 잠재력을 보여줄 수 있다.

Key words : Carrier selective contact(캐리어 선택 접합), Passivating contact(패시베이션 접합), Transition metal oxide(전이금속산화물), Rear emitter silicon solar cells(후면 에미터 접합 실리콘 태양전지)

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보론, 갈륨으로 도핑 된 결정질 실리콘 내에서 철 농도에 따른 광열화 분석

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LID analysis in boron and gallium doped crystalline silicon according to Fe concentration

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Abstract : Light Induced Degradation(LID)은 태양전지의 효율을 감소시키는 현상으로, 태양광 산업에서 중요한 이슈 중 하나이다. 해당 현상은 보론으로 도핑 된 p-type 결정질 실리콘에서 특히 발생하며, 발생하는 원인에 관해서 보론과 산소 이합체의 결합, 보론과 철의 결합, 보론과 구리의 결합 등 많은 문헌에서 이미 보고가 되어있다.
본 연구에서는 앞선 문헌에서 보고 된 매커니즘을 기반으로, 보론으로 도핑 된 결정질 실리콘과 갈륨으로 도핑 된 결정질 실리콘 내에서 철 농도에 따른 Light Induced Degradation(LID)를 비교 해 보았다.
샘플은 각각 1.22Ω㎝, 0.62Ω㎝ 의 비저항을 가지고 있고 두께는 188㎛, 166㎛ 이다. 양면에 100㎚의 실리콘 질화막을 증착 시킨 후 측정을 진행하였으며, LID 챔버 내에서 1000w/m^2의 광을 조사하여 광을 조사하기 전,후 그리고 열처리 전,후로 effective lifetime 및 SRH lifetime을 비교 분석하였다.
실험의 결과를 살펴보면 열처리 전,후로 벌크 내에 잔여하는 철의 농도가 감소 하는 것을 확인할 수 있었고, 순수한 보론으로 도핑 된 p-type 결정질 실리콘은 이 농도에 따라 light-induced defect density(빛을 조사하기 전,후의 effective lifetime의 차이)가 영향을 받는 다는 것을 확인할 수 있었다. (반면에 갈륨으로 도핑 된 결정질 실리콘에서는 Light Induced Degradation(LID)를 확인 할 수 없었다.)
해당 결과를 통하여 순수한 보론으로 도핑 된 결정질 실리콘 내에서도 일정 수준 이하(10^{10} atoms/$㎝^3$)로 철의 농도가 감소하면 Light Induced Degradation(LID)가 발생하지 않는 다는 점과 더불어, 갈륨으로 도핑 된 결정질 실리콘 내에서는 산소 이합체가 갈륨과 결합하여 단일상을 형성함으로 인해 Light Induced Degradation(LID)가 발생하지 않는 다는 기존에 문헌에서 보고 된 사실을 확인 할 수 있었다.

Key words : light-induced defect density, Lifetime, Boron, Iron

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초미세선폭 및 높은 종횡비 구현을 위한 금속스크린 마스크 제작 및 평가

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Fabrication and evaluation of metal screen mask for ultra fine line and high aspect ratio

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Abstract : 현재 결정질 실리콘 태양전지의 성능의 한계점에 도달과 원가절감의 한계로 인해 태양전지 셀에서는 특히 전극화 공정에서의 초미세 선폭 및 1에 가까운 높은 aspect ratio 구현을 통한 성능개선과 원가절감을 동시에 구현하려는 노력이 태양광 산업계 전반에 걸쳐 필수불가결한 요소가 되고 있다. 기존의 mesh screen (망사스크린)으로는 20μm이하의 초미세 선폭을 구현하기 어렵고, 설사 구현을 한다하더라도 mesh에 의해 개구부의 막힘 현상으로 인해 균일하고 단선없는 전극선으로 프린팅하기 어렵다는 단점을 가지고 있다. 이에 본 연구에서는 금속판을 활용 레이저가공 기술을 도입함으로써 20μm 또는 그 이하의 선폭을 구현하고, 이러한 미세선폭에서도 페이스트의 토출성이 우수한 metal screen (금속스크린)을 제작 평가하였다. 또한 페이스트의 특성에 좌우되는 프린팅 품질은 PERC, TOPCon등의 고온형 페이스트와 헤테로정션에 사용되는 curing기반의 저온형 페이스트에 대해 각각 그 프린팅 특성을 비교 평가하였다.

Key words : metal screen(금속스크린), mesh screen(망사스크린), high aspect ratio(높은 종횡비), high temperature paste(고온형 페이스트), Curing paste(저온형 페이스트)

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n-TOPCon 태양전지 공정을 위한 에미터 보호막 공정 최적화 연구

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Study on Emitter Protection Layer for the Fabrication of n-TOPCon Solar Cells

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Abstract : 지난 10여 년간 글로벌 태양광 발전 시장에서 가장 많이 설치가 된 태양전지는 p타입 기반의 PERC(Passivated Emitter and Rear Contact) 태양전지였으나 p-PERC 태양전지의 효율 한계와 n타입 태양전지 웨이퍼 가격의 하락으로 인해 최근에는 n타입 기반의 Passivated Contact이 적용된, 즉 n-TOPCon(Tunnel Oxide Passivated Contact) 태양전지가 각광을 받고 있다. Fraunhofer의 F. Feldmann이 2014년에 출판한 논문[1,2] 이후 활발하게 연구되어 왔으며 국내에서는 2019년 LG전자에서 NeON2라는 제품명으로 상용화가 되었다.

n-TOPCon 태양전지는 전면에 일반적으로 확산 공정을 통해 에미터(Emitter)를 형성시킨 후 후면에 터널산화막(Tunnel Oxide)와 n타입 고도핑 비정질 실리콘 박막을 증착한다. 이후 열처리를 통해 폴리실리콘 박막으로 형성이 된다(Tox/n-poly-Si). 후면에 Tox/n-poly-Si 구조는 LPCVD나 PECVD를 활용하게 되는데 이 과정에서 전면 수광부에 넓게 혹은 테두리부에 원하지 않는 막이 형성되어 후속 식각 공정이 필요하게 된다. 이러한 과정에서 미리 형성된 에미터가 손상되어 태양전지의 효율이 떨어질 수 있어 주의가 요구된다.

본 연구에서는 n-TOPCon 공정 시 전면에 가해질 수 있는 데미지를 최소화하고자 전면 에미터 형성 후 에미터 보호막을 증착하여 식각 공정으로부터 에미터를 보호하고 이후에 제거하는 공정을 논하고자 한다. 우리는 Tox/n-poly-Si 구조는 PECVD를 활용하여 구현하였고 후속 식각 공정은 단면 식각만 선택적으로 할 수 있는 in-line wet station을 활용하였다. 양산공정에 투입될 수 있도록 식각액의 농도에 맞춰 KOH에는 잘 견디고 dHF에는 잘 식각될 수 있는 보호막의 두께 최적화 실험 결과를 본 발표에서 논하고자 한다.

Key words : n-TOPCon(탑콘 태양전지), Protection layer(보호층), n-type(n타입)

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나노전자소재부품연구센터, 구미전자정보기술원

쉉글링 실리콘 태양광 모듈 적용을 위한 실리콘 웨이퍼 절단면 패시베이션

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Surface passivation method of cutted wafer edge area for application of shingling Si photovoltaic module

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Abstract:결정질 Si 태양전지는 1953년을 시작으로 꾸준한 연구개발이 진행되어 태양광 시장 대부분을 차지하고 있다. 최근 Si 태양광 모듈의 출력 향상을 위하여 셀을 작게 laser cutting 하여 직렬연결하는 방식인 쉉글링 (Shingling) 기술 등을 적용한 모듈이 다양하게 연구되고 있다. 그러나 이러한 모듈은 셀을 laser cutting으로 작게 분리할수록 cutting 면적이 증가하고, 이는 Si 셀의 전/후면 이외에 cutting 면의 또 다른 재결합 영역의 증가로 모듈 출력을 저하하는 요인으로 작용하고 있다. 지금까지는 Si wafer 한 장 전체를 셀로 제작하였기 때문에 laser cutting 면이 없어 cutting 면 passivation에 대한 연구가 거의 진행되지 않았지만 셀을 작게 소형화하여 모듈을 제작하는 연구가 시작되면서 cutting 면의 passivation에 대한 부분도 무시할 수 없게 되었다. 이에 본 연구에서는 laser cutting 된 Si wafer의 절단면 passivation 연구를 진행하였다. 제작된 Si wafer를 laser cutting 후 절단면에 damage를 줄이기 위해 etch rate를 조절하여 절단면 damage만 etching하는 선택적 etching 공정을 진행하였다. Passivation 방법은 plasma enhanced chemical vapor deposition(PECVD) 방식으로 진공증착 하였고, 증착 물질은 SiNx를 사용하였다. Si wafer 절단 후 passiavation 기술에 따른 Si wafer 특성 변화를 확인하기 위해 quasi-steady-state photocontuctance (QSSPC) 및 photoluminescence (PL) 등을 측정하여 비교 분석하였다.

Key words: Si solar module(Si 태양광 모듈), Shingling technology(쉉글링 기술), Miniaturization (소형화), Edge passivation(절단면 패시베이션), Selective etching process(선택적 에칭 공정)

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실리콘 나노와이어 기반의 온칩형 마이크로 수퍼커패시터 연구

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Silicon nanowires based on-chip micro-supercapacitor

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Abstract :
On-chip micro-supercapacitors (MSCs) have shown great potential as miniature micro-power supplies for various applications, such as biosensors, portable electronic devices, and implantable medical devices, due to their high power density, safety, and cycling lifespan. Despite the promising results achieved with carbon-based electrodes, such as carbide-derived carbon (CDC), onion-like carbon (OLC), carbon nanotubes, and graphene, their limited compatibility with Si-based semiconductor devices has hindered their commercialization. In addition, the absence of a reliable strategy for achieving on-chip integration, miniaturization, and high electrochemical performance has been a major challenge. Si-based materials, such as Si nanowires (Si NWs), Si nanotrees, and their derivatives, have emerged as attractive alternatives to carbon-based electrodes due to their excellent mechanical, electronic, and thermal properties, as well as their low cost, non-toxicity, and well-established manufacturing processes. Si NWs, in particular, can be directly integrated onto Si wafers commonly used in micro-electronic devices, making them a promising candidate for on-chip integration. Furthermore, transition metal silicide nanowires, including Co_2Si, have been shown to have high conductivity, surface area, effective electrolyte transport, and ease of fabrication and integration to silicon, making them promising materials for on-chip MSCs. In this study, recent progress in the development of on-chip MSCs using Si NW-based nanowires is presented. This presentation focuses on their electrochemical performance, miniaturization, and integration strategies for high-performance MSCs.

Key words : Silicon(실리콘), Nanowire(나노선), Si-based nanowire (실리콘 기반 나노선), On-chip (온칩), Micro-supercapacitor(마이크로 수퍼커패시터)

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Improving PV module efficiency and power by forming a regular pattern

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The power of a PV module affects the amount of incident light collected by the cells. It causes optical loss in the process of modularizing solar cells. Optical loss in the PV module is reflected due to refractive index mismatch at the air/glass interface. To reduce the optical loss, we form periodic patterns using a femtosecond laser, which is a non-thermal process and form various patterns through a chemical etching process. The laser patterned glass having a light-trapping structure with a periodic pattern improved transmittance of 1.59% in the visible ray region (380 nm – 780 nm) and haze ratio of 55% at 550 nm. Laser patterned glass was applied to the module, and the power was improved by 1.56% with a current gain of 1.56% due to the light-trapping structure.

Keywords: femtosecond laser, chemical etching process, laser patterned glass, light-trapping structure

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실리콘 이종접합 태양전지에서 비정질 실리콘 적층 시 표면 부동태화와 Si-H 결합 변화의 상관관계 연구

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Study on the correlation between amorphous silicon-based surface passivation and Si-H bonding change for silicon heterojunction solar cells

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Abstract : In this presentation we report on the relationship between Si-H bonding change and surface passivation quality by using hydrogen exodiffusion measurements after stacking of a-Si:H and ITO layers. It is well known that, by optimizing the hydrogenated intrinsic amorphous silicon (i-a-Si:H) / crystalline silicon (c-Si) heterostructure of silicon heterojunction (SHJ) solar cell, open circuit voltage (V_{OC}) of 700 mV and above can be realized with excellent surface passivation quality. Typically, plasma-enhanced chemical vapor deposition can be used to deposit passivating i-a-Si:H layer with a wide range of densities and hydrogen contents depending on various process parameters, such as temperature, pressure, gas flow rate, etc. However, passivation characteristics achieved with i-a-Si:H passivating layers do not frequently lead to the high V_{OC} of the actual SHJ solar cell. Hydrogen plays a crucial role in the surface passivation of SHJ solar cell because Si-H bonds passivate dangling bonds in a-Si:H and on the c-Si surfaces. Si-H bonding configuration of the a-Si:H/c-Si heterostructure is strongly influenced and modified by the subsequent layer stacking of doped a-Si:H and indium−tin oxide (ITO) layers on the i-a-Si:H layer. We discuss in the presentation that tracking change of the Si-H bond structure by using hydrogen exodiffusion measurements is an effective method for optimizing a-Si:H passivating layer process and realizing a high efficiency SHJ solar cell.

Key words : Silcon heterojunction solar cells(실리콘 이종접합 태양전지), Surface passivation(표면 부동태화), Hydrogen(수소), Amorphous silicon(비정질 실리콘), Hydrogen exodiffusion(수소 방출)

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수소 플라즈마 처리 후 수소에 의한 plasma epitaxial 실리콘 박막의 미세구조 변화에 대한 연구

모성인[1)]*, 홍지은[1)], 안정호[1)], 오준호[1)]**, 김가현[2)]**

Study on Microstructure Change Induced by Hydrogen Plasma Treatment for Plasma Assisted Epitaxial Silicon

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Abstract : Epitaxial 실리콘 박막은 실리콘기반 microelectronics, micro electronic mechanical systems, photonics, 태양전지 공정 등에 널리 쓰여왔다. Epi-Si은 박막 또는 epitaxial wafer 증착 공정을 통해 형성되는데, 기존에는 electronic 특성관점에서 웨이퍼 물성과 유사하게 결함을 최소화하는 관점으로 epitaxial 실리콘 공정이 최적화되어 왔다. 하지만, 기존에 결함으로 여겨졌던 것들을 의도적으로 epi-Si 내부에 다량 형성할 경우 epi-Si 박막의 공극률을 자유롭게 제어할 수 있으며, 이를 통하여 신개념 분야에 다공성 epi-Si을 적용 가능하다. 우리는 기존에 기존의 식각 기반의 top-down 방식이 아닌 bottom-up 방식인 증착공정변수 제어를 통해 다공성 plasma epi-Si 박막을 제작하는 기술을 보고한 바 있다. 이 포스터 발표에서는 다공성 plasma epi-Si 박막을 증착할 때, 수소 분위기에서 박막 성장 공정 중과 성장 후 표면에 수소 플라즈마 처리를 진행 했다. 이 수소 플라즈마 처리 실험을 통하여 수소가 실리콘 박막의 계면과 표면 미세구조와 porosity에 어떤 영향을 미치는지 연구한 결과를 발표한다.

Key words : Plasma epitaxial silicon film(플라즈마 에피택셜 실리콘 박막), hydrogen(수소), porosity (다공성), microsturcture(미세구조).

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자연 잎을 모방한 태양광 물분해 시스템

진원주[1)]* 신창환[1)]*, 장지욱[1)]**, 서관용[1)]**

Natural leaf-inspired solar water splitting system

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Abstract :

We designed a monolithic artificial leaf that mimics a natural leaf; the artificial leaf has a crystalline silicon (c-Si) interdigitated back contact (collectively, c-Si IBC) structure. On the front-side of the artificial leaf, the c-Si module acts similar to chlorophyll in natural leaves, converting solar energy into photo-carriers. On the rear-side of the artificial leaf, a hydrogen and oxygen evolution catalyst converts the carriers into hydrogen; this occurs without blocking light, similar to the conversion of photo-carriers into chemical energy, which mostly occurs on the backside of natural leaves. The solar-to-hydrogen conversion efficiency of the c-Si IBC photoanode and artificial leaf was 10.1 % and 8.4 % respectively, which are higher than that of a natural leaf (0.1-1 %).

Key words : Crystalline silicon (결정질 실리콘), Artificial leaf (인공 잎), Photoelectrochemical cell (광전기화학 전지), Water splitting (물 분해)

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레이저 스크라이빙의 공정 조건에 따라 Heterojunction 태양전지에 미치는 영향에 관한 연구.

오트곤게렐 줄만다크[1)]*, 전다영[1)], 문지연[1)], 박고등[1)], 남혜령[1)], 권오련[1)], 임현수[1)], 김성현[1)]**

A study on the influence of different laser scribing conditions on heterojunction solar cells.

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Abstract : Recently, innovations such as half-cut or shingled cells have been widely discussed and utilized in the solar industry. The main advantage of half-cutting cells is the reduction of cell-to-module (CTM) loss by decreasing series resistance loss and minimizing mechanical stress on the cells, which can increase the lifetime of photovoltaic modules. Futhermore, Laser scribing technology is a promising way to increase photovoltaic output power ratings for high-efficiency solar cells. The Indium Tin Oxide (ITO) layer can be heavily damaged with unoptimized laser scribing conditions, leading to increased sheet resistance and deteriorated electrical characteristics of the solar cells. ITO is an essential layer for heterojunction (HJT) solar cells because amorphous silicon has low conductivity. We conducted a study comparing the electrical characteristics of the front and rear surfaces of HJT solar cells using Infra-red (IR) laser scribing processes. Therefore, we confirmed that laser scribing on the emitter-free side (Front-side) resulted in higher output power compared to laser scribing on the emitter side. In our study, we used an emitter on the rear surface of the HJT cells. The fill factor with the front surface cutting cell was 0.95% greater than the rear surface cutting cell, and the maximum output power was 0.13 W higher on the front cutting surface. This suggests that the output power of HJT cells mainly comes from the front cutting surface, as the scribing process may cause damage to the emitter side.

Key words : Heterojunction solar cell , Laser scribing separation, Half-cut cells.

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Al_2O_3 와 doping 물질의 표면 passivation 에 의한 Si 태양전지 효율 향상

조영준[1)]*, 장효식[1)]**

The improvement of the efficiency of Si solar cell by the surface passivation of Al_2O_3 and doping materials

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Abstract :

As the solar wafer thickness becomes thin, the passivation becomes more important to reduce carrier recombination losses and to get the higher conversion efficiency in crystalline Si (c-Si) solar cell. Recombination at surfaces of Si due to (surface) defect states can significantly limit Si solar cell performance, where initially performance was limited by defects in the silicon bulk. However, as the Si bulk material quality kept improving, recombination processes at the surface became the main issues. Proper surface passivation is therefore critical to reduce the number of defects at the surface, which are generally expressed in terms of the interface defect density (Dit). Reduction of the Dit leads to a reduction of Shockley-Read-Hall (SRH) recombination enabled by these defects.

In this study, we have investigated the improvement of surface passivation quality for crystalline silicon solar cell using atomic layer deposited (ALD) Al_2O_3 with several doping materials. We examined passivation properties by measuring uniformity, minority carrier lifetime, thickness, interface defect density at AlO_x/Si interface, and reflectance. Lifetime and implied Voc were measured by Sinton WCT-120 in the mode of quasi steady state photoconductance (QSSPC) to study the passivation quality. X-ray photoelectron spectroscopy (XPS) was used to analyze the difference of interface states Al_2O_3/Si substrate.

Key words : Al2O3, ALD(원자층 증착법), passivation, doping

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결정질 실리콘 마이크로와이어를 이용한 대면적/웨이퍼스케일 실리콘 태양전지

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Wafer-scale crystalline silicon solar cells using crystalline silicon microwires

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Abstract : 결정질 실리콘 마이크로와이어는 우수한 광흡수와 효과적인 전자/전공 분리 능력으로 차세대 결정질 실리콘 태양전지의 상부 구조체로 많은 관심을 받고 있다. 우수한 광학적, 전기적 특성에도 실리콘 마이크로와이어 기반의 태양전지는 낮은 발전효율을 보이고 있다. 본 연구팀은 결정질 실리콘 마이크로와이어 태양전지의 도핑구조, 표면보호막, 후면전극 등을 최적화하여 효율을 극대화하였다. 또한, 태양전지 면적을 5 cm x 5 cm 까지 구현하여, 결정질 실리콘 마이크로와이어 태양전지의 상용화 가능성을 보였다.

Key words : 실리콘 마이크로와이어 (silicon microwries), 대면적(large-scale), 방사형 접합 (radial junction)

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수직 배열된 실리콘 마이크로구조 위 금 나노갭이 형성된 고성능 3D SERS 기판

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High-performance 3D SERS substrate based on creating Au nm gaps on vertically aligned Si microstructure

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Abstract : Surface enhanced Raman spectroscopy (SERS) is a highly sensitive technique that enable single-molecule detection by enhancing Raman scattering of molecules adsorbed on nanostructures and provide special fingerprints spectra. The ultra-high sensitivity and selectivity of SERS was utilized in many application such as catalyst, bio- and chemical-sensing. There are may research focus on the preparation of SERS substrate to increase the SERS signal intensity, better uniformity and reproducibility via nanoassembly and nanotailoring methods. In this work, we suggest a simple 3D SERS substrate based on Au nm gaps formed on vertically aligned and well pixelated Si microstructures for it application to a patterned microchip. The Si microstructure were fabricated via photolithography and wet chemical etching process. The E-beam evaporation process was applied to form a thickness-controllable layer of Au, in which create Au nm gaps − the SERS hot spots on the Si microstructure. This 3D SERS substrate has advantage over the flat SERS substrates due to creating more SERS hot spots on specified pixel areas by larger surface areas of inclined Si microstructure. The sensing perfomance of this 3D SERS substrate was characterized and provided a high SERS enhancement factor of 7.4×10^8 and a good SERS signals uniformity with the standard deviation of 4.6%, which gave the 3D SERS substrate the possibility to utilized as a strong SERS platform in sensing applications.

Key words : Surface enhanced Raman spectroscopy(표면증강라만분광법), 3D SERS substrate(3차원 SERS 기판), Plasmon(플라즈몬), Si microstructure(실리콘 마이크로구조), Au nanostructures(금 나노구조체), High sensitivity(고 민감도),

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Simulation-based Feasibility Study on The Optimization Method For Solar Cell Design

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Abstract : The increasing demand for renewable energy sources has propelled intense research into solar cells development. However, the current solar cell technology faces several limitations, such as low efficiency and power output. To overcome these challenges, the new optimization framework for the solar cell design is proposed, which can maximize the objective function (e.g. the power efficiency) while satisfying all of the required constraints (e.g. open-circuit voltage, short circuit current and maximum power) with several structural and electrical design variables (e.g. area of the cell, thickness of each layer of the solar cell, etc.). The proposed method was applied to the application model of the silicon solar cell and the efficiency was improved while all the constraints are satisfied. Therefore, it can be concluded that the proposed method was succesfully validated by the simulation.

Key words : silicon solar cell, optimization, MATLAB program.

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태양광-수증기 생성 및 SERS 검출, 이중 기능성 플라즈모닉 나노구조체 기판

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Dual-functional solar-to-steam generation and SERS detection substrate based on plasmonic nanostructure

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Abstract : Solar-to-steam generation based on plasmonic materials has attracted significant attention as a green method for producing freshwater. Herein, a simple in situ method is introduced to fabricate Au nanoparticles (AuNPs) on cellulose filter paper as a dual-function solar-to-steam generator and surface-enhanced Raman spectroscopy (SERS) substrate. The substrates exhibit 90 % broadband absorption between 350 and 1800 nm, with a maximum and minimum absorption of 95 and 78 % in the visible and near-infrared regions, respectively. The substrates achieve an evaporation rate of 0.96 $kg.m^{-2}.h^{-1}$ under 1-sun illumination, room temperature of 20 °C, and 40 % relative humidity. Additionally, the enriched SERS hotspot between AuNPs endow the substrates with the ability to detect chemical contamination in water with a ppb limits of detection for rhodamine 6G dye and melamine in water, within 1 min. After investigating the solar-to-steam water by SERS, the purified water was reinvestigated to confirm the dual-functional properties of the substrate in real applications. The substrate exhibits high stability when working under 1-sun illumination, with no decrease in evaporation rate. Hence, this substrate can be a promising candidate for use as an efficient solar-to-steam generator and SERS substrate.

Key words : Dual-function(이중 기능), Gold nanoparticle(금 나노입자), Filter paper(거름종이), Solar to steam generation(태양광-수증기 생성), Surface enhanced Raman scattering(표면증강 라만산란), Water purification(정수)

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태양광-수증기 생성을 위한 dry plasma 환원 기반 광대역 플라즈모닉 흡수체 제작

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Broadband plasmonic absorber fabricated via dry plasma reduction for solar steam generation.

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Abstract : Efficient solar energy harvesting of plasmonic absorbers play an important role for many applications, including solar water-evaporation. Here, we demonstrate a simple method of depositing the AuNPs on cellulose filter paper using dry plasma reduction under atmospheric pressure and low temperature to form the black plasmonic AuNPs paper and its application in interfacial solar water-evaporation technology. The substrate was fabrication by reducing gold precursor to form gold nanoparticle on the surface of cellulose paper. The surface morphology of these substrates can be controlled by optimizing the synthesis condition, such as plasma power and the precursor concentration, and characterized by using transmission electron microscopy (TEM). The substrate shows the broadband solar absorption up to 93% in the wide spectral range (350 to 1800 nm, AM 1.5G), with maximum absorption of 98.4% in the visible region and the minimum absorption of 79.3% in the near-infrared region. Using the BPAP as the absorber, our interfacial solar water evaporation system showed the evaporation rate of 1.2 $kg.m^{-2}.h^{-1}$ under the illumination power of 1000 $W.m^{-2}$, with the solar energy conversion of 72.1%. The substrates had strong stability under mechanical test and long-time continuous evaporation works. The system can also work as self-cleaning desalination system based on capillary force of cellulose fibers. With the simple fabrication method, high efficient solar energy absorption, high efficient in solar water-evaporation system and good stability working, the substrate will be a good plasmonic absorber for solar-to-steam generation.

Key words : Gold nanoparticle(금 나노입자), Filter paper(거름종이), Dry plasma reduction(Dry plasma 환원), Solar to steam generation(태양광-수증기 생성), Desalination(담수화), Anti-fouling (방오성).

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고굴절 투명 지르코니아 나노콤포지트의 응용과 실리콘 태양전지에서의 광확산

Trinh Ba Thong[1)]*, 이든찬[1)], 윤일선[1)]**

Applications of zirconia nanocomposites with high refractive index and transparency, and diffusion in silicon solar cells

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Abstract : Polymer nanocomposites have been in great demand in various fields, such as batteries, catalysts, and optoelectronics. Polymer nanocomposites prepared by incorporating nanoparticles (NPs) into the polymer matrix have both properties from the polymer and incorporated NPs. It has been considered an efficient synthetic fabrication to modify or add functionality into a polymer rather than cumbersome polymer chain or branch modification and elongation. Due to efficient light manipulation, polymer nanocomposites with high refractive index and transparency have attracted various industries, such as optical fibers, lenses, displays, and photovoltaic devices. ZrO_2 NPs with high refractive index, transparency, and physical and chemical stability are more suitable for incorporation into a polymer matrix than other metal oxide NPs. This study introduces the optical theory, applications, and principles of ZrO_2 NPs incorporated polymer nanocomposites with high refractive index and transparency. Furthermore, antireflection polymer nanocomposites with ZrO_2 NPs enhancing diffusion for silicon solar cells were introduced.

Key words : zirconia(지르코니아), nanocomposite(나노콤포지트), application(응용), antireflection(저반사), diffusion(확산)

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n-TOPCon 태양전지의 랩어라운드 검출을 위한 머신비전시스템 개발

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Development of Machine Vision System to Detect Wrap-around of n-TOPCon Solar Cells

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Abstract : p-PERC(Passivated Emitter and Rear Contact) 태양전지는 지난 10여 년간 전 세계 태양광 발전 시장에서 가장 각광받는 실리콘 태양전지 구조였으나, 효율의 한계에 부딪히면서 새로운 태양전지 구조 개발이 필요하게 되었다. 2014년 프라운호퍼(Fraunhofer)의 Feldmann에 의해 TOPCon(Tunnel Oxide Passivated Contact)에 관한 논문[1,2]이 출판되면서 n-타입 기반의 TOPCon 태양전지 연구가 활발하게 진행되었다.

n-TOPCon 태양전지 제작을 위해 Passivated contact(SiO_x/n^+-polysilicon)을 증착할 때 LPCVD나 PECVD로 후면에 증착하는데 증착하는 과정에서 전면에 원하지 않는 터널산화막과 폴리실리콘이 증착되며, 이를 랩어라운드(Wrap-around)라고 한다. 고농도로 n-타입 도핑된 폴리실리콘이 전면에 증착될 경우 광손실(Optical loss)이나 누설전류(Leakage current) 등이 발생하면서 효율 저하를 야기할 수 있다. 따라서 Wrap-around를 제거하는 습식 또는 건식 식각 공정을 후속 공정으로 진행하는 것이 일반적이다.

본 연구에서는 Wrap-around 생성을 최소화하기 위하여 PECVD를 이용하여 Passivated contact을 증착하였다. 줌렌즈가 장착된 디지털 현미경을 이용하여 Wrap-around를 촬영하였고 이미지 필터와 이미지 프로세싱 알고리즘을 통해 잔류 Wrap-around 검출 성공 여부를 집계하였다. 집계 결과, 총 10장의 샘플에서 평균 61%의 검출 성공률을 보였다. 검출 성공률이 아직 낮지만, 이미지 프로세싱 알고리즘 개선을 통해 검출 성공률을 높인다면 검사기로서의 역할을 할 수 있을 것으로 생각된다.

Key words : n-TOPCon(탑콘 태양전지), Wrap-around(랩어라운드), Machine vision system(머신비전시스템)

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나노전자소재부품연구센터, 구미전자정보기술원

보론 에미터의 도핑 프로파일과 Ag/Al 전극의 상관관계

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Study on the correlation between the doping profile of boron emitter and Ag/Al electrode

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Abstract : 본 연구는 보론 에미터의 도핑 프로파일이 Ag/Al 전극에 미치는 접촉 저항의 영향을 확인하였다. 보론 에미터의 형성은 액체형 Boron tribromide(BBr_3)를 기반으로 한 열 확산로에서 도핑을 진행하였다. Ag/Al 전극은 스크린 프린팅을 활용하여 전극을 형성한 뒤 소성로에서 소성을 진행하였다. 주요 매개 변수는 에미터의 표면 농도와 접합 깊이의 변화가 접촉 저항에 미치는 영향이다. 에미터의 도핑 프로파일 분석을 위해서 four point probe(FPP)와 electrochemical capacitance-voltage(ECV)를 통하여 면저항, 표면농도 그리고 접합깊이를 관찰하였으며, 소성 이후 보론 에미터와 Ag/Al 전극 간의 접촉 저항은 Transmission length method(TLM) 을 활용하여 측정되었다. 그 결과로 접합 깊이의 증가는 접촉 저항의 감소를 확인할 수 있었다. 이 결과로 부터 보론 에미터에 Ag/Al 전극화는 접합 깊이의 의존성이 높다는 것을 확인할 수 있었다.

Key words : Boron emitter(보론 에미터), Ag/Al electrode(Ag/Al 전극), Screen printing(스크린 프린팅)

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유연 박막 결정질 실리콘 태양전지의 효과적인 광흡수 설계

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Effective Photon Management of Non-Surface-Textured Flexible Thin Crystalline Silicon Solar Cells

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Abstract : Thin crystalline silicon (c-Si) shows outstanding flexibility. Therefore, it has been considered a means for developing flexible solar cells. However, the thin c-Si shows severe light absorption loss of over 48.0%. To improve the light absorption of the thin c-Si, we need to design effective photon management to realize highly efficient thin c-Si flexible solar cells. Although the light absorption of the thin c-Si can be improved by the formation of the nano/micro surface structures, such surface structures would concentrate mechanical stress, inducing degraded flexibility. Therefore, a new strategy is required to satisfy both high light absorption capability and stable flexibility of the thin c-Si solar cells simultaneously. Here, we introduce random inverted pyramidal polydimethylsiloxane (RIP-PDMS) film on the surface of thin c-Si solar cells to secure high absorption and flexibility. The surface reflection of the solar cell is significantly reduced by attaching the RIP-PDMS film to the front surface of the device and the NIR recycling is further improved by attaching the RIP-PDMS film to the rear surface of the device as a diffuse mirror. Notably, the thin c-Si solar cells with the RIP-PDMS films exhibited maximum power conversion efficiency of 18.4% while showing constant efficiency during the 1000 times repeated bending test with a bending radius (Rbending) of 10 mm.

Key words : Crystalline silicon (결정질 실리콘), Flexible solar cell (유연 태양전지), Surface structure (표면구조체), Light absorption (광흡수)

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Optimal solar cell sorting method for high module production reliability

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Abstract : In photovoltaic module manufacturing processes, it is essential to achieve high production reliability of modules based on the given cells with scattered characteristics. This study aims to investigate the optimal cell sorting method to minimize the deviation of module power via simulation analysis. We consider the given solar cells to have different electrical characteristics with Gaussian distributions and ideal interconnections. We examine the resultant power distributions of modules for various cell sorting methods based on various cell parameters such as maximum power current, maximum power voltage, and maximum power of the cells. Our simulation shows that the average powers maximum of the modules in different sorting
methods have a marginal difference and the mismatch loss by the different cell characteristics
is not a key factor to reduce the module reliability, but the standard deviation of the maximum
powers of modules can be largely reduced by one order of magnitude if the cells are sort out
based on the reference of the average power maximum of the participated cells. Our study will
provide useful guidance for cost-efficient and reliable photovoltaic modules in the manufacturing process.

Key words : Cell sorting(셀 선별), PV module(태양전지 모듈), Module reliability(모듈 신뢰성)

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RF 스퍼터링 파워 변화에 따른 ITO의 면저항의 변화

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Sheet resistance change of ITO depending on RF sputtering power

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Abstract : A transparent electrode is an essential part of perovskite and c-si/ perovskite tandem solar cells and ITO (Indium tin oxide) is a representative material among the transparent electrodes. The most commonly used method for depositing the ITO is the RF sputtering. In this study, to optimize the quality of ITO in terms of sheet resistance and transmittance was investigated by controlling the RF power. Main conclusion of this work was that the sheet resistance of ITO exhibited inverse-proportional relation with the RF power. Finally, we obtained the optimized ITO film with sheet resistance of 15 Ω/□ at a thickness of 150 nm, which was prepared at a power of 150 W with high temperature of 400 ℃.

Key words : ITO(인듐주석산화물),Crystalline Silicon Solar cell(결정질 실리콘 태양전지), Perovskite solar cell(페로브스카이트 태양전지), RF sputter(RF 스퍼터)

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실리콘 태양 전지의 터널 산화막 패시베이션 접촉에 대한 열 프로파일 효과

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Heating profile effects on tunnel oxide passivated contacts in silicon solar cells

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Abstract : Tunnel oxide passivated contacts (TOPCon) have emerged as a promising approach to develop highly efficient solar cells. In this study, we examined the impact of different heating profiles on the passivation properties of p-type TOPCon structures. We varied the initial temperature and annealed the samples at 950°C, followed by cooling to the initial temperature. Our results revealed that the passivation properties were improved compared to the conventional rapid annealing process, and an optimal initial temperature was identified as 800°C. To gain insight into the underlying mechanism responsible for the improved passivation properties, we investigated the active dopant profiles following the thermal annealing with different thermal profiles. We observed that the competition between field effect passivation due to boron in-diffusion and Auger recombination played a crucial role in achieving the optimal heating profile maintaining a robust tunnel oxide layer. Our findings provide a valuable approach for designing and understanding high-quality TOPCon structures for developing highly efficient crystalline silicon solar cells.

Key words : Heating profile (열 프로파일), Passivation, TOPCon, Silicon solar cell (실리콘 태양전지)

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알칼리 폴리싱을 이용한 실리콘 웨이퍼 표면 형태 조절

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Abstract : 현재, 단일 접합 태양전지의 이론적 한계효율을 극복하기 위해 다중 접합 태양전지 중 페로브스카이트/실리콘 탠덤 태양전지를 중심으로 연구가 진행되고 있다. 그동안 페로브스카이트 박막은 스핀-코팅법으로 유리 기판 위에 제작되었기 때문에 탠덤 태양전지에서도 연마된 실리콘 웨이퍼 위에 페로브스카이트 박막을 형성하고 있다. 하지만 탠덤 태양전지의 상용화를 고려했을 때 페로브스카이트 박막은 연마된 실리콘 웨이퍼가 아닌 표면이 거친 태양전지용 실리콘 웨이퍼에 코팅될 수 있어야 한다. 페로브스카이트 박막을 태양전지용 실리콘 웨이퍼 위에 코팅하기 위해서는 실리콘 웨이퍼의 표면 거칠기를 감소시키거나 페로브스카이트 두께보다 표면 피라미드를 작게 하는 방법이 있다. 우리는 상용화된 식각 공정을 통해 위에서 언급한 두 가지 방법으로 실험을 수행했다.

Key words : Surface roughness(표면 거칠기), Etching (식각)

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Polycrystalline on oxide 구조 태양전지의 붕소 도핑된 폴리실리콘을 위한 새로운 패시베이션 층 적용 : 붕소 도핑된 실리콘 옥사이드 (SiO_2 : B)

이희연[1], 최동진[1], 강동균[1], 심명섭[1], 강윤묵[2], 이해석[2], 김동환[1]*

Application of new passivation layer for p+ polysilicon in polycrystalline on oxide(POLO) solar cell : boron-doped silicon oxide (SiO_2 : B)

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Abstract : Passivating contact 기술은 금속과 bulk Si 간의 직접적인 접촉을 줄임으로써 고효율을 달성할 수 있게 만드는 기술이다. 그 중 poly-Si과 터널링이 가능한 얇은 산화막(T.O)을 사용한 태양전지 구조는 훌륭한 passivation 특성을 가지며, 비정질 실리콘을 이용한 태양전지와 달리 고온 공정이 가능하기 때문에 활발히 연구가 진행되고 있다. poly-Si/T.O 기반의 태양전지 중 하나인 polycrystalline on oxide(POLO)는 doped poly-Si/ T.O. 가 전 후면에 모두 적용되며 각각의 passivation 품질이 태양전지의 효율에 크게 영향을 끼친다. 하지만, 이미 많은 선행 연구들로 최적화가 거의 완료된 phosphorus doped poly-Si과는 달리 boron doped poly-Si(p+ poly-Si)은 아직 연구가 더 필요한 실정이다. 따라서, 본 연구에서는 p+ poly-Si의 패시베이션 품질을 향상시키기 위해 도핑 공정 전 실리콘 산화막을 poly-Si 층 위에 삽입하여 in-diffusion 보호막으로 이용해 Auger recombination을 최소로 줄이며 동시에 도핑된 산화막 층(SiO_2:B)을 표면 passivation 막으로 사용하였다. 실험에서는 SiO_2:B 막을 spin on doping 방법을 사용하여 형성시켰으며, 산화막의 존재 유무 및 poly-Si의 두께 등의 형성 조건을 조절하여 시료를 제작하였다. 완성된 시료는 QSSPC를 통해 passivation 품질을 측정하였다.
해당 결과를 바탕으로 SiO_2:B 막이 in-diffusion을 효과적으로 막아줄 뿐만이 아니라 도핑 공정 후 nanocrystalline SiOx 상이 되어 negative charge를 띠는 layer가 됨으로써 n-Si/T.O/poly-Si 계면에서의 소수 캐리어를 줄임으로써 높은 passivation 품질을 가지는 것을 확인하였다. 결과적으로, SiO_2:B 층을 표면 passivation 막으로 적용할 경우, 표준 passivation 막인 SiN_x /Al_2O_3 에 비해 약 10 mV 높은 iV_{oc}를 달성할 수 있었다.

Key words : passivating contact(패시베이팅 접촉), in-diffusion barrier(내부 확산 보호막), in-diffusion barrier(내부 확산 보호막), SiO_2:B(붕소 도핑 실리콘 산화막), field effect passivation(전계 효과 패시베이션), nanocrystalline silicon oxide (나노크리스탈라이트 실리콘 산화막)

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블록 타입 대면적 일체형 태양광 수전해 시스템

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The block-type large-scale PV-electrolyzer all-in-one water splitting system

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Abstract : Hydrogen energy is attracting much attention because hydrogen fuel cells do not cause environmental pollution in the process of generating electricity. Most of the hydrogen is gray hydrogen that generates carbon dioxide in the production process from fossil fuels, which contradicts the fact that hydrogen fuel cells do not emit environmental pollutants. Green hydrogen, which produces hydrogen through water splitting by using renewable energy, is a promising candidate as an ultimate clean energy source. In this study, we implemented the block-type PV-electrolyzer all-in-one water splitting system to produce green hydrogen. Our system consists of block-type all-in-one modules that can be combined with other blocks in various configurations, such as triangles and squares. This flexibility to space allows the system to be easily optimized for the specific shape and size of the installation site. Furthermore, in terms of maintenance, since each block is independent from other blocks, any malfunction or damage in a specific block can be easily identified and repaired without disrupting the entire system and thus it can reduce maintenance costs. Moreover, the system can be easily scaled up by just connecting multiple blocks, while maintaining the flexibility and efficiency of the entire system.

Key words : Crystalline silicon(결정질 실리콘), Electrolyzer(전해조), Water splitting(물 분해), Photo electrochemical cell(광전기화학 전지)

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Optimization of radiative cooling effect by anti-reflection layer PDMS for silicon solar cell efficiency

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Abstract : Photovoltaic(PV) system have become increasingly important in renewable energy. The output of PV systems can be reduced by environmental factors, because the efficiency of solar cells can be impacted by temperature changes. Passive cooling of solar cells is a crucial aspect in ensuring their optimal long-term performance. In this study, we investigate the use of polydimethylsiloxane (PDMS) coating on silicon solar cells using screen printing techniques as a cooling system. We demonstrate that the PDMS coating does not interfere light absorption, and emits a long-wavelength band (8-13 micrometers), which provides cooling to the silicon substrate and prevents a decrease in overall efficiency. We find that the PDMS-coated solar cells exhibit superior cooling performance under high temperature conditions, and we analyze the PDMS impact of temperature on the bandgap widening and voltage drop using dark IV measurements. Additionally, we observe that the refractive index of PDMS serves as an anti-reflection layer that improves light absorption by the solar cells. Our results indicate that PDMS can be an effective and efficient material for passive cooling of solar cells, and may have potential for broader applications in PV systems.

Key words : Solar cell(태양전지), PDMS(폴리디메틸실록산), radiative cooling(복사 냉각), Anti-reflection(반사방지), silicon(실리콘)

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Intrinsic poly-Si을 삽입한 TOPCon 태양전지 후면구조에서의 열적 안정성 분석

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Analysis of thermal stability of SiOx/poly-Si passivated contacts with inserting intrinsic poly-Si layer

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Abstract :

Tunnel oxide passivated contact (TOPCon) solar cells have achieved high efficiency, but the stability of the metallization and firing process is crucial for their long-term performance. This study aimed to improve the stability of the firing process and reduce defects by controlling the polysilicon layer at the TOPCon solar cell rear contact. An intrinsic polysilicon layer was inserted between the tunnel oxide and doped poly-Si layer using plasma-enhanced chemical vapor deposition (PECVD), and the firing peak temperature was conducted from 500 to 700 °C using rapid-thermal-process (RTP). The thermal stability of SiOx/poly-Si passivated contacts with and without an intrinsic poly-Si layer was analyzed by measuring the contact resistance with the TLM pattern. The results showed that the insertion of an intrinsic polysilicon layer improved the thermal stability of the SiOx/poly-Si passivated contacts, resulting in a reduced loss of open-circuit voltage (Voc) and lifetime at high temperatures. This study provides a promising approach for improving the stability of TOPCon solar cells in the metallization and firing process.

Key words : Tunnel oxide passivated contact (탑콘 태양전지 특성), Passivation quality (패시베이션 특성), Metallization (메탈증착 공정), Firing peak temperature (소성 최고점 온도), Thermal stability (열적 안정성)

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Si-Ag 접촉형성을 이용한 페로브스카이트/실리콘 탠덤 태양전지 인터레이어 분석 연구

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Ag Nano-Crystallite-Assisted Interlayer Enables High-Conductive Transport in Monolithic 2-T Perovskite/Si Tandem Solar Cells

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Abstract : This article focuses on the interconnection layer (interlayer) of monolithic 2-terminal (2-T) perovskite/silicon (Si) tandem solar cells. The interlayer serves as a recombination layer that recombines photo-generated majority-carrier charge from the top and bottom cells. The efficient recombination of majority-carrier charge is essential for improving the electrical characteristics of the 2-T perovskite/Si tandem solar cells. To enhance the solar cell output, a design for a high-conductive carrier transport layer (CTL) is explored. The high-conductive CTL is achieved by placing the top cell directly on the bottom cell with the aid of Ag nano-crystallites. The low contact resistivity between the CTL and interlayer is also a key factor in facilitating efficient recombination of majority-carrier charge. Proof-of-concept monolithic 2-T perovskite/Si demonstrates the feasibility of this approach. By using the Ag nano-crystallites assisted high-conductive CTL, the electrical characteristics of the 2-T perovskite/Si tandem solar cells can be improved, resulting in an increase in the solar cell output. This approach provides a simple and effective way to design a high-conductive CTL, with potential implications for improving the performance of other types of tandem solar cells.

Key words : Perovskite solar cell(페로브스카이트 태양전지), Silicon solar cell(실리콘 태양전지), Recombination layer(재결합층), 2-T tandem solar cell(2-T 탠덤 태양전지)

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Analysis of carrier induced degradation in Cz wafer via hydrogen behavior

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Abstract : The increase of efficiency of crystalline silicon solar cells is only 0.6%p in the last 15 years. That is why it almost approaches the value of literature such as S-Q limit. Therefore, the topic of long-term stability in solar cells is a interested to many researchers and manufacturers. Among them, Light elevated Temperature Induced Degradation(LeTID) is the rising degradation issue and its precise mechanism. With the light and elevated temperature, the generated carrier reduces the lifetime of the minority carrier through the long-term scale. In this study, we examine the factors affecting light and elevated temperature induced degradation (LeTID) in Silicon wafer, where passivation layer deposited on the surfaces lead to degradation when annealing temperature exceeds 700 ℃. Our research focuses on how hydrogen distribution affects the degradation rate and extent in Czochralski wafers. We analyze how doping type (n/p) and crystallinity of the wafer, as well as the presence of an emitter, influence hydrogen diffusivity in Silicon wafer. To counteract LeTID, we propose a hydrogenation process that increases the total amount of hydrogen atoms diffused into the wafer compared to traditional methods. This result indicates that the maximum degradation extent and hydrogen concentration are not necessarily correlated, and that hydrogen distribution and the formation of carrier sinks at temperatures above 75 ℃ are the key determinants of degradation extent. Our proposed hydrogenation process effectively suppresses defect formation and LeTID. This research sheds light on the impact of hydrogen migration and activation on defects in Si wafers.

Key words : Silicon(실리콘), Degradation(열화), Hydrogen(수소), LeTID(광온도열화), Solar cell(태양전지)

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넓은 시야각을 위한 마이크로 카운터보어 배열이 적용된 투명 결정질 실리콘 기판

이명현[1)]*, 이강민[1)], 서관용[1)]**

Micro-counterbore array assisted transparent c-Si substrate for wide view

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Abstract : Transparent solar cells are in the spotlight as a technology that can maximize the applicable fields of solar cells. In 2020, neutral-color c-Si transparent photovoltaics was reported by Lee et al. They implemented selective light-transmission technology by forming vertical micro-hole arrays on an opaque crystalline silicon substrate and it shows neutral color, high efficiency of 12.2%, and high stability. However, angled incident light could be reached vertical side walls of the micro-hole arrays and thus transmittance and visibility through the transparent c-Si substrate could be hindered. The transparent c-Si substrate with 21.6% transmittance which used the vertical holes, showed a decreased transmittance to 8.4% at an angled light incidence of 15°. As the angle of incident light increases, the c-Si solar cell becomes more opaque. In this study, to improve the viewing angle of the transparent solar cells, we applied a counterbore structure which is a hole with different diameters of the lower and upper parts. The transparent c-Si substrate with the counterbore arrays showed a transmittance of 16.5% even at an angled light incidence of 15°. It clearly proved that the transmittance of the transparent c-Si substrate was significantly improved by applying the counterbore arrays.

Key words : crystalline silicon(결정질 실리콘), counterbore(카운터보어), viewing angle(시야각)

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마이크로 키리가미 구조가 적용된 유연 실리콘 기판

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Flexible crystalline silicon substrate using micro-kirigami structure

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Abstract : Flexible solar cells are spotlighted as next-generation solar cells because they can be installed on uneven surfaces. Among them, flexible crystalline silicon (c-Si) solar cells show relatively high efficiency and stability rather than other emerging solar cells. In general, a relatively thin c-Si substrate with a thickness of less than 50 um is used for feasible flexibility with a bending radius of less than 10 mm. Nonetheless, thin c-Si flexible solar cells face critical challenges because of the low absorption coefficient and surface reflection. In this study, we present a novel strategy that can show flexible properties on thick bare c-Si wafers with a thickness of over 200 um. In this strategy, flexible property of thick c-Si wafers can be achieved by employing micro-kirigami structures to the c-Si wafers. The micro-kirigami structure could be flexible thanks to a spring shape configuration. As a result, the micro-kirigami structure-based thick (~ 525 um) c-Si wafer shows better flexibility compared to bare c-Si wafer.

Key words : crystalline silicon(결정질 실리콘), flexible(유연), micro structure(마이크로 구조)

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유전체층 및 도핑 농도를 제어를 통한 결정성 실리콘 태양전지 후면 최적화

김예은[1], 서관용[2]*

Rear side optimization of crystalline silicon solar cells via controlling dielectric layer and doping concentration

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Abstract : Various strategies with improvement the characteristics of rear side passivation have been studied for high-efficiency crystalline silicon (*c*-Si) solar cells . To maximize the effect of rear side passivation, introduction of adequate dielectric materials for passivation layer and design for control the contact area of *c*-Si and metal electrode should be considered. By optimizing the rear contact design of the device, surface recombination between silicon and metal electrodes is possible to reduce and the collection efficiency of the photo-generated carriers at the long-wavelength region is improved significantly. Here in, the Passivated Emitter Rear Totally diffused (PERT) structure and Passivated Emitter Rear Locally diffused (PERL) structure were employed to optimize the rear structure of the device. Controlling the *c*-Si/metal contact ratio and the back surface field (BSF) doping concentration were intensively studied to maximize the efficiency of the PERT and PERL solar cells. To anlayze the effect of rear side design, the carrier lifetime and implied V_{oc} were measured by controlling the BSF doping temperature and Si/metal contact ratio. As a result, the PERT and PERL structured *c*-Si solar cells exhibit the highest V_{oc} of 621 mV, 546 mV with the BSF sheet resistance of ~ 10 ohm/sq, ~ 8 ohm/sq and *c*-Si/metal contract ratio of 2.2%, 5%, respectively. This result can provide a foundation for optimizing the design of the rear structure of cells for achieving high efficiency.

Key words : Crystalline silicon solar cells (결정질 실리콘 태양전지), Localized rear electrode (국부적 후면 전극), Back surface field (후면 전계층), Carrier recombination (캐리어 재결합), Open circuit voltage (개방 전압)

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마이크로 홀의 종횡비에 따른 투명 결정질 실리콘 기판의 광학적 특성 연구

이정택[1)]*, 이강민[1)], 박정환[1)], 서관용[1)]**

Optical Properties of Transparent Crystalline Silicon Substrates depending on the Aspect Ratio of Microhole

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Abstract : In this work, we analyze the optical properties of the transparent crystalline silicon solar cells depending on changes in the aspect ratio of microhole structures. The previously reported transparent crystalline silicon solar cells have a circular microhole structure that the light can pass through. However, when the light incident on the substrate has an angle, the light is blocked by the wall of the silicon substrate. Therefore, If the angle reaches a specific value, there is a viewing angle in which the transmittance becomes zero. This greatly hinders the utilization of transparent crystalline silicon solar cells in the real world. As one of the strategies to improve the viewing angle of transparent crystalline silicon solar cells, we adjusted the aspect ratio of the circular microhole structure. Microhole structures having various aspect ratio conditions were fabricated using the same process as the previously reported one, and the transmittance was measured according to changes in angle of incident light. Through the equation, the transmittance was calculated at a given angle and compared with the measured value. Additionally, compared to circular microhole structures having the same long diameter, we analyzed whether there is any difference in a visual for the human eyes to recognize.

Key words : Transparent solar cell(투명태양전지), Crystalline silicon(결정질 실리콘), Microstructure(마이크로구조)

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투명 마이크로 구를 이용한 결정질 실리콘 마이크로선 태양전지의 입사각에 따른 효율 감소 개선 연구

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Diminished angular dependency of crystalline silicon microwire solar cells by broadband antireflection effect using transparent spheres

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Abstract : Light absorption is one of the most important factors affecting the power conversion efficiency (PCE) of solar cells. However, since the position of the sun changes depending on the season and time, the light absorption of the solar cell is not constant. The amount of light absorbed by the solar cell decreases as the angle of incidence of light increases. Therefore, it is necessary to minimize the light absorption loss induced by the increase in the angle of light incidence for maximizing solar power generation. In this study, we used microwire structures not only for maximizing light absorption but also for minimizing light absorption loss according to the angle of light incidence. As a result, we confirmed that the PCE of the solar cell without the structure decreased by over 55% when the incident angle of the light changed from 0 to 60°, whereas the PCE of the solar cells with microwire structures decreased by less than 35%. Furthermore, we added the light-scattering silica beads, which is almost no self-light absorption, between the microwire structures to minimize light absorption loss according to the angle of incidence of light. This work provides a novel strategy to reduce the angular dependence of PCE degradation of the solar cells.

Key words : Scattering effect(다중 산란 효과), angular dependency(각도 의존성), Crystalline silicon (결정질 실리콘), Microwire (마이크로선)

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밴드갭 튜닝된 (A)CI(G)S와 페롭스카이트로 제조된 2단자 탠덤 태양전지의 최적화

김성연[1)*], 전동환[1)], 김수관[2)], 이재백[1)], 조효정[1)], 황 반 쿠이[1)], 박시내[1)], 최종민[2)], 성시준[1)], 양기정[1)], 황대규[1)], 강진규[1)], 김대환[1)**]

Optimization of two terminal Tandem Solar Cells fabricated by Bandgap-Tuned (A)CI(G)S and Perovskite

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In the recent photovoltaic technologies, fabrication of tandem solar cells is one of promising technology, because in terms of reducing the thermalization loss to overcome theoretical power conversion efficiency(PCE) of Shockley-Queisser limit[1]. Nowadays, the power conversion efficiency of Perovskite/Si tandem solar cells have achieved 31.25% from CSEM and EPFL[2] and Perovskite/CIGS tandem solar cells are achieving 24.2%[3] To achieve highest efficiency in tandem solar cells band gap energies of top cell and bottom cell should be about 1.63 and 0.96 eV, respectively[4]. Cu(In,Ga)Se_2(CIGS) and $CuInSe_2$(CIS) chalcogenide thin film solar cells are quite promising bottom cells tuning for more lower band gap energy[5].

We have controlled thicknesses of Zinc Oxide(AZO) layer which is being used transparent conducting oxide(TCO) a recombination layer of tandem solar cells. We also have synthesized self-assembled monolayer(SAM) which is one of promising hole transport layer(HTL) by MeO-2PACz for better miscibility on the interfacial layer and conformality with AZO recombination layer of the CI(G)S bottom cells.

CIS solar cells have achieved about 13% of PCE by controlling the thickness of absorber layer during the co-evaporation process. To reduce back contact(BC) recombination, we have pre-deposited Ga graded CI(G)S layer between CIS and Mo layers and achieved about 14% of PCE with improved Voc without Jsc drops. Further, we have incorporated Ag into CI(G)S absorber layer of bottom cells to enhance conversion efficiency of about 17% and to reduce surface roughness for higher PCE of the tandem solar cells.

We will introduce our results of fabricated tandem solar cells by integrating the processes mentioned above and discuss the future optimization process for high efficiency achievement of Perovskite/(A)CI(G)S tandem solar cells.

This work was supported by the DGIST R&D programs of the Ministry of Science, ICT (23-CoE-ET-01).

Key words : Ag doped CIGS, CISe, Perovskite, Tandem Solar Cells, Integration, Self-assembled monolayer(SAM), MeO-2PACz, AZO, ITO

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Tailoring the Bandgap Grading of Ag-Alloyed CIGS Solar Cells for Enhanced Photocurrent and Efficiency

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Abstract :

Recent advancements in chalcopyrite $Cu(In,Ga)Se_2$ (CIGS) solar cells have demonstrated their potential for high efficient and low-cost photovoltaics, while also offering inherent operational stability for large-scale commercialization. Silver (Ag) alloying in CIGS to form $(Ag,Cu)(In,Ga)Se_2$ (ACIGS) has been investigated to modify the valence and conduction band edge of the absorber layer, leading to improved morphology due to improving values of both open-circuit voltage (V_{OC}) and fill factor (FF) over a wider temperature range.

The V-shape grading bandgap of the absorber layer plays an important role in avoiding interface recombination at the front and back interface, which can result in voltage losses. The presence of Ag alloy in the CIGS absorber layer changes the V-shape double grading bandgap with an increase in the notch point region and a slight widening of its bandgap. This leads to decreased current density in ACIGS solar cells compared to conventional CIGS.

This work aims to modify the detailed shape of the double V-shape grading bandgap in the notch region of ACIGS configuration by taking advantage of a turntable band-gap characteristic. The goal is to fabricate ACIGS solar cells with large grains and good crystallinity, resulting in high photocurrent for efficient perovskite-CIGS tandem solar cells. The decreased notch position leads to reducing the minimum band gap and elevated absorption in the low band gap region, enhancing current density. The lower notch region near the front surface contact is also beneficial for sweeping free electrons from the neutral region to the heterojunction region in high Ga concentration, increasing photocurrents. These advantages translate into a high conversion efficiency of 17.8% for ACIGS devices without any post-deposition treatment and anti-reflection coating.

Key words : Silver alloying, conduction band, photocurrent

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유연 CIGS 박막 태양전지의 기계적 내구성 분석

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Investigation of mechanical durability of flexible CIGS thin film solar cells

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Abstract : CIGS thin-film solar cells have been considered as a strong alternative to crystalline silicon solar cells due to their high performance, radiation hardness, and flexible substrate applicability. Various studies on flexible CIGS solar cells have been conducted for a long time, which recently reached a power conversion efficiency of 22.2%. However, mechanical characterizations of the flexible CIGS solar cells such as bending durability have rarely investigated. In this work, we successfully developed high-performance flexible CIGS solar cells by lift-off method and demonstrated their great bending durability. In addition, we investigated mechanical properties of the flexible CIGS solar cells by using nanoindentation technique and finite element analysis to understand the excellent mechanical durability of our flexible CIGS solar cells under the mechanical bending.

Key words : Flexible CIGS solar cells(유연 CIGS 박막 태양전지), Mechanical properties(기계적 물성)

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RF 마그네트론 스퍼터링법으로 증착된 Cu_2O 박막의 물리적 특성에 대한 산소 유량의 영향

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Effects of Oxygen Flow Rates on the Physical Characteristics of RF Magnetron Sputtered-Cu_2O Thin Films

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Abstract : 산화구리(Cu_2O)는 높은 화학적 안전성과 무독성 특성을 갖는 환경친화적 소재입니다. Cu_2O는 1.9 ~ 2.6 eV 범위의 직접 밴드 갭 특성을 나타내며, 이러한 특성으로 인해 광전자 및 광전지 응용 분야에서 매우 유망한 반도체 재료로 부각되는 소재 중 하나입니다. Cu_2O 박막은 열 진공증착(thermal evaporation), 전기화학 증착(electrochemical deposition), 화학기상증착(chemical vapor deposition) 및 스퍼터링(sputtering)과 같은 다양한 증착 기술로 제조됩니다. 이러한 기술 중에서 스퍼터링 방법은 Cu_2O 박막의 결정성 및 두께 제어가 쉬운 이점이 있으며, 비교적 단순한 박막 공정 및 대면적 증착이 가능한 장점이 있습니다. 본 연구에서는 RF 마그네트론 스퍼터링 방법으로 아르곤 가스와 산소 가스의 유량 비를 조절하여 Cu_2O 박막을 제작하였습니다. 성장된 Cu_2O 박막의 구조적, 조성적, 광학적 및 전기적 특성에 산소 가스가 미치는 영향을 고찰하였습니다.

Key words : Cu_2O(산화구리), Sputtering(스퍼터링), Thin film(박막), Oxygen gas(산소 가스), Physical property (물성)

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과열된 태양열 공기 히터를 냉각시키기 위한 그래핀 플레이크와 은 나노와이어로 표면처리 된 고다공성 구리 폼

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Abstract

태양열 공기 히터 (Solar Air Heater)는 복사열을 조사된 패널 아래로 흐르는 공기에 전달합니다. 하지만 패널의 과도한 가열은 열 응력을 유발하고 태양광 장치의 오작동을 일으킬 수 있습니다. 따라서 패널을 냉각시키는 방법이 필수적입니다. 우리는 그래핀 플레이크 (G)와 은 나노와이어 (AgNW)를 초음속으로 분사한 고다공성 금속 폼을 사용해 표면적을 증가시켜 과열된 태양열 집열판을 냉각하는 효과적인 방법을 개발했습니다. 특히 표면처리 된 표면을 통해 대류 냉각은 수집된 복사열 총량에 영향을 주지 않고 표면 온도만을 감소시켰습니다. G/AgNW 표면처리의 영향과 고다공성 금속 폼의 냉각 효과가 평가되었습니다. 실험을 통해 표면처리 되지 않은 금속 폼에 비해 G/AgNW 으로 표면처리 된 금속 폼은 DT = 18 °C 의 온도 감소와 25.3%의 h_{eff} 상승을 보였습니다. 또한 G/AgNW 표면처리는 DT = 81 °C 의 온도 증가와 함께 수집된 태양열의 양을 크게 증가시켰는데, 이는 G/AgNW 표면이 헬름홀츠 병의 완벽한 흑체 (blackbody)와 유사하게 복사열의 포획을 촉진했기 때문입니다. 따라서 SAH 패널의 태양열 집열면과 대류 냉각면 모두에 G/AgNW 층을 보강하는 것이 좋습니다.

***Keywords*:** 복사 열전달, 태양열 공기 히터, 그래핀, 은 나노와이어, 초음속 스프레이

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모놀리식 2단자 CZTSe/Perovskite 탠덤 태양전지의 개방 회로 손실 최소화 및 이해

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Understanding and Minimizing Open Circuit Voltage Losses in Monolithic Two-terminal CZTSe/perovskite Tandem Solar Cell

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Kesterite-based chalcogenide $Cu_2ZnSn(S_xSe_{1-x})_4$ (CZTSSe) has recently attracted intensive attention as one of the most promising photovoltaic absorbers due to the non-toxicity and low-cost availability of the material system. However, the power conversion efficiency (PCE) of the $Cu_2ZnSnSe_4$ (CZTSe) solar cells is much lower than other thin film competitors like $Cu(In,Ga)Se_2$ (CIGS), CdTe, and organic-inorganic metal halide perovskites, due to some intrinsic reasons including the complex defect chemistry. One feasible way to drastically increase the efficiency of the CZTSe solar cell is to make tandem solar cells with wider bandgap materials like halide perovskites. In spite of the high potential economic feasibility of the tandem solar cells consisting of the halide perovskite and the kesterite CZTSe, they have rarely been demonstrated due to the difficulty in implementing solution-processed perovskite top cell on the rough surface of the bottom cells.

In this study, demonstrate an efficient monolithic (rigid & flexible) two-terminal CZTSe/perovskite tandem solar cell by significantly reducing the surface roughness of the thermally evaporated CZTSe bottom cell. For that purpose, the effect of Ag doping was explored on the structural, electrical and surface properties of the CZTSe absorber-based solar cell. Ag was evaporated before the CZTSe film deposition on the Mo/SLG substrate. Interestingly, the surface roughness of the CZTSe thin film was significantly reduced after optimized Ag doping for rigid substrate and all the photovoltaic (PV) parameters were improved compared to the control device. For the development of a monolithic 2-T CZTSe/perovskite tandem solar cell, the perovskite top cell with a bandgap of 1.63 eV could be prepared using a solution process on the flattened CZTSe bottom cell prepared by the Ag doping. The best-performing tandem device exhibited a high PCE of 14.2% with very low open circuit voltage (V_{OC}) losses on the rigid glass substrate. In contrast, relatively lower efficiency (8%) was achieved on the flexible substrate with the complete addition of V_{OC} however, the J_{SC} and FF are lower than the rigid monolithic 2-T CZTSe/perovskite tandem solar cell which could be associated with the poor microstructure of the CZTSe absorber due to the unoptimized Ag doping.

Key words : Ag doping, low bandgap $Cu_2ZnSnSe_4$, grain growt, two-terminal tandem cells

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과량 Cu_{2-x}-Se 액상에 따른 Cu(In,Ga)Se_2 박막 미세구조 영향 및 이를 적용한 유연 태양전지에 대한 연구

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Effects of Excess Cu_{2-x}-Se Liquid Phase on Microstructure of Cu(In, Ga)Se_2 Thin-film and its applications to Flexible Solar Cells

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Abstract :

Chalcopyrite-structured chalcogenides have drawn great attentions as a photovoltaic (PV) absorber since the Cu(In,Ga)Se_2 (CIGSe) record cell has exceeded more than 23% power conversion efficiency (PCE). In general, the surface and interface conditions of CIGSe films play a critical role in achieving high-efficiency solar cells. Additionally, for use of rough surface of flexible strainless steel substrate, the surface planarization is necessary to make robust p/n hetero-interface between buffer and absorber layers. As a result, various efforts on smooth surface with large CIGSe grains have been conducted while discovering passivation of surface and bulk defects by alkali post-treatment (PDT) For examples, NaF and RbF (or CsF) PDT. More recently, the inclusion of low-melting point Ag metal in the film has been widely adopted to improve the film misconstrue. Nevertheless, the most desirable way to obtain high-quality CIGS films is a precise control over $Cu_{2-x}Se$ liquid phase-assisted growth in Cu-rich composition in terms of process simplification. In this regard, the relationship between excess flux of Cu-Se and film morphology has been studied during three-stage process for CIGSe films.

When excess supply time of Cu-Se elemental vapor was adjusted from 1/100 to 1/10 of total Cu-Se supply time (i.e., 2^{nd} stage duration), the film morphology showed rough surface with deep voids because of uncontrolled amount of $Cu_{2-x}Se$ phase on top of Cu-rich film. With optimal excess time of 2/100 of total Cu-Se supply time, the large-grained and smooth CIGS surface was obtained. More interestingly, the possibility to form impurity phases such as binary and/or ternary phases was decreased. Through the process optimization, high-efficiency CIGS solar cells on flexible stainless steel substrate yielded more than 18%. Details on fabrication procedures and characterizations of CIGS PV devices will be discussed.

Keywords: Cu(In,Ga)Se_2, $Cu_{2-x}Se$, Liquid-phase grain growth, Flexible solar cell

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Process dependent physical properties of zinc tin oxide films deposited by sputtering

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Abstract : The Zn_2SnO_4 (ZTO) is an oxide materials with high optical transparency and is promising to be used as an alternative to commonly used intrinsic ZnO in thin film solar cells. RF sputtering is an industrially scalable method commonly employed to deposit ZnO layer. Therefore, the RF sputtering was employed in this attempt. Deposition process type is one of the crucial parameter in sputtering process, in which it might affects the structure and properties of the films. In this work, the effects of changing deposition process on the optical and electrical properties of ZTO films were discussed. The presence or absence of the baking process affects the properties of the ZTO films. The deposited ZTO films showed the polycrystalline nature. The surface morphology and thickness of films are observed by SEM. The optical and electrical properties of the ZTO films were observed by XRD and UV-Vis-NIR, and Hall-Effect measurement. From the results, it is observed that no baking is the best process for obtaining high transparent ZTO films.

Key words : Zn_2SnO_4, transparent conducting oxide, sputtering, thin films

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Fabrication and characterization of alkali-alloyed kesterite CZTSSe solar cells

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Abstract : In this study, we utilized the aqueous spray deposition method to fabricate alkali metals alloyed kesterite CZTSSe solar cells. Through in-situ alloying, Li, Na, K, Rb, and Cs were all incorporated into the CZTSSe absorber. We performed structural and opto-electrical analyses on all samples to investigate the effects of alkali alloying. The results showed that all alkali-alloying led to improved power conversion efficiency (PCE) at optimal amounts, which can be attributed to defect passivation in the alloyed absorbers. This paper will provide a detailed discussion of the passivation effect based on our experimental findings.

Key words : Alkali alloying, Aqueous spray deposition, Kesterite solar cell, in situ alkali alloying

1) 인천대학교 물리학과

단일집적모듈을 위한 $Cu(In,Ga)Se_2$ 박막 태양전지의 P3 레이저 가공 방식에 따른 전기적 손실 분석

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Analysis of Electrical Losses in $Cu(In,Ga)Se_2$ Monolithic-integrated Modules due to the P3 Laser Scribing Methods

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Abstract : 탄소중립 달성에 필수적인 태양광발전의 시장 확대에 기여할 수 있는 $Cu(In,Ga)Se_2$ (CIGS) 박막 태양전지 셀 및 단일집적모듈의 효율 향상을 위한 지속적인 연구개발이 이루어지고 있다. CIGS 박막태양전지 모듈은 기존 실리콘 태양전지 모듈 대비 가볍고 유연한 특성으로 건물 일체형 태양광발전 (BIPV), 차량 일체형 태양광발전(VIPV)에 매우 적합하다. 단일집적 모듈 구조는 하나의 대면적 셀을 다수의 소면적 셀로 분할시켜주기 위해 P1, P2, P3 스크라이빙 공정을 이용하여 분할한 후 각 인접셀을 이어 직렬로 연결한다. P1과 P3 공정은 각각 하부전극과 상부전극을 절연시켜주는 역할을 하며, P2 공정은 하부전극과 상부전극을 연결시켜주는 역할을 한다. 레이저를 적용한 P1, P2, P3 가공은 박막을 선택적으로 가열하여 빠르고 정밀하게 에칭할 수 있으므로 높은 생산성 뿐만 아니라 가공으로 인한 광발전불능 영역을 최소화할 수 있어, 고효율 모듈 기술 개발에 필수적이다. 그러나, 레이저 가공은 열발생을 동반하는 공정으로 가공조건에 따라 다양한 손상을 유발할 수 있다. 특히, Mo 후면전극을 사용하는 표준 CIGS 태양전지에서 P3 가공 공정은 Mo의 532nm 파장에 대한 흡수로 인해 TCO 층으로부터 레이저를 입사시킬 수밖에 없고, 이는 pn 접합에 해당하는 CIGS/버퍼층에 열적 손상을 유발하므로 전기적 손실을 피하기 어렵다.
본 실험은 P3 레이저 스크라이빙 공정에서의 전기적 손상을 최소화하고자 532nm 파장에 높은 투과성을 가진 ITO 후면전극을 사용하여 ITO/CIGS 계면의 가열을 통해 CIGS/버퍼층/TCO 구조체 전체를 제거하는 방법론을 평가하였다. 기판입사 방식과 필름입사 방식에 따른 태양전지의 전기적 손실 차이를 확인하였다. 532nm 피코초 레이저의 세기, 가공속도, 빔 크기를 다양화하여, 박막 에칭 thershold와 전기적 손실 threshold를 평가하여 조건별로 비교하였다. 손상회피가 어려운 필름 입사 가공방식에 비해 기판입사 가공방식은 전기적 손상을 일으키지 않는 공정 윈도우가 훨씬 넓은 것으로 나타났다. 두 가지 가공 방식을 적용하여 CIGS 단일집적모듈을 제조하여 손실 여부를 비교하였다. 필름입사 P3 가공 모듈에서 8.4%의 FF 손실이 발생한 반면, 기판입사 가공을 적용하면 전기적 손실이 없는 고효율 모듈 제작이 가능하였다.

Key words : $Cu(In,Ga)Se_2$ solar cell (CIGS 태양전지), Monolithic-integrated module (단일집적모듈), laser scribing (레이저 스크라이빙), P3 scribing (P3 가공), 기판입사 (substrate illumination), 필름입사 (film illumination)

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Se 분압이 KF-PDT CIGS 광흡수층의 표면구조 및 셀효율에 미치는 영향

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The Effects of Se Flux on Surface Morphology and Cell Efficiency of KF-PDT CIGS absorbers

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Abstract : CIGS 광흡수층의 표면은 CdS, Zn(S,O)와 같은 버퍼층과 pn 접합을 형성하므로 CIGS 태양전지의 성능을 결정하는 데 중요한 역할을 한다. 특히, KF, RbF, CsF등 알칼리 후열처리(Alkali-PDT)에 의해 형성된 표면구조는 표면을 패시베이션할 수 있는 고저항 알칼리층과 전류 통과가 용이한 접촉패턴으로 구성돼 있어 셀효율을 향상시키는 것으로 알려져 있다. CIGS 공정 중 Se 분압은 CIGS 광흡수층 표면구조, 결정성, 결정립 크기에 영향을 미친다. 따라서 알칼리 PDT와 Se 분압 조절을 이용한 CIGS 표면구조 제어 기술은 고효율 CIGS 태양전지 구현에 유용할 것으로 판단된다. 본 연구에서는 KF-PDT CIGS 광흡수층에 Se분압이 미치는 영향을 분석하고자 하였다. 이를 위해 CIGS 광흡수층 증착용 동시진공증발공정에서 Se flux를 15Å/s, 7.5Å/s, 5Å/s로 조절하였고, CIGS 광흡수층의 표면구조를 SEM으로 관찰하고 광전변환효율을 평가하였다. Se flux가 15Å/s인 표면 구조에서는 휘발성이 강한 Se에 의해 큰 hole들이 관찰되었다. 반면 7.5Å/s이하의 Se flux에서는 큰 hole들의 생성 빈도가 확연하게 감소하였으며, 7.5Å/s, 5Å/s의 Se flux에서는 유사한 표면구조를 형성하였다. 또한 물세척을 조절함으로써 나노 크기의 접촉패턴을 형성하는 것을 관찰할 수 있었다. 이러한 나노 크기의 접촉패턴을 형성하는 표면 구조에서 높은 광전류 확보를 위해 bandgap을 1.20eV에서 1.15eV로 낮추었을 때, 광전압은 0.70V~0.71V 이상을 유지하며 광전류가 향상되어 2%이상의 셀효율을 높일 수 있었다. 이는 광여기 전자가 Se분압과 KF-PDT에 의해 유도된 표면 구조로 인한 패시베이션 효과와 더불어 전류가 잘통하는 광흡수층의 접촉패턴 때문에 전류 통과가 원활해졌을 것으로 판단한다. 이 점을 활용하여 우수한 광전압 및 광전류 특성을 갖는 셀효율을 달성할 수 있었다.

Key words: Alkali-PDT(알칼리 후열처리), Se flux(Se 분압), CIGS morphology(CIGS 표면구조), Passivation(패시베이션)

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SUS기판을 이용한 유연 CIGS 태양전지 제조

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Fabrication of flexible CIGS solar cell using SUS substrate

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Abstract : The chalcopyrite semiconductor CIGS have been studying as absorber layer of thin film solar cells. The record conversion efficiency of CIGS solar cells is achieved 22.3%. The CIGS absorber layer can catch whole available photons to generate photocurrent in its area with less than 1 μm due to its high absorbtion coefficient(~10^{15} cm^{-3}) and its tuneable direct band gap(~ 1.6 eV) is suitable for absorber layer of thin film solar cells. Therefore CIGS solar cell can be adapted various industrial items with flexible substrate. To fabricate CIGS solar cell on flexible substrate, it is required to supply alkaline sources and it is well known that alkaline affect on CIGS solar cell performance. To investigate alkaline effect on flexible CIGS solar cells, NaF and KF deposited on CIGS precursors by post-treatment deposition(PDT) and completed CIGS solar cells were fabricated by depositing CdS/TCO on the precursors. FE-SEM, EDS, I-V curve, C-V measurement, SIMS were used to investigate structural and electrical properties.

Key words : CIGS, PDT, Flexible solar cell(유연기판 태양전지), Alkaline effect(알칼리 효과)
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Ag-passivation effects on high efficiency ACZTSSe solar cell

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Intrinsic defects in CZTSSe solar cells can lead to poor device performance due to recombination centers, electrostatic fluctuations, and other factors. Silver substitution in CZTSSe has been proposed as a solution to mitigate these issues. However, high-performing CZTSSe devices typically require more silver and complex fabrication processes, which is problematic for using cheap CZTSSe materials. To address these challenges, we suggested substituting silver locally at the front (F), back (B), or both front and back (FB) regions to reduce the silver content to around 2-3%. Experimental results show that F-passivation reduces copper/zinc defects and limits interface/bulk recombination. In contrast, B-passivation enhances grain growth at the back interface and improves charge carrier transport. Employing a dual Ag-passivation approach leads to significant improvements in CZTSSe device parameters, resulting in a remarkable PCE of 12.43%. Furthermore, this eco-friendly aqueous solution process is a significant advancement in CZTSSe manufacturing, as it reduces the silver requirement and simplifies the fabrication process, making it more cost-effective and scalable.

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Spray-based low band gap CIGSSe colar cell

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The CIGSSe solar cell with a low band gap, is a promising option for the bottom cell in a high-efficiency tandem solar cell. This study investigated narrow band gap CIGSSe solar cells, both with and without alkali treatment, which were fabricated using aqueous spray pyrolysis in an air environment with precursor solution prepared by dissolving constituent metal salts. The results showed that the power conversion efficiency (PCE) of the solar cell significantly increased when rubidium post-deposition treatment (PDT) was applied to the CIGSSe absorber. This was due to the Rb PDT facilitating defect passivation and downshifting of the valence band maximum of the CIGSSe absorber, leading to an improvement in all device parameters. We obtained a champion cell with a PCE of ~15% and with an energy band gap of less than 1.1 eV. Therefore, the CIGSSe solar cell, especially with Rb PDT, is suitable for use as the bottom cell in a highly efficient tandem solar cell.

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투광성 및 광흡수층 두께 차이에 따른 양면수광형 초박막 CIGSe 태양전지 성능에 대한 영향

김동렬[1)*], 안진기[1,2)], 김주원[1,2)], 이상민[1)], 안승규[1)], 조아라[1,3)], 유진수[1)], 신동협[1,3)], 조준식[1,3)], 박주형[1,3)**]

Effect of Transparency and Absorber Layer Thickness Differences on the Performance of Bifacial Ultrathin CIGSe Solar Cell

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Abstract : $Cu(In,Ga)Se_2$ (CIGSe)는 높은 광흡수계수, 조절 가능한 밴드갭, 장기 안정성 등과 같은 장점으로 박막 태양전지의 광흡수층으로 많은 연구가 진행되고 있다. 또한, CIGSe 박막 태양전지는 투명 전극 기판에도 적용 할 수 있기 때문에 건물 일체형 태양전지 기술 중 창호형 태양전지로 응용이 가능하다. 뿐만 아니라, CIGSe 광흡수층의 두께 조절이 용이하기 때문에 투광형 및 양면형 태양전지로 제작할 수 있다. 하지만, 광흡수층 두께를 얇게 조절하여 투광성을 높이면 전류 밀도의 감소로 인해 태양전지의 성능이 감소하게 된다. 따라서, 양면형 태양전지의 투광성과 광전변환효율의 상관관계에 대한 이해가 필수적이다. 이에 광흡수층 두께에 따른 투광형 및 양면형 태양전지의 특성 변화를 살펴보기 위해, CIGSe 광흡수층의 두께를 300 nm 이하로 줄이고 전면 1 sun, 후면 1 sun의 각각의 광량을 조사하여 태양전지의 특성을 분석하였다. CIGSe 태양전지의 특성은 주사 전자 현미경 (SEM), 전류 밀도-전압 (J-V), 외부 양자 효율 (EQE), 자외선-가시광선 분광법 (UV-Vis Spectrometer)을 포함한 다양한 방법으로 분석하였다. 광흡수층 두께를 300 nm에서 150 nm 로 감소시켰을 때, 전면 1 sun 광조사 조건에서의 태양전지 효율은 상대적으로 약 30% 감소하였다. 특히, 전류밀도의 감소가 태양전지 효율 저하의 원인으로 나타났다. 반면, 후면 1 sun 광조사 조건에서 태양전지 효율은 상대적으로 약 17% 감소하였다. 이는 흡수층 두께가 얇아질수록 전면과 후면 각각의 1 sun 광조사 조건에서 전류 밀도의 차이가 점차 줄어들게 된다는 것을 의미한다. 결론적으로 본 실험을 통하여 CIGSe 광흡수층 두께에 따라 투광성을 조절 할 수 있음을 확인하였고, 광흡수층 두께가 감소할수록 양면형 태양전지의 전면과 후면 광조사에 따른 효율 차이가 점차 감소하는 것을 확인하였다.

Key words : $Cu(In,Ga)Se_2$ (CIGSe), Ultrathin (초박막), Bifacial (양면수광형)

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Physical and Optical Properties of $Zn_{(1-x)}Mg_xO$ for CIGS Solar Cell Application

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Abstract : Zinc oxide (ZnO) and its derivatives are one of the most prominent semiconductors in the research field today. The induction of magnesium into the ZnO structure was done to make $Zn_{(1-x)}Mg_xO$, which was not found to be altering the crystal structure of ZnO due to the similar ionic size of zinc and magnesium. Without the change in crystal structure, while increasing its bandgap, $Zn_{(1-x)}Mg_xO$ is one of the prime ZnO descendants to study. A facile chemical bath deposition was done to deposit $Zn_{(1-x)}Mg_xO$, with physical and optical properties observations done after. Compact films were observed, with the thickness varied between 300-600 nm. XRD measurement showed the zincite phase formed with negligible changes in ZnO peak locations with the addition of magnesium. The bandgap energy was not varied much, with the average value of 3.2 eV. The three different parameters mainly influenced physical properties, which are thickness and film uniformity. More uniform thin films and higher magnesium content were to be done in the future before applying to CIGS solar cells.

Key words : CIGS Solar Cell, Buffer Layer, ZnMgO, Chemical bath deposition

Investigation of conduction flow and surface potential in S/Se ratio controlled $Sb_2(S,Se)_3$ thin-film solar cells

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Abstract : Antimony selenosulfide, $Sb_2(S,Se)_3$ has been emerged as a prospective light absorbing layer material for thin-film photovoltaic technology with high stability and minimized environmental impact. The ratio of S/Se in $Sb_2(S,Se)_3$ and its structural bonding, that can be controlled by various deposition method, affects the device efficiency.[1] In this study, we investigated the morphology and electrical transport properties of the $Sb_2(S,Se)_3$ surfaces, that were made by various deposition methods resulting in different S/Se ratios.[2] Four samples, (i) Se 2 mM H. (hydrothermal) deposition (ii) Se 2 mM H.+V. (vapor transport) deposition (iii) Se 6.9 mM H. (iv) Se 6.9 mM H.+V., were prepared to investigate the effect of S/Se ratio on the electrical properties. Se ratio at the surface was higher in the samples that were made both H. and V. deposition methods. Conductive atomic force microscopy was used to probe the current flow at the surfaces. The results show that the amount of surface current was larger in the $Sb_2(S,Se)_3$ made with both H. and V. deposition methods than the layer which was fabricated by the H. deposition only. It indicates that the larger ratio of Se at the surface increase the conductivity of $Sb_2(S,Se)_3$. In addition, Kelvin probe force microscopy was conducted to investigate the distribution of the suface potential. All samples showed positive potential difference across the grain boundaries which act as an electron barrier. This could draw minority carriers to grain boundaries (GBs) and reduce the carrier recombination by separating the charge carriers. For the future works, optoelectronic properties at the interface will be investigated to improve the device efficiency of heterojunction thin-film solar cells.

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Key words : Sb2(S,Se)3(셀레늄황화 안티몬), thin-film solar cells(박막 태양전지), conductive-atomic force microscopy(전도성 원자힘 현미경), Kelvin probe force microscopy(켈빈 탐침 힘 현미경), surface carrier transport(표면 전하 수송)

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SnO_2 패시베이션 층을 갖춘 Flexible CZTSSe 박막 태양전지의 성능 향상

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Enhancing the Performance of Flexible Kesterite-based Thin-Film Solar Cells with SnO_2 Passivation Layer via Atomic Layer Deposition

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Abstract :

$Cu_2ZnSn(S,Se)_4$ (CZTSSe) is a promising photovoltaic material due to its suitable optical bandgap, high absorption coefficient, non-toxicity, and abundance in the Earth's crust. However, kesterite-based thin-film solar cells (TFSCs) using CZTSSe absorber layers have a lower open-circuit voltage (V_{oc}) compared to $Cu(In,Ga)Se_2$ (CIGS), which limits their practical application for large-scale solar energy conversion. To address this issue, we developed a SnO_2 passivation layer using atomic layer deposition (ALD) that can suppress the formation of secondary phases and improve the carrier transport properties of the absorber layer. The SnO_2 passivation layer was deposited on top of the precursor film at a temperature of 90 ℃, with a deposition rate of 0.12 nm/cycle and a final target thickness of 1 nm, using TDMASn source and H_2O gas for SnO_2 deposition. In this work, we analyzed the crystal structure and morphology of the CZTSSe films using techniques such as XRD, Raman spectroscopy, and FE-SEM to confirm the effectiveness of the passivation layer. Our results demonstrated that the SnO_2 passivation layer not only prevented the formation of secondary phases but also enhanced the crystallization properties of the CZTSSe films, resulting in a homogeneous and compact film structure with improved surface coverage and grain size. These findings offer new insights into the development of high-performance kesterite-based TFSCs and suggest that atomic layer deposition can be a promising approach for passivating the absorber layer and improving the overall efficiency of CZTSSe-based solar cells.

Key words : CZTSSe, thin film(박막), solar cell(태양전지), flexible substrate(유연기판), SnO_2, passivation layer(패시베이션)

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Reduced interfacial defects and roughness in $Cu_2ZnSn(S,Se)_4$ thin-film solar cells with In_2S_3 passivation layers

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Abstract : $Cu_2ZnSn(S,Se)_4$ (CZTSSe) has generated considerable research interest owing to its composition of abundant elements and excellent light-absorption properties. However, CZTSSe thin-film solar cells suffer from a considerable deficit in the open-circuit voltage V_{OC}, which is mainly due to the severe interfacial recombination induced by the rough surface of CZTSSe and numerous physical defects. In this study, to improve the morphology and reduce the interfacial recombination, an In_2S_3 passivation layer was introduced between the CZTSSe and CdS layers via a chemical bath deposition process, and the effects of the In_2S_3 layer on the device performance were systematically examined by performing various electrodynamic analyses. The CZTSSe solar cells with thin In_2S_3 layers exhibited impressive increases in V_{OC} and conversion efficiency (from 7.33% to 9.24%), due to the suppression of physical defects and the refined surface morphology resulting from filling the voids and pinholes. In addition, the nanoscale roughness on the CZTSSe surface induced by the In_2S_3 layer provided many nucleation sites for the CdS layer, which may contribute to reducing the activation energy of the heterogeneous nucleation, resulting in uniform growth of CdS without macroscopic CdS agglomerates and improving the quality of the interface. These findings confirm that the reduction of physical defects and the improved deposition of the CdS layer enabled by the added In_2S_3 passivation layer improved the device performance.

Key words : CZTSSe, In_2S_3, Passivation layer, Solar cell(태양전지), Roughness(거칠기)

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셀레늄 후 열처리 및 정공 수송층 적용을 통한 슈퍼스트레이트 구조 Sb_2Se_3 태양 전지의 후면 패시베이션에 관한 연구

왕야즈[1)]*, 지승환[1)], 신병하[1)]**

Rear surface passivation of superstrate-structured Sb_2Se_3 solar cells via selenium post-deposition annealing treatment and hole-transport layer application

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Abstract : Earth-abundant and environmentally benign antimony selenide (Sb_2Se_3) has emerged as a promising light-harvesting absorber for thin-film photovoltaic devices due to its high absorption coefficient, suitable bandgap, excellent long-term stability, and intrinsically benign grain boundaries if properly oriented at [hk1] directions. The vapor transport deposition (VTD) method is prone to facilitate the growth of [hk1]-oriented Sb_2Se_3 thin films so as to achieve better device performances of Sb_2Se_3 solar cells. Nevertheless, the possible decomposition of Sb_2Se_3 during the cooling process may occur, resulting in Se deficiencies on the surface of the Sb_2Se_3 absorber layer, accompanied by the formation of deep-level donor-like defects, such as Se vacancies (V_{Se}) and Sb on Se sites antisite defects (Sb_{Se}), which are detrimental to cell performances. In this regard, comprehensive defect passivation strategies are presented for the rear surface of Sb_2Se_3 solar cells in a superstrate configuration, namely, post-deposition annealing treatment (PAT) under Se atmosphere and a hole-transport layer application. The application of PAT effectively passivated the Se deficiency-related defects, thus significantly improving the open-circuit voltage and fill factor of Sb_2Se_3 thin-film solar cells. Furthermore, the Sb_2Se_3 solar cells in this work finally achieved a power conversion efficiency of 7.0% via introducing a hole-transport layer.

Key words : Sb_2Se_3, Vapor transport deposition (VTD), Post-deposition annealing treatment (PAT)

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유연기판 상에 제조된 무카드뮴 기반 $Cu(In,Ga)Se_2$ 박막 태양전지의 i-ZnO 창층의 물성에 따른 영향

아웻 마나 아마레[1)], 황인찬[1)], 정인영[1)], 박주형[1)], 안진기[1)], 송수민[1)], 어영주[1)], 조아라[1)], 조준식[1)], 안승규[1)], 유진수[1)], 안세진[1)], 곽지혜[1)], 박현욱[2)], 윤재호[2)], *신동협[1)], **김기환[1)]

Influence of i-ZnO Window Layer Properties on the Performance of Cadmium-free $Cu(In,Ga)Se_2$ Thin-film Solar Cells on Flexible Ultra-thin Glass

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Abstract:

$Cu(In,Ga)Se_2$ (CIGSe) based solar cells have been evolving for decades and have reached an efficiency of 23.35%. Solar cells made with CIGSe absorbers typically have CdS buffer layers. However, cadmium (Cd) is toxic, posing a threat to the environment. Therefore, an alternative buffer has been researched for over a decade. Furthermore, CdS has a narrow band gap of approximately 2.40-2.50 eV, limiting CIGSe solar cell performance at short wavelengths. Zn(O,S) and (Zn,Mg)O are suitable replacements for CdS thin films as a buffer layer for CIGSe solar cells due to their abundant availability, low cost, and non-toxic nature. Moreover, their wider band gap could increase the efficiency of CIGSe solar cells because of the increased spectral response of short wavelengths. In this regard, the use of a Cd-free buffer layer could be one of the ways to improve the performance of flexible CIGSe solar cells.

In this work, CIGSe films were grown on flexible ultra-thin glass (UTG) by a three-stage co-evaporation process with Ga grading followed by alkali treatments. To make Cd-free CIGSe solar cells, a (Zn,Mg)O film was deposited by atomic layer deposition (ALD) technique. Then, an intrinsic zinc oxide (i-ZnO) window layer was additionally deposited at the same ALD equipment. To understand the role of the i-ZnO layer and its effects on CIGSe solar cell performance, the film thickness was varied from 10 to 50 nm. When the film thickness exceeded more than 30 nm, the efficiency of Cd-free CIGSe solar cells seems to be saturated and shows the best efficiency of >17% (without anti-reflection coating). Interestingly, the open-circuit voltage of a Cd-free CIGSe solar cell with a 30 nm-thick i-ZnO was higher than one of CIGSe solar cells with a CdS layer and i-ZnO which were prepared by chemical bath deposition and sputtering methods, respectively. It means that the optimal i-ZnO acts as a second buffer layer to minimize ITO sputtering damage and suppress shunting pathways. Overall, through process optimization and coating of the anti-reflection layer, the Cd-free CIGSe solar cells on UTG showed higher than 18%. It is worth mentioning that the solar cells have metastability issues related to the light-soaking effect. It would be discussed in the near future.

Keywords: $Cu(In,Ga)Se_2$, intrinsic ZnO, Cadmium-free buffer, (ZnMg,)O, Ultra-thin glass, Flexible solar cells[ii]

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Selective scribing of ITO/glass substrate with picosecond laser

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Abstract :

The laser scribing method is one of the integral parts of the module fabrication technology. It is a non-destructive technique that has several advantages over the mechanical scribing method. In this work, we performed selective laser scribing for ITO/glass substrate with a picosecond laser (532 nm) and optimized conditions with different preparative parameters. The initial optimization study was performed by varying laser power and pulse repetition frequency. Later laser spot overlap and processing speed were controlled to obtain a precise scribing edge. During the study, we found that the low laser (power) fluence fails to effectively separate the two scribing regions, while the application of high laser power and laser spot overlap caused ITO damage. Thus, by controlling the laser power, processing speed, and laser spot overlap we successfully achieved the P1 scribing conditions for ITO/glass substrate. The present could be useful for the fabrication of BIPV, semitransparent, and different solar cell technologies.

Key words : Solar cell, Module, Laser scribing, P1, ITO

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전기도금에 의한 금속 메쉬 투명전극

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Metal Mesh Transparent Conducting Electrodes by Electrodeposition

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Abstract : The Transparent Conducing Electrodes (TCEs) require flexibility to apply wearable and flexible devices. Indium Tin Oxide (ITO), which is currently commercialized TCEs, has a transmittance of 90% in the visible light region and a sheet resistance of 10 ohm/sq, but is not suitable for flexible TCEs due to mechanical brittleness. Silver mesh TCEs have excellent mechanical flexibility as well as optical-electrical performance. In this study, to improve conductivity, silver mesh was electrodeposited to increase the electrode thickness. Electrodeposited silver mesh (ED-Ag mesh) was fabricated by electrodepositing a silver mesh using a self-cracking template. ED-Ag mesh exhibits excellent optical-electrical performances with a transmittance of 88% at 550nm and a sheet resistance of 1.01 ohm/sq. ED-Ag mesh shows outstanding flexibility, it has obtained stable resistance results through bending tests at a small radius of 2mm.

Key words : Transparent Conducting Electrodes(투명 전극), Self-Cracking template(자체 균열 템플렛), Ag deposition(은 증착), Electrodeposition(전기도금), Flexible(유연성)

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Sb_2Se_3 박막 태양 전지 효율 향상을 위한 기체 수송 증착법에서 정밀한 Se 유량 제어의 중요성

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Importance of precise Se flux control for enhancing the performance of Sb_2Se_3 solar cells fabricated via vapor transport deposition

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Abstract : Sb_2Se_3 possesses a quasi-1-dimensional (Q1D) structure, which generates an anisotropic charge transporting behavior in which the carrier transport is very efficient along the Q1D direction, which is advantageous for solar cells provided the absorber is aligned along the preferred orientation. However, the presence of donor-like defects such as V_{Se} can negatively impact cell performances. Therefore, it is crucial to control the growth of Sb_2Se_3 along the preferred orientations and suppress the formation of V_{Se} to produce highly efficient solar cells. In this work, we discuss the significance of controlling the extra supply of Se during the deposition of Sb_2Se_3 for controlling crystallographic orientations and the population of V_{Se} in Sb_2Se_3 films. This control determines the performance of the solar cells produced from a superstrate configuration with a CdS buffer. Due to the passivation of V_{Se}, the incorporation of Se during growth resulted in a higher open-circuit voltage. However, an excessive supply of Se degraded the short-circuit current by selenizing the top region of the CdS, which disrupted the favorable orientation. The power conversion efficiency was increased from 3.7% to 5.2% as a result of optimizing the additional Se vapor supply.

Key words : Sb_2Se_3 Solar cell(Sb_2Se_3 태양전지), Vapor transport deposition(기체 수송 증착), Crystallographic orientation(결정학적 방향), Donor-like defect(도너형 결함)

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Application of atomic layer deposited tin dioxide for tandem solar cells

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Abstract : We deposited tin dioxide (SnO_2) thin films by using low-temperature atomic layer deposition (ALD) process and confirmed the feasibility of the ALD-SnO_2 thin films as a buffer layer for the perovskite/CIGS tandem solar cells. This work was supported by the DGIST R&D Program of the Ministry of Science and ICT (23-ET-08).

Key words : ALD(원자층증착), tin dioxide(이산화주석)

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페로브스카이트 탠덤용 전착기반 CZTSSe 박막 태양전지 계면 제어

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Interfacial engineering of the co-electrodeposited CZTSSe thin-film solar cells for perovskite tandem application

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Abstract : Tandem solar cells have attracted considerable attention as a successful strategy to overcome the Shockley-Queisser limit of single-junction solar cells by effectively utilizing the solar spectrum. In particular, the combination of hybrid perovskite and $Cu_2ZnSn(S,Se)_4$ (CZTSSe) has the tremendous potential for realizing a high efficiency and the lowest-cost thin-film tandem solar cells. However, the perovskite/CZTSSe monolithic tandem solar cells suffer from the unreliable electrical contact between two sub-cells, resulting from the surface roughness of the CZTSSe bottom cell. To address this critical issue, we developed the roughness control strategy consisting of a bottom-up approach through potentiostatic method and a top-down approach through the etching of the recombination layer. First, the roughness of CZTSSe films was significantly reduced by potentiostatic method rather than the conventional galvanostatic method because of the selective deposition of precursor metallic cations by the large over-potential at the initial step during the electrodeposition of potentiostatic mode. In addition, the surface roughness of CZTSSe solar cells can be further reduced through etching of the indium-tin-oxide (ITO) surface without significant alternation of solar cell properties. Moreover, the thickness of perovskite absorber layers was controlled to optimize the current matching. The wide bandgap perovskite solar cells (~1.65 eV) were fabricated on top of the roughness-controlled CZTSSe solar cells (~1.12 eV). As a result, a monolithic CZTSSe/perovskite tandem solar cells (*i.e.*, Mo/CZTSSe/CdS/*i*-ZnO/ITO/PTAA/perovskite/C_{60}/ITO) is successfully realized and achieved the record efficiency of over 17%. This extraordinary device performance reported in this study exceeds firstly the highest record of 4.6% for the monolithic CZTSSe/perovskite tandem thin-film solar cells and also 13.0% for single-junction CZTSSe solar cells.

Key words : **Tandem** (탠덤), solar cell (태양전지), CZTSSe, perovskite (페로브스카이트), roughness (거칠기)

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박막 태양전지를 위한 계층적 금속 네트워크 투명전극

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Hierarchical Metal Network Transparent Conducting Electrodes for Thin-Film Solar Cells

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Abstract : With the development of electronic and energy devices, flexibility and wearable properties of transparent conducting electrodes(TCEs) are required. One of the most practical approaches to being flexible and capable of maintaining conductivity over a large area is to apply nano-scale interconnected metal networks. Therefore, metal networks including metal meshes and nanowires are expected to be promising candidates for the next generation of transparent electrodes. However, inter-plane conduction must be considered in order to properly integrate a metal network TCE into a device. The hierarchical network fabricated in this study consists of a silver mesh as a main framework and silver nanowires as an secondary framework. The mesh provides a primary path for current to flow in an in-plane direction, and the nanowires provide a local path for current to reach some point in the voids of the mesh. Nanowires minimize the drop in transmittance and reduce the travel distance of charge carriers. When applied to Cu(In,Ga)Se_2 thin-film solar cells, the hierarchical network achieved better device performance than a single silver mesh. The mesh in the hierarchical network enables low sheet resistance and the nanowires enable good integration with the device while maintaining high optical transmittance. As a result, the hierarchical network has excellent electro-optical performance and flexibility and has been properly integrated into devices by enhancing carrier transport.

Key words : Hierarchical network(계층적 네트워크), Transparent conducting electrode(투명전극), Solar cells(태양전지), Metal mesh(금속 메쉬), Metal nanowire(금속 나노와이어)

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흡수층 형성을 위한 열처리 시간이 CZTSSe 태양전지의 특성에 미치는 영향

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Effect of annealing time for formation of absorber layer on characteristics of CZTSSe solar cell

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Abstract : Kesterite-based $Cu_2ZnSn(S,Se)_4$ (CZTSSe) has been considered as one of the most promising absorber material for thin-film photovoltaic application owing to its earth abundant, non-toxic constituent elements and favorable optoelectronic properties as compared to its currently existing $Cu(In,Ga)Se_2$ (CIGS) solar cells. Due to the above-mentioned advantages, a systematic fabrication of CZTSSe device has been conducted to further improve the efficiency of the device. The absorber layer plays a very important role as it absorbs the sunlight and generates the power and due to this reason, the quality of absorber layer greatly affects the overall device efficiency. Thus, optimizing the device fabrication parameters (such as temperature, time, pressure, etc.) is highly necessary to further improve the device efficiency. In this study, we fabricated the device with different annealing time which could further improve the quality of the absorber layer. In this study, the thermal treatment conditions were fixed to 530°C with 500 mtorr pressure to fabricate CZTSSe absorber layer, and the time was adjusted to 5 minutes 30 seconds, 6 minutes 30 seconds, 7 minutes 30 seconds, 8 minutes 30 seconds, and 9 minutes 30 seconds, respectively, and a device was manufactured with a Mo/CZTSSe/CdS/i-ZnO/AZO/Al structure. Finally, the crystallinity of the absorber layer and the change in crystal growth according to the annealing time were analyzed, and the electrical properties of each absorber layer were analyzed.

Key words : CZTSSe , absorber layer, annealing time

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화합물 박막 태양전지에서의 Zn(S,O,OH) 버퍼층 연구

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Zn(S,O,OH) buffer layer in compound thin film solar cells

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Abstract : In $Cu(In,Ga)Se_2$-based thin film solar cells, mostly cadmium sulfide (CdS) is used as a buffer layer deposited by chemical bath deposition (CBD). However, CdS exhibits problems as high toxicity and relatively low bandgap energy. Hence, an earth-abundant and non-toxic Zn(S,O,OH) is studied as a potential material to use. Thus, in order to obtain high quality solar cells with ZnS-based films as a buffer layer, understanding of the CBD-reaction growth mechanism is an important factor to overcome deposition obstacles.

Zinc compounds (ZnS, ZnO and $Zn(OH)_2$) are occurring almost at the same time due to similar solubility values. To form bufffer layer, two mechanisms were already demonstrated: (i) heterogeneous reaction, associated with the ions are attached one by one on the surface in order to form films, and (ii) homogeneous reaction, with appearing agglomeration of colloidal particles pre-formed in the bulk of the solution which leads to adsorption on the surface to make particulate films. The homogeneous deposition is highly undesirable because it leads to non-adherent films resulting in a porous layer structure. However, in practice, both mechanisms may occur and/or interact at the same time during the reaction, leading to deposition of films in which colloidal materials are included.

We have investigated the anion effect for Zn(S,O,OH) layer using two different precursors. The prepared materials are characterized using SEM, TEM, and XPS. The results will be presented and discussed in detail in order for better understanding of introduced deposition mechanism.

Key words : Zn(O,S,OH), buffer layer (버퍼층), compoind thin film solar cell (화합물 박막 태양전지)

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용액성장법으로 매우 빠르게 증착된 Zn(O,S) 버퍼층을 가진 $Cu(In,Ga)Se_2$ 박막 태양전지의 p-n 접합 특성

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p-n junction property of $Cu(In,Ga)Se_2$ thin-film solar cells with a Zn(O,S) buffer layer grown by chemical bath deposition with a very high deposition rate

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Abstract : 친환경 태양전지에 대한 관심과 함께 $Cu(In,Ga)Se_2$ (CIGS) 박막 태양전지의 버퍼층으로 널리 사용되는 CdS 물질을 대체하고자 Zn(O,S) 버퍼층에 대한 연구가 활발히 진행되고 있다. 다양한 방법으로 Zn(O,S) 버퍼층을 형성할 수 있으며, 그 중에서도 용액성장법은 다른 방법에 비해 공정이 간단하고, 고가의 진공장비를 사용하지 않으면서도, 넓은 면적의 박막 공정이 가능하고, 재현성이 우수하다는 장점이 있다. 용액성장법으로 Zn(O,S) 박막을 증착할 경우, Zn와 S의 이온공급원, 촉매용액, 공정온도, 공정시간등에 의해 박막의 특성이 결정된다. 기존 용액성장법으로 성장된 Zn(O,S) 박막은 CdS 박막에 비해 공정속도가 길다는 단점이 있는데, 이는 thourea (TU)로부터 공급되는 S 이온과 Zn 이온의 결합 속도가 느리기 때문이다. 이를 극복하기 위하여, 본 연구에서는 TU 대신 thioacetamide (TAA)를 이용하여 Zn-S의 결합속도를 증가시켜 Zn(O,S) 박막의 증착속도를 증가시키고자 하였다. 기존 TU 대신 TAA를 사용하여 Zn(O,S) 공정시간을 80분에서 7분으로 단축하였으며, 효율 향상을 위해 Zn 이온공급원인 $ZnSO_4$의 몰 농도 변화(0.05, 0.1, 0.2, 0.3 M)에 따른 CIGS 태양전지를 제작하여 특성을 비교 분석하였다. $ZnSO_4$ 몰 농도 0.1 M에서 태양전지의 효율이 가장 높게 측정되었으며, $ZnSO_4$ 몰농도에 따라 Zn(O,S) 박막의 두께 및 형상 변화를 관찰하였다. 박막의 표면 및 계면 분석을 통하여 용액공정법으로 매우 빠르게 성장된 Zn(O,S)박막의 성장 매커니즘을 규명하고, CIGS/Zn(O,S) 계면에서의 p-n 특성과 CIGS 태양전지 성능과의 상관관계를 도출하였다.

감사의 글
이 논문은 과학기술정보통신부의 재원으로 한국연구재단-단계도약형 탄소중립 기술개발 사업(No. 2022M3J1A1063019)과 한국전자통신연구원 내부연구과제(22YB1500)의 일환으로 수행되었음.

Key words : $Cu(In,Ga)Se_2$ thin-film solar cell($Cu(In,Ga)Se_2$ 박막 태양전지), Zn(O,S) buffer layer(Zn(O,S) 버퍼층), chemical bath deposition (화학용액성장법), p-n junction (p-n 접합)

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Ag 혼입 순서가 동시진공증발법으로 형성된 CIGS 박막 태양전지 특성에 미치는 영향

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Effects of Ag incorporation-timing on device performance of co-evaporated CIGS thin film solar cells

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Abstract : Cu(In,Ga)Se_2 (CIGS) 박막 태양전지에서 광흡수층은 소자 성능을 결정하는 핵심적인 요인으로서 고효율화를 위한 특성 개선을 위해 연구가 꾸준히 이루어지고 있다. 광흡수층 개선을 위한 다양한 방법 중 기존 구성 원소 외 새로운 원소를 추가하는 방법은 CIGS 물질 특성을 쉽게 변화시킬 수 있어 많이 활용되고 있다. 그 중 Ag 첨가는 1족 원소인 Cu와 치환되어 CIGS 물질의 융점을 낮춰주는 특성을 가지고 있다. 이는 결과적으로 CIGS 물질의 구조적/전자적 결함 감소를 유도 할 수 있는 등의 이점으로 각광받고 있다. 하지만 이러한 귀금속의 활용은 경제성에 대한 문제를 고려할 필요가 있어 보다 활발한 활용을 위해 효율성을 고려할 필요가 있다.

본 연구에서는 동시진공증발법을 이용해 3단계 공정을 적용하여 공정 중의 다양한 지점에 일정량의 Ag를 첨가하여 박막 특성이 개선된 $(Ag_xCu_{1-x})(In_yGa_{1-y})Se_2$ (ACIGS) 박막 태양전지의 특성을 조사하였다.Ag가 일정량 첨가된 ACIGS 박막은 Ag 첨가 순서에 따라 다양한 특성변화가 나타났다. Ag의 고유한 효과로 인한 미세구조의 변화는 모든 공정 순서에서 확인 할 수 있었다. 하지만 효율 등 소자 특성에서는 Ag 첨가 순서에 따른 변화가 나타났으며 특히 1단계 이전에 Ag를 첨가한 소자에서는 가장 큰 효율 증가와 FF증가를 확인 할 수 있었다.

Key words : CIGS thin film solar cells(CIGS박막 태양전지), Ag incorporation(은 혼입)

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thin-CIGS 태양전지의 고효율을 위한 효과적인 후면 패시베션층 연구

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Investigation of effective local contact rear passivation for high-efficiency thin CIGS solar cells

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Abstract : 얇은 두께의 CIGS ($Cu(In,Ga)Se_2$) 태양전지는 후면 전극과 흡수층 계면 사이에서의 높은 재결합과 낮은 반사율로 인해 높은 효율 특성을 얻기에 한계가 있다. 최근 CIGS 태양전지 후면에 패시베이션 층을 적용하여 이러한 문제를 극복하고자 한 연구 사례들이 많이 보고되고 있다. 그러나 패시베이션 층의 두께에 따라 얇은 CIGS 흡수층 표면 형태가 변하게 되고, 이는 광흡수와 광전특성에 영향을 줄 수 있다. 본 연구에서는 CIGS 태양전지 후면에 국부 접촉 Al_2O_3 패시베이션 층 (LC-Al_2O_3)을 적용하여 CIGS 태양전지 특성 변화를 확인하였다. 또한 CIGS 흡수층의 표면 변형을 최소화 할 수 있는 LC-Al_2O_3의 최적 두께를 확인하고자 하였다. 광학 및 전기 시뮬레이션을 사용하여 CIGS 태양전지에 대한 LC-Al_2O_3 층의 두께 효과를 확인하고, CIGS 셀을 제작하여 그 효과를 확인하였다.

Key words : Local contact rear passivation layer (후면 국부접촉 패시베이션층), LC-Al_2O_3 thickness (후면 패시베이션층 두께), $Cu(In,Ga)Se_2$ (구리인듐갈륨셀렌)

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광 산란 특성이 우수한 ZnO nanorods

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ZnO nanorods with enhanced light scattering properties

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Abstract : In this study, a light diffuser based on ZnO NRs (zinc oxide nanorods) was fabricated using the CBD (Chemical Bath Deposition) method. A systematic approach was implemented by carefully tailoring the microstructure of ZnO using ammonia as a complexing agent. ZnO NRs formed with CBD induce preferential nucleation on the (0001) plane and inhibit lateral growth such as the (1010) plane, resulting in sharp tips. This plays a key role in exhibiting a large scattering angle, high light diffusivity, and high haze, which are important parameters in evaluating the properties of a light diffusing film. As a result, a ZnO NRs film superior to commercial 3M light diffusion film was obtained.

Key words : Zinc oxide nanorod (ZnO 나노 로드), Light scattering (광 산란), Chemical bath deposition (화학조 증착)

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고효율 $CuInSe_2$ 광흡수층 형성을 위한 표면처리 방법 연구

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Surface treatment for high-efficiency $CuInSe_2$ absorber layer

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Abstract : 칼코피라이트(Chalcopyrite)계 태양전지를 하부셀로 활용한 탠덤태양전지(Tandem solar cells) 가 최근 활발하게 연구되고 있으며, Perovskite/CIGS 탠덤 태양전지 구조에서 24.6% 광변환효율을 보고한 바 있다. 탠덤태양전지에서 최적 구조는 상부셀은 높은 밴드갭을, 하부셀은 낮은 밴드갭을 가져야 효율적으로 빛을 흡수할 수 있다. 하지만 하부셀로 사용하는 $Cu(In,Ga)Se_2$ (CIGS) 태양전지의 광흡수층은 밴드갭이 1.1 eV 이상에서 고효율 고성능 특성이 보고되고 있으며, 이는 다량의 Ga을 광흡수층 내부에 포함한다. Ga을 포함하지 않는 CuInSe (CIS) 광흡수층은 1.0 eV 의 낮은 밴드갭을 갖고 있어 탠덤태양전지 하부셀로 적합하나, 낮은 밴드갭으로 인해 개방전압이 낮아 태양전지 소자 광변환효율이 CIGS 태양전지 대비 낮은 단점이 있다. 본 연구에서는 CIS 광흡수층 형성 시, 표면 영역에서 국부적으로 넓은 밴드갭을 갖도록 금속 원소를 도입하거나 Cu-poor 광흡수층 표면에 생성되는 결함을 알칼리 금속으로 표면처리하여 CIS 태양전지 소자에서 개방전압을 개선하고 고효율의 CIS 태양전지를 얻고자 하였다. CIS 광흡수층의 밴드갭을 낮게 유지하고 국부적인 표면처리를 통해 태양전지 소자에서 개방전압을 개선하여 고효율의 CIS 태양전지 소자를 얻고자 하였다.

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Key words : $CuInSe_2$(구리인듐셀레나이드), Surface treatment(표면 처리), High efficiency (고효율)

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지구상에 풍부한 Kerterite 기반 물질을 이용한 PEC 물분해 광음극과 박막태양전지의 특성

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Earth abundant kesterite-based PEC water-splitting photocathodes and thin film solar cells

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Abstract : $Cu_2ZnSnS_xSe_{4-x}$ materials are earth-abundant and non-toxic, so they are used in various devices. Among them, the highest efficiency of about 13% was reported when used as a thin-film solar cell, but the half-cell solar hydrogen efficiency is at a low level of up to 7%. In order to improve this low solar-hydrogen efficiency, studies such as element doping, structural change, and catalyst deposition are being conducted. Among them, many studies have been reported on improving photocurrent using a CZTSSe/CdS/TCO/Pt structure similar to the structure of a solar cell. In this study, the photocurrent performance of the CZTSSe photocathode was analyzed using the Mo substrate widely used in solar cells and the FTO substrate widely used in water splitting. The HER half-cell was fabricated with a Mo(FTO)/CZTSSe/Pt structure and a Mo(FTO)/CZTSSe/CdS/i-ZnO/FAZO/Pt structure, respectively, and the photocurrent enhancement due to the deposition of an additional layer was analyzed. When measuring the photocurrent, the electrolyte was Na_2SO_4 0.2 M solution (~pH 6.5) and the catalyst, Pt, was deposited for 0, 80, and 120 seconds, respectively. In addition, a CZTSSe solar cell was also manufactured and the device's performance was compared. As a result, the photocurrent of about 4.84 mA/cm^{-2} was measured with the cell deposited in multi-layers on the Mo substrate with the best properties.

Key words : $Cu_2ZnSnS_xSe_{4-x}$, Photoelectrochemical(광전기화학), Water-splitting(물분해), Photocurrnet(광전류)

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Current path and charge barrier at grain boundaries in heavy alkali doped flexible Cu(In,Ga)Se_2 thin film solar cells

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Abstract : Cu(In,Ga)Se_2 (CIGS) thin film solar cells have reached the efficiency over 23% and that of flexible CIGS thin films solar cells keeps rising. Especially, flexible substrate such as polyimide does not contain alkalis, optimization of alkali incorporation is required to maximize the performances. [1] Herein, four flexible CIGS solar cells were prepared with various alkali post deposition treatment (PDT) (NaF, NaF+RbF, NaF+CsF) to investigate the impact of heavy alkali on the surface charge transport. To investigate the optical properties, photoluminescence (PL) spectrum was obtained and the samples with heavy alkali showed the PL peak in lower energy compared to the sample without alkali and NaF PDT only sample. Kelvin probe force microscopy (KPFM) was conducted to probe the electrical properties of CIGS surface and the charge barrier formed at the grain boundaries (GBs) did not significantly increase or decrease with heavy alkali PDT indicating that the extra heavy alkali does not enhance the charge barrier at GBs. Furtheremore, conductive-atomic force microscopy (c-AFM) was utilized to characterize the current path and the samples with alkali showed the higher surface current values compared to the that of sample without alkali. In addition, the sample with NaF PDT and NaF+CsF PDT showed the formation of surface current along the GBs while the sample with NaF+RbF showed the surface current formed in the intragrain regions which means the type of alkali can changed the current path. For the future work, changes in charge transport at the surface in CIGS by mechanical stress will be studied based on atomic force microscopy-based measurements.

[1] Kihwan Kim et al., Nano Energy 67 (2020) 104201

Key words : Flexible Cu(In,Ga)Se_2 (CIGS) thin film solar cells (유연 CIGS 계 박막 태양전지), Alkali post deposition treatment (알칼리 증착 후처리), Atomic force microscopy (원자 힘 현미경)

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DC 스퍼터링 공정을 사용하여 Zn 증착 시간을 조절한 $Cu_2ZnSn(S_x,Se_{1-x})_4$ 박막 태양전지의 광전지 성능 향상 분석

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Analysis of photovoltaic performance improvement of $Cu_2ZnSn(S_x,Se_{1-x})_4$ thin-film solar cells by controlling Zn deposition time using DC sputtering process

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Abstract : As the demand for energy sources continues to increase due to the rapid development of technology, the need to develop next-generation renewable energy sources is drawing attention. Among many next-generation renewable energies, solar energy can be widely used as eco-friendly energy and is the most promising energy source that can continuously supply energy indefinitely. Actively studied CdTe and $Cu(In,Ga)Se_2$ (CIGS) light absorbers suffer from the toxicity of Cd and the lack of Te and In. To replace these, $Cu_2ZnSn(S_x,Se_{1-x})_4$ (CZTSSe) light absorber is composed of universal non-toxic elements, which has abundant reserves on earth and has suitable physical and chemical properties for photovoltaic devices. Therefore, CZTSSe is one of the promising candidates as an light absorber layer for next-generation solar cells. However, current CZTSSe thin-film solar cell records an efficiency much lower than the theoretical efficiency of 32.2% of the Shockley Queisser Limit. In this study, CZTSSe absorbers was prepared according to the deposition time of Zn monolayer to fabricate high-efficiency CZTSSe thin film solar cells, and the crystallographic, structural, and morphological characteristics of the thin films were analyzed.

Key words : CZTSSe, Thin film(박막), Solar cell(태양전지), absorber(흡수체)

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ITO 기반 전도성 광학필터를 활용한 컬러 $Cu(In,Ga)Se_2$ 박막 태양전지

조대형[1], 이우정[2], 황태하[3], 정용덕[4]*

Colorful $Cu(In,Ga)Se_2$ thin-film solar cells employing ITO-based conductive optical filter

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Abstract : 최근 도심의 에너지 자립을 위해 건물, 차량, 모바일 기기 등 다양한 응용 분야에 적용 가능한 태양광 모듈의 필요성이 높아지고 있다. 사람이 쉽게 볼 수 있는 태양광 모듈은 주변 환경과 조화를 이룰 수 있는 미적 요소가 중요하다. 따라서 기존의 어두운 색 계열의 태양광 패널이 아닌 주변과 잘 어우러질 수 있는 다양한 색상의 패널을 구현할 필요가 있다. 일반적으로 간섭 코팅이 있는 다층 광학 필터가 태양전지의 색상을 구현하는 데 이용되는데, 고굴절률 및 저굴절률 산화물 박막을 교대로 증착하면 특정 파장의 간섭이 일어나 원하는 색상을 얻는 방법이다. 그러나, 산화막 기반의 컬러필터는 일반적으로 전기전도도가 매우 낮아 전기전도도 향상을 위해 금속막 등이 추가로 필요하다. 컬러필터의 산화물 자체가 전기전도성을 갖는다면 태양전지의 투명전극층을 대체함과 동시에 색상을 구현할 수 있는 장점이 있다. 본 논문에서는 전도성 인듐주석 산화물 (Indium Tin Oxide, ITO) 박막의 SnO_2 조성을 변화시켜 전기전도도, 굴절률, 소멸계수를 조절하였다. 스퍼터링을 이용해 SnO_2 조성이 서로 다른 ITO 박막을 반복적으로 증착하여 높은 전기전도도와 선명한 색상을 갖는 광학 필터를 제작하였고, 이를 $Cu(In,Ga)Se_2$ 박막 태양전지에 적용한 결과를 보고한다.

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Key words : $Cu(In,Ga)Se_2$, thin-film solar cell(박막 태양전지), Color(색상), Indium tin oxide(인듐주석 산화물), Optical filter(광학 필터)

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효율적인 기상 수송 증착 SnS 박막 태양 전지: 승온 속도의 역할

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Efficient Vapor-Transport-Deposited SnS thin-film Solar Cells: The Role of Temperature Ramping Rate

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Abstract : In this work, the vapor-transport-deposited (VTD) tin sulfide (SnS) has been studied for the thin film solar cell (TFSCs) applications. In detail, the effect of process temperature ramping rate on orientation, morphology, and crystallinity of the SnS absorber layer and its photovoltaic performance was investigated. The temperature ramping rate was varied between 5 to 20 °C min^{-1} to achieve the process temperature of 600 °C. The SnS deposited at a minimum temperature ramping rate (5 °C min^{-1}) exhibited nonuniform crystalline size with the preferred orientation along (111) direction. Whereas, at a maximum ramping rate of 20 °C min^{-1}, compact and uniform growth of SnS crystals having preferred orientation along (120) was observed. The TFSCs were fabricated using various temperature ramping rates having SLG/Mo/SnS/CdS/i-ZnO/AZO/Al device structure. The *C-V* analysis under dark conditions revealed the improved diode characteristics due to suitable morphology, crystal structure, and orientation of the SnS deposited using ramping rate of 20 °C min^{-1}. The highest power conversion efficiency (PCE) of 3.98% along with short-circuit current density (J_{sc}) of 20.16 mA cm^{-2}, open-circuit-voltage (V_{oc}) of 0.34 V and fill factor (FF) of 0.58 was obtained for the 20 °C min-1 device. For the 5 °C min^{-1} device, the PCE of 2.45% was observed, which is comparatively low than that of the 20 °C min^{-1} device. The further analysis revealed the improved shunt properties and subsequently the FF of the device fabricated using 20 °C min^{-1} temperature ramping rate.

Key words : Thin film solar cells (박막태양전지), SnS, vapor transport deposion (기상증착법), ramping temperature (승온)

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SnS/CdS 박막 태양전지 성능 향상을 위한 VTD-SnS 흡수체의 상부 표면 개질 연구

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Top Surface Modification of VTD-SnS Absorber for Enhancing the Performance of SnS/CdS Thin Film Solar Cell

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Abstract : The surface modification of vapor transport deposition (VTD) grown tin monosulfide SnS-absorber layers and their impact on SnS/CdS heterojunction thin-film solar cells (TFSCs) has been investigated. The Orthorhombic SnS having promising properties for a thin film solar cells absorber including optical band gap (~1.35 eV), high absorption coefficient (> 104) also, comprises of relatively earth abundant constituents and non-toxicity. The theoretical efficiency limit of SnS is ~32% but cell efficiency has mostly remained below 4% which is fairly low as compared to theoretical, because of low heterojunction quality with CdS buffer layer as well as due to short circuit loss.

In this study the highest efficiency of 2.75% with Voc o 0.298 V, Jsc 19.01 mA-cm-2, and FF 48% was found to observe for VTD-SnS absorber/CdS heterojunction solar cells for a 3 min treatment of SnS absorber surface with 20 mol % of HNO_3 solution. While without treatment of SnS surface the device shows a performance of 2.35% with Voc o 0.308 V, Jsc 15.85 mA-cm-2, and FF 48%. These improved characteristics are primarily attributed to the reduction in interface defects of the SnS/CdS heterojunction, which can occur either due to direct CdS deposition on SnS or annealing of SnS/CdS heterojunction at 300 °C or during the deposition of transparent conducting oxide (i-ZnO). The detailed analysis of the device performance has been presented for different concentration and time of HNO_3 treatment.

Key words: Tin sulfide(황화주석), Thin film solar cells(박막태양전지), Absorber layer(흡수층), Interface(계면)

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열화상 분석법을 이용한 CIGS 박막 태양광 모듈의 단락 결함 특성화

이승훈[1)*], 김민규[2)], 강윤묵[3)*], 이해석[3)], 김동환[1)**]

Lock-in thermography characterization of shunt defects in CIGS thin film solar modules

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Abstract : In this study, we investigated the structural shunt defects induced by delamination of the absorber in alcohol-based solution-processed CIGSSe solar modules. Characterization with the use of lock-in thermography indicated that most of the delamination-induced shunt defects emerged locally near the patterned regions. Further, we revealed the distribution of the alkali elements to be the key factor responsible for absorber delamination near the patterned regions. The rationale for this was as follows: First, we found that the alkali elements in the CIGSSe solar modules were concentrated near the patterned regions, rather than being uniformly distributed. Second, we confirmed that the defects induced by absorber peel-off could be alleviated by controlling the diffusion of the alkali elements. Ultimately, the energy conversion efficiency of the alcohol-based solution-processed CIGSSe solar modules was enhanced from 4.24 to 7.59% by inserting a thin-film diffusion barrier.

Key words : Lock-in thermography (열화상 분석법), CIGS solar module (CIGS 태양전지 모듈)

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열처리를 통한 CIGS 박막 조성제어

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Control of CIGS Thin Film Composition through Heat Treatment

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Abstract : MOCVD (metal-organic chemical vapor deposition)를 이용하여 Cu(In,Ga)Se2 박막의 특성을 연구하였다. 기화 된 후 버블러로에서 챔버로 들어간 유기 금속 전구체는 기판에서 열분해된다. 단일 또는 이원 원소로 구성된 유기 금속 전구체가 Mo 기판 상에 증착 될 때, 증착된 박막은 상분리된다. 고순도 CIGS 박막을 제작하기 위해서는 균질화가 필요하므로 CIGS 박막의 균일한 조성을 얻기 위해 다양한 온도의 불활성 환경에서 박막을 열처리했다. Pristine CIGS 박막은 상부 Se, Ga-rich 층 및 하부 Cu, In-rich 층을 나타내는 두 개의 층으로 분리된다. 550°C 이상에서 열처리 된 후, 분리된 두 층은 CIGS 박막의 벌크 전체에 걸쳐 균일해진다. 176 cm-1의 라만 스펙트럼에서 CIGS 박막의 A1 모드와 260 cm-1의 진동 모드는 후 열처리 과정 후에 사라진 Cu-Se 화합물의 A1 모드를 나타낸다.

Key words : Cu(In,Ga)Se2(구리-인듐-갈륨-셀레늄 태양전지), Post-Annealing (후열처리)

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Ge and Cd double cation study to achieve high-efficiency of CZTSSe thin film solar cells

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Abstract : The kesterite $Cu_2ZnSnSSe_4$ (CZTSSe) based solar cells have the potential to replace conventional Cu(In, Ga) $(S,Se)_2$ (CIGS) and CdTe based solar cells as they consist of earth-abundant and non-toxic elements. However, the CZTSSe solar cells still show low power conversion efficiency (PCE) compared to CIGS solar cells because of their high V_{oc} deficit. In this study, Cd and Ge co doped CZTSSe thin film solar cells were investigated. Cd and Ge cations were doped to CZTSSe absorber as a dopant. Ge layer was deposited on Mo coated SLG substrate and the thickness was varied from 5 nm to 15 nm by evaporation, Cd elements was added on Cu-Zn-Sn alloyed precursor by solution method. All annealed samples showed large grain size and few pin holes when double cations were added. Especially, when the thickness of Ge layer was 5 nm, the depletion width of device were significantly increased, and also CZTSSe solar cells showed the highest efficiency of 10.80%.

Key words : CZTSSe, Kesterite, Cd, Ge, doping

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Effect of cation substitution on device performance of $Cu_2ZnSn(S,Se)_4$ thin film solar cells

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Abstract :

The developments in kesterites encouraged the researcher to use $Cu_2ZnSn(S,Se)_4$ (CZTSSe) based photo absorber materials in diverse optoelectronic applications. However, the detrimental bulk and interface defects induced high carrier recombinations at corresponding regions stagnated further improvement in the device performance of kesterite solar cells. The present work demonstrates a facile Silver (Ag) and Germanium (Ge) incorporation approach to cure these defects. The Ag incorporation mainly reduced the interface defect states, whilst the Ge incorporation mainly cures the deep-level defect states, suppressing the carrier recombination within the space charge and quasi-neutral regions. As a result, an improved carrier separation process, minority carrier lifetime, and reduced nonradiative carrier recombination losses increased device performance by more than 20%. Finally, the champion device with double cation incorporation of Ag and Ge in the CZTSSe absorber layer delivers enhanced device performance from 9.11 to 11.32 %.

Key words : CZTSSe; kesterite; solar cell; doping; Silver; Germanium

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Synthesize various compositions of organolead halide perovskite nanoparticles using ultrasonic spray

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Abstract : Because of crystalline characteristics of organo lead halide perovskites (OHPs), perovskite can be used as various forms such as single crystal, bulk film, colloidal quantum dots (QDs), and nanoparticles (NPs). OHPs are considered as promising material for next-generation light emitting diodes (LEDs) due to their easy color tunability, high color purity, and high photoluminescence quantum yield (PLQY), but low exciton binding energy of OHP limit its prospects. To overcome this problem, nanoscale perovskite crystals, especially QDs, are being considered as more suitable candidates for LEDs by its higher exciton binding energy. However, high quality perovskite QDs are difficult to synthesize and their size-dependent bandgap difference by quantum confinement effects cause change of emission wavelength and relatively low color purity. We report here the synthesize method of tens of nanometers sized perovskite nanoparticles (PeNPs), which characteristics are not affected by quantum confinement effect, with various halide compositions by a simple, easy, and fast method with using ultrasonic spray. Micro droplets of perovskite precursor solutions from ultrasonic spray form solid PeNPs at the surface of anti-solvent and passivated with various ligand materials. We controlled synthesize methods, temperatures, and ligand materials to control size of NPs. These colloidal solutions emit light with a narrow full width at half maximum (FWHM) value of the visible spectrum and have exciton binding energy between bulk and QDs as shown in Figure 1. These NPs could be applied to optoelectronic devices.

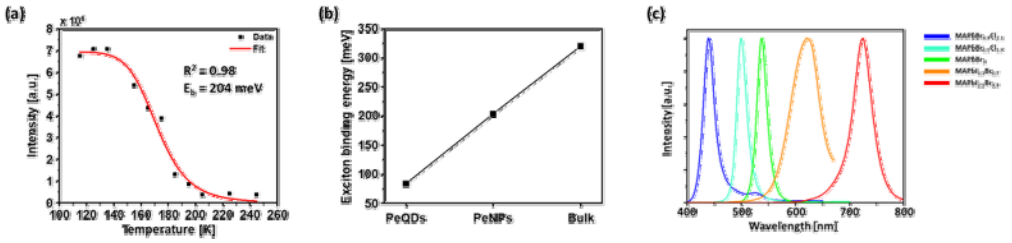


Fig. 1. (a) Temperature dependent PL intensity of PeNPs. (b) Comparison of exciton binding energy between PeQDs, PeNPs, and bulk perovskite. (c) PL spectra of $MAPbX_3$ with various halide compositions.

Key words : Ultra sonic spray(초음파스프레이), organolead halide perovskite(유기납페로브스카이트), perovskite nanoparticles(페로브스카이트 나노입자), perovskite nanocrystals(페로브스카이트 나노결정), mixed-halide perovskites(혼합 할라이드 페로브스카이트), beyond quantum confinement(양자구속을 넘어선), ligand engineering (리간드엔지니어링), exciton binding energy(엑시톤 결합에너지)

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Manipulated Interface for Enhanced Energy Cascade in Quasi-2D Blue Perovskite Light-Emitting Diodes

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Abstract : Quasi-two-dimensional (quasi-2D) perovskites have recently emerged as emitters in blue perovskite light-emitting diodes (PeLEDs). The cascading energy-transfer process between different 2D phases plays an essential role in the high performance of this class of PeLEDs. Herein, we propose an interfacial engineering strategy by incorporating a zwitterionic additive, L-phenylalanine, into the hole-injection layer (HIL), enabling suppression of trap-assisted deactivation channels by virtue of the coordination interactions between the additive and Pb2+ defects in the perovskite phase. In addition, the introduction of L-phenylalanine reduces the release of metallic indium species from indium tin oxide substrates initiated by acidic HILs, resulting in the suppression of luminescence quenching in the perovskite layer. The synergetic benefits create an ideal energy landscape, blocking energy losses and boosting PeLED performance with a peak external quantum efficiency of 10.98% at 480 nm and extended device lifetimes. Our approach provides a versatile strategy to achieve high-performance blue PeLEDs.

Key words : Zwitterion, Hole-injection layer, Energy cascade, Quasi-2D perovskite, Blue electroluminescence

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Ternary Organic Solar Cells Using New Non-Fullerene Acceptors Based on the Y Series Structure

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Keyword : Ternary, alloy like model, OSCs, NFAs, Y-series

Abstract

The present, OSCs (Organic solar cells) are an active field of research due to various advantages. However, OSCs have various problems, and research is being conducted to improve them. First, non-fullerene acceptors (NFAs) were used instead of fullerene acceptors, which were previously used, to compensate for the narrow absorption area and low oxidation stability due to structural problems, which were previously disadvantages. Second, bulk-heterojunction (BHJ) has a narrow absorption region and large energy loss limits, so ternary blends were used to compensate for this. In this study, NFAs and Ternary blends were grafted to compensate for the shortcomings of OSCs. NFAs were synthesized and used as a new material, Y5-BT, by changing the side chains and end groups of Y6 and Y5. PM6:Y6:Y5-BT acts like an alloy-like model, and Y5-BT, which has a high lowest unoccupied molecular orbital(LUMO) level than Y6, improves energy level charge transport. Optimized PM6:Y6:Y5-BT device has open circuit voltage (V_{oc}) = 0.870 V, short circuit current density (J_{sc}) = 26.2 mA/cm^{-2}, fill factor (FF) = 73.6% power conversion efficiency (PCE) = showed 16.9% performance.

Effect of PFI buffer-HIL with PEDOT:PSS for High Efficiency of Perovskite Nanocrystal Light-Emitting Diodes

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Keywords : Perovskite NCs, Energy level matching, Band alignment, Hole injection

Abstract

Poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) is mainly used in perovskite light-emitting diodes (LEDs) with high efficiency. It is the most representative material among highly conductive polymers, and is widely used to make photoelectronic devices due to its excellent electrical conductivity and light transmittance. Despite the advantages of PEDOT:PSS, the electron-blocking characteristics are insufficient, which may interfere with charge balance by allowing electrons. To address this problem, poly(triarylamine) (PTAA) with the high lowest unoccupied molecular orbital (LUMO) level of 1.8 eV was introduced as an hole transport layer (HTL) material between the PEDOT:PSS and the perovskite emission layer. Since the LUMO level of PTAA is 1.8 eV, which creates a large energy barrier with a $CsPbBr_3$ conduction band minimum (CBM) of 3.5 eV, it contributes to trapping electrons in the emission layer and increases radiative recombination, which can improve efficiency. It was thought that if electrons were trapped in the emission layer and hole injection was made smoother, the charge balance in the emission layer would be improved, thereby further improving efficiency. Therefore, in order to reduce the LUMO gap between PEDOT:PSS and PTAA to facilitate hole injection, PFI that can produce a band bending effect was mixed with PEDOT:PSS. The LEDs produced based on this energy level matching effect improved the external quantum efficiency (EQE) by about 2.8 times from 1.07% to 2.81% compared to device with PEDOT:PSS only, current efficiency (CE) by about 2.5 times from 3.74 cd/A to 9.35 cd/A, and luminance by about 11.3 times from 1,745 cd/m^2 to 19,780 cd/m^2.

평면 이종 접합을 이용한 고효율 유무기 하이브리드 태양전지 설계

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Design of the high performance organic-inorganic hybrid solar cell via planar hetero structure

*Min seok Kim, Byeong su Kim, **Jung yong Lee

Key words : Hybrid photovoltaics(하이브리드 광전소자), Hybrid solar cell(하이브리드 태양전지), Polymer(고분자), Quantum dot(양자점), Lead sulfide quantum dot(황화납 양자점), Planar heterojunction(평면 이종 접합), Nanocrystal(나노 결정)

Abstract : The organic solar cell(OSC)s using polymers has attention to the next generation solar cells due to some advantage like solution process, low cost, high absorption spectrum.
Nonetheless, conventional organic solar cells using fullerene derivative reached about 11% power conversion efficiency(PCE) comared inorganic devices, it is fairly low value.
The main factor restricted the efficiency is the significantly low intrinsic carrior mobility of the organic material, and hense form the bulk heterojunction(BHJ) that increase the recombination at the interface. Also the fullerene derivative can`t contrubute the photocurrent due to their weak absorption properties. Accordingly, the concept of the hybrid solar cell(HSC)s is that by using the inorganic nanocrystal(NC) having the high intrinsic carrier mobilities as the acceptor overcome the existing problems and also due to the strong absorption properties, the NCs can contribute the photocurrent. but the PCEs of the HSCs cannot exceed about 6% it is due to the organic-inorganic interface problems like the difference of the polarity. we tried to suitable combination between the polymer and lead sulfide(PbS) quantum dot(QD)s and change the device structure to optimize the device performance. Here we achieved the PCEs of the HSCs about the 8% under AM 1.5 solar illumination. ㅇ

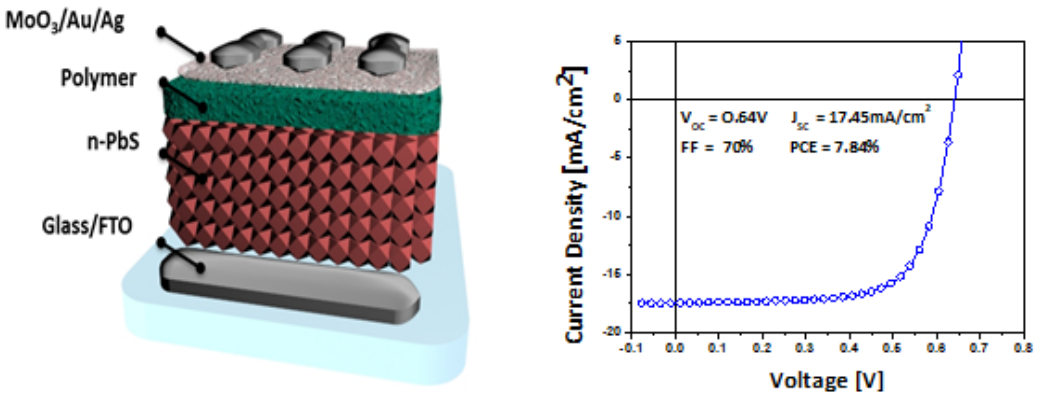


FIG. 1. A schematic illustration of a hybrid photovoltaic device and J-V characteristics of hybrid photovoltaic devices.

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단분자 브릿지 도입을 통한 양자점/유기 하이브리드 태양 전지의 근적외선 흡수 향상

*김 병수[1], 백 세웅[2], **이 정용[3]

Enhanced near-infrared absorption in hybrid colloidal quantum dot/organic solar cells mediated by small molecule bridges

*Byeong-Su Kim, Se-Woong Back, **Jung-Yong Lee

Key words : Quantum dot(양자점), Organic semiconductor (유기 반도체), hybrid solar cell(하이브리드 태양전지), Small molecule(단분자), Near-infrared sensitizer (근적외선 감응체)

Abstract : Solution-processed semiconductors are promising materials to realize optoelectronic devices that combine high performance and inexpensive manufacturing. Among them, The CQD-organic hybrid photovoltaic devices have been drawing attention because the CQD and organic material have complementary absorption. Unfortunately, the CQD-organic hybrids have been limited to power conversion efficiencies (PCEs) below 10% due to the short exciton lifetime in polymer. In this paper, we introduce small-molecules having near-infrared absorption properties as the bridge between CQD and polymer. The small-molecule bridges contribute the formation of additional exciton dissociation sites leading to enhanced charge extraction and additional photocurrent inducing the near-infrared absorption. The resulting hybrid solar cells exhibit an AM1.5 PCE of 13.1%. The devices retain over 80% of their initial PCE following 150 hours of continuous operation at the maximum power point.

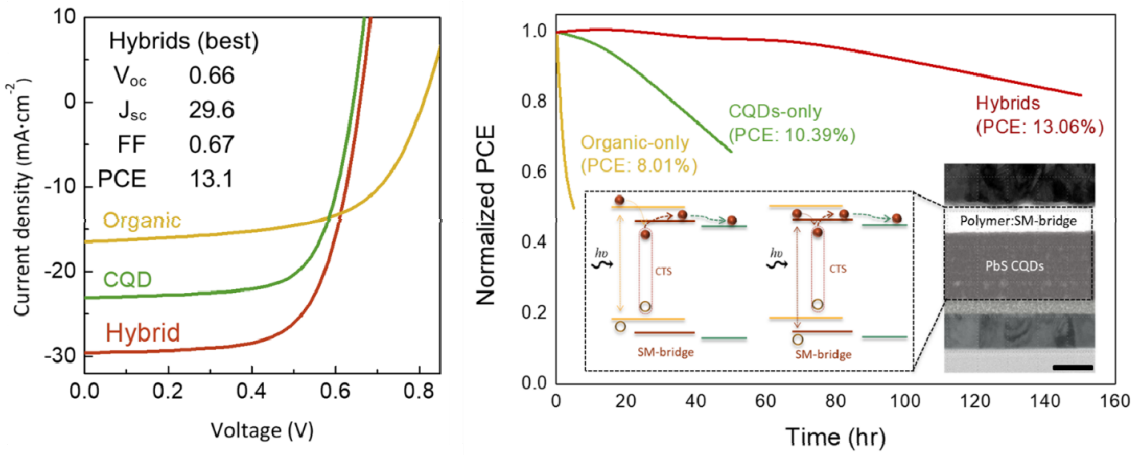


Figure 1. Representative J-V curves and Operating lifetime of organic-only (yellow), CQDs-only (green) and SM-bridge utilized CQD/polymer hybrids (red). All devices were measured in ambient condition without encapsulation.

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Improvments perovskite solar cell with surface passivation by using $SnCl_4$

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Abstract : The last decade has seen a rapid and remarkabel rise in the power conversion efficiency (PCE) of perovskite solar cells (PSCs), accompanied by 25.5%. Recently, electron transport layer (ETL) are widely used as the SnO2 ETL via chemical bath deposition (CBD) to achieve efficient and stable PSCs. CBD has been demonstrated as an amazing electron transporting layer for PSCs over 25%.

Herein, we introduced the ultrathin and compact SnO2 layer derived from SnCl4 at the interface of ETL/perovskite to enhance the electron coupling between layer, passivate the trapping defects and optimize the energy level alignment. AS a result of the increased interface electron collection and reduced interface recombination, PSC with CBD SnO2 post-treated by SnCl4 show the PCE enhancement from 24.7% to 25.8% and the device hysteresis has also been significantly restrained. Moreover, when measuring post-treated solar cells with QSS-IV, surprisingly, we achieved a power conversion efficiency of 25.4%

Key words : perovskite solar cell, CBD, SnCl4

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스핀코팅법을 통한 대면적 페로브스카이트 태양전지 기술개발

김학범[1], 최인우[1], 김민진[1], 최승주[1], 송지원[1], 조임현[1]*

Large-Area Perovskite Solar Cell Fabricated by Spin Coating Process

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Abstract : In recent years, perovskite solar cells have attracted great attention in the field of solar research due to their high efficiency (certificated 25.5%). However, high efficiency has not yet been realized in large-area perovskite solar cells (< 20%). Here in, high efficiency large-area perovskite solar cells are demonstrated by spin coating process high-quality perovskite films. We provides an understanding of the mechanism of formation of perovskite films fabricated by sequential solution-based methods. It compares two sequential spin-coating methods. The first is the "static spin-coating process," and the second is the "dynamic spin-coating process," where the dynamic process drops while the substrate rotates. As a result, mini-module solar cells achieve more than 20% efficiency. the dynamic process in air of perovskite films results in mini-module efficiencies of 21.98% and 20.88% measured at aperture areas of 25 cm^2 and 64 cm^2, respectively. Finally, we achieved 19.18% efficiency in a module with an area of 204 cm^2. We provides a simple way to scale up high-efficiency, perovskite modules for a variety of applications.

Key words : Perovskite(페로브스카이트), Solar Cells(태양전지), Large-Area(대면적), High-Performance(고효율), Spin Casting(스핀 캐스팅)

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용해된 분자의 동적 THz 스타크 효과

강봉주[1)*]

Dynamic THz Stark Effect of Solvated Molecules

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Abstract : For decades, Stark spectroscopy has been an invaluable tool to reveal information about the physicochemical properties of a molecule, specifically its dielectric properties or charge redistribution. Using intense single-cycle terahertz (THz) pulses as the electric field source and monitoring transient spectral responses with a coincident fs-supercontinuum pulse offers advantages over traditional Stark spectroscopy and opens previously inaccessible perspectives. THz pulses, with their picosecond transients, oscillate faster than typical solvent responses and consequently eliminate the requirement to freeze the samples to prevent poling effects. Most importantly, field effects, e.g., non-Markovian behavior (correlations and hysteresis) or higher order Stark contributions, can be time-resolved on the scale of molecular rotations and vibrations. Thus, we can now conduct time-resolved studies at room temperature and at ambient conditions more relevant to physiological or operative conditions. As a first milestone to establish such novel methodology, we measured the THz-field induced spectral signatures associated with changes in dipole moment and polarizability. The results are compared to first principle calculations and traditional Stark spectroscopy.

Key words : Stark effect, Solvated molecule, Intense THz pulse, Time-resolved spectroscopy

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반도체의 초고속 전계 유도 캐리어 생성 역학

강봉주[1)*]

Ultrafast Field-Induced Carrier Generation Dynamics in Semiconductors

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Abstract : In this work, we shed further light on carrier generation at THz frequencies in nanometer size volumes and its dynamics, especially concerning mode switching of two-dimensional nonlinear metamaterials on different semiconductors. Currently, field-induced nonlinear responses of semiconductors and semiconductor-based metamaterials is an important issue in the field of THz photonics, because the phenomenon is relevant for the performance of semiconductor-based high-frequency optoelectronic devices. So far, several studies have reported proof-of-principle experiments and even though the underlying physics was tentatively assigned to specific carrier generation mechanisms, a detailed picture and especially the relevant time scales of mode switching are still under debate. By fabricating two-dimensional metallic metamaterials on different bandgap semiconductors and featuring different degrees of nano-scale electric field enhancement, we are able to identify the relevant carrier generation mechanisms. Moreover, we combine high fidelity simulations with time-resolved nonlinear THz spectroscopy to analyze the dynamics and to establish the time scales of mode switching. We find that mode switching can happen as fast as a few hundred femtoseconds. Our results not only elucidate dominant carrier generation mechanisms and dynamics but also pave the route toward optically driven modulators with THz bandwidth.

Key words : Terahertz nonlinearity, Semiconductors, Carrier Generation, Metamaterials, Ultrafast mode switching

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QPOD-P-11

시간 분해 분광법을 통해 혼합 페로브스카이트 박막의 향상된 광전자 특성 규명

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Elucidating improved optoelectronic properties in mixed perovskite thin films via time-resolved spectroscopy

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Abstract : Recently, the power conversion efficiency (PCE) of perovskite solar cells (PSCs) has been achieved by over 25%. One of the most effective strategies for achieving high-efficiency PSCs is compositional engineering. However, the photo-physics of mixed perovskite thin films and the origin of improved device performance have not yet been fully understood. In particular, the charge carrier dynamics of carrier thermalization and recombination process, and photo-electric properties play a crucial role in the performance of solar cell devices. Therefore, a comprehensive elucidation of charge carrier dynamics and structural disorder is required to further improve the PCE and stability of PSCs. In this work, we reveal the crucial links between structural disorder, charge carrier dynamics, and photo-electric properties of mixed perovskite thin films. Based on structural and morphological analysis, it is found that the disorder of mixed perovskite thin films exhibits a composition dependence in the form of a checkmark. In time-resolved transient absorption spectroscopy, it is demonstrated that charge carrier dynamics and optoelectronic properties exhibit corresponding dependence with the disorder. As the structural disorder of the perovskite thin film decreases, the trap density decreases, the charge carrier loss decreases during the thermalization process, and the carrier lifetime is prolonged. In addition, optical pump-THz probe measurement reveals improved charge transport properties such as effective mobility and diffusion length. Our comprehensive investigation shows the importance of understanding the charge carrier dynamics, and provides novel insight for optimizing the composition of mixed perovskite to further improve the PCE and stability of the PSCs.

Key words : Mixed perovskite thin films, Charge carrier dynamics, Transient absorption spectroscopy, Optical pump-THz probe spectroscopy

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1.5V 이상 고전압 태양전지 제작을 위한 와이드 밴드갭 페로브스카이트 소재의 격자면 최적화

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Optimizing the Lattice Plane of Wide-Bandgap Perovskite Materials for High-Voltage (Over 1.5V) Planar Solar Cells with Enhanced Efficiency and Durability

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Abstract : The passage describes a study on the micro tuning of crystal-lattice in bromide based perovskites by incorporating Cs into the A-site on low temperature processed Formamidinium lead tribromide ($CH(NH_2)_2PbBr_3$ = $FAPbBr_3$) perovskite films. The study aimed to investigate the effect of Cs incorporation on the photovoltaic performance and stability of perovskite solar cells. We found that incorporating 8% Cs into $FAPbBr_3$ (forming $Cs_{0.08}FA_{0.92}PbBr_3$) significantly improved the power conversion efficiency (PCE) of the perovskite solar cell to 8.56%, compared to the PCE of 7.07% for the FAPbBr3 device. The open-circuit voltage (V_{OC}) of the $Cs_{0.08}FA_{0.92}PbBr_3$ device was also higher, at 1.516 V compared to 1.428 V for the $FAPbBr_3$ device. The study also used laser scanning confocal time-resolved microscopy (LCTM) to investigate the photoluminescence-intensity and temporal-imaging of the perovskite films. The results showed that CsBr incorporation into $FAPbBr_3$ significantly reduced non-radiative recombination pathways and homogenized the spatial distribution of photoluminescence. Finally, aging experiments were conducted to assess the stability of the perovskite solar cells under ambient and severe conditions. The $Cs_{0.08}FA_{0.92}PbBr$ devices were found to be more robust than the $FAPbBr_3$ devices, withstanding exposure to air for 2000 h and 65 °C and 65% RH for 500 h. Overall, the study highlights the importance of micro tuning crystal-lattice by Cs incorporation into A-site in bromide based perovskites for improving the performance and stability of perovskite solar cells, particularly for photoelectrochemical water splitting systems and tandem solar cells.

Key words : bromide based perovskite solar cell(Br 기반 페로브스카이트 태양전지), perovskite solar cell(페로브스카이트 태양전지), Wide-Bandgap(와이드 밴드갭), High-Voltage(고전압) $FAPbBr_3$($FAPbBr_3$), $Cs_{0.08}FA_{0.92}PbBr_3$ ($Cs_{0.08}FA_{0.92}PbBr_3$)

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Passivation Strategy for Perovskite film via Schiff Base Reaction for Highly Stable Perovskite Solar Cells

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Abstract : Commercialization of the perovskite solar cell is challenging due to its relatively low stability when compared to other solar cells. To address this issue, it is crucial to improve the stability of the perovskite film itself fundamentally. We enhanced the stability of perovskite films by utilizing the Schiff base reaction. The Schiff base reaction occurs when an aldehyde and amine mixture reacts to form a Schiff base. By reacting benzaldehyde with perovskite cations, in this case, formamidinium and methylammonium, this study reduced the generation of PbI2 with more stable ABX3 crystals and improved the film's stability. Analysis based on XRD, FTIR, UV-vis, PL, and TRPL revealed that the stability of perovskite films is improved without a reduction in efficiency through Schiff base reaction. We achieved an increase in stability such that after 720h, the reference is maintained at 68% of its initial efficiency, while the film treated with Schiff base reaction is maintained at 78~86%.

Key words : Schiff base reaction, Benzaldehyde, Perovskite solar cells, stability

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Suppression of Undesirable Losses in Organometal Halide Perovskite-Based Photoanodes

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Organometal halide perovskites (OHPs) have emerged as promising candidates for high-efficiency photoelectrochemical (PEC) water splitting applications. However, non-radiative recombination of photogenerated carriers and sluggish reaction kinetics of PEC water splitting limit the maximum efficiency of OHP-based photoelectrodes. In this study, we report high-efficiency OHP-based photoanodes with a rational design that effectively suppresses these undesired losses.

Our rational design for OHP-based photoanodes includes defect-passivated electron transport layers (ETLs) that effectively suppress undesired recombination of photogenerated carriers from OHP layers. Additionally, the use of Fe-doped Ni3S2 as a highly catalytic material promotes the reaction kinetics of PEC water oxidation, thereby suppressing undesired losses at the interface between OHP photoanodes and electrolytes.

By suppressing undesired losses, the Fe-doped Ni3S2/Ni foil/OHP photoanodes fabricated in this study exhibit a remarkable applied bias photon-to-current efficiency (ABPE) of 13%, which represents the highest ABPE among OHP-based photoanodes. Our strategies for achieving high-efficiency OHP-based photoanodes provide valuable insight into rational design for OHP-based photoelectrodes.

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TFSI 용액을 이용한 CsPbI3 페로브스카이트 태양전지의 안정성 향상

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Stability improvement of CsPbI3 perovskite solar cell using TFSI solution

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Abstract :

The $CsPbI_3$ perovskite solar cell has a bandgap of 1.65~1.75eV, which is suitable for making a tandem structure with a silicon solar cell. In addition, $CsPbI_3$ was attracting attention as a method to solve the low thermal stability and phase separation occurring in the existing wide bandgap perovskite solar cells. CsPbI3 has significantly improved process temperature, efficiency, and stability with volatile additives. However, the image stability and efficiency were still poor. Studies using additives in precursors to improve stability and efficiency are reported. Although a lot of research has been done on using additives directly in the precursor to improve stability, if additives are used directly, unwanted problems such as the additives not being dissolved any more may occur. In this study, we introduced a method of spraying the TFSI solution in the spin coating process to avoid these unwanted problems. Ba-TFSI added using the spray method reduced the formation of the delta phase and improved the stability enough to maintain 93% for 600 hours. As a result, the efficiency was raised to 18.56%, and a solar cell with stable output of 17.8% was developed.

Key words : Perovskite solar cells(페로브스카이트 태양전지), Ba-TFSI(바륨(II) 비스(트리플루오로메탄술포닐)이미드), Additives(첨가제)

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적외선 하베스팅 양자점 태양전지에서의 광흡수층 두께 조절 연구

장은지[1),2)], 하치[1),2)], 김주경[1),2)], 정소희[1),2)]*

Infrared Harvesting in Colloidal Quantum Dot Photovoltaics with Vairous Active Layer Thickness

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Abstract : Colloidal Quantum Dots (CQDs) have drawn significant attention as emerging infrared (IR) photovoltaic materials due to their unique ability to harvest IR range and capability to be implemented as a thin-film in tandem solar cells. Designing thin-film solar cells based on depleted heterojunction requires specific considerations in both optical and electrical properties that significantly rely on the active layer thickness. In this study, we investigate how the thickness of PbS CQD active layer affects the performance of photovoltaics, particularly in terms of charge-carrier extraction behavior in both optics and electrics. We find that the amount of generated charge carriers depends on the active layer thickness, as the absorptance is affected by the interference effect obtained via transfer matrix calculation. We further investigate the external quantum efficiency under various bias conditions and find the amount of collected charge carriers is limited by the relationship between the depletion width and the actual layer thickness. Therefore, this study suggests the helpful guidelines for the optimization strategy of CQD-based thin-film applications.

Key words : Colloidal Quantum Dot(양자점), Infrared Harvesting(적외선 하베스팅), Photovoltaics(태양전지), Charge-Carrier Extraction(전하 운반자 추출), Active Layer Thickness(광흡수층 두께)

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High Performance and Long-Term Stability of PM6:Y6 based Inverted Organic Photovoltaic Device

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Abstract : It is often reported that high performance organic photovoltaic (OPV) is always fabricated using conventional structure, while the inverted structure OPV (i-OPV) shows a considerably lower power conversion efficiency (PCE). However, the conventional architecture device is known to have poor environmental stability which is an obstacle for commercialization. In this work, we developed the PM6:Y6 based i-OPV with PCE of 17.42% which is comparable to the state-of-the-art conventional structure OPV, by suppressing the interfacial defects using chemical modification of 1.2-ethanedithiol (EDT). Furthermore, the modified i-OPV (mi-OPV) significantly improve the long-term storage and photostability of i-OPV, which showed 90% and 80% retention of the original PCE after 1200h of air storage and illumination, respectively, whereas the pristine i-OPV showed only 51% and 54%. We systematically investigated and resolved the origin of deteriorated PCE and long stability of PM6:Y6 based i-OPV, which caused by deep and shallow traps at the ETL/PM6:Y6 and within the PM6:Y6 active layer. These results are important for the development of OPV from viewpoint of commercialization.

Key words : Organic photovoltaic(유기태양전지), Inverted structure(역구조), Stability(안정성), Defects(결함)

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Rationally Designed Eco-friendly Solvent System for High-performance, Large-area Perovskite Solar Cells and Modules

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One of the key remaining challenges in achieving mass production of perovskite solar modules is developing a large-area fabrication method for high-quality perovskite films using eco-friendly and viable production methods. While progress has been made in this area, the development of an eco-friendly solvent system that can be scaled up remains a challenge.

To address this challenge, we introduce a new eco-friendly solvent/co-solvent system for producing high-quality perovskite films through a process involving bathing in an eco-friendly antisolvent. The co-solvent/additive, methylsulfonylmethane (MSM), is shown to significantly improve overall solubility and provide suitable binding strength to the perovskite precursor, resulting in high-quality perovskite films over large areas.

Perovskite solar cells fabricated using this new method show a high power conversion efficiency of over 24% (in reverse scan) and exhibit good long-term stability under continuous light illumination or damp-heat conditions. Additionally, the MSM-based solvent system is effective for producing perovskite layers at low-temperature or high-humidity conditions.

We further demonstrate the scalability of our method by applying the MSM-based solvent system to large-area fabrication, resulting in highly efficient perovskite solar modules with power conversion efficiencies of 19.9% (by aperture) or 21.2% (by active area) in reverse scan.

Overall, our findings represent a significant step forward in achieving mass production of perovskite solar modules using eco-friendly methods.

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Scalable Fabrication of High-performance Perovskite Solar Modules and their Application to High Power Output Solar Rechargeable Batteries

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Rapid climate change and increasing global power demands require active implementation of transition of traditional power sources to renewable energy sources. Perovskite solar cells (PSCs) have been of great interest due to the inherent superior optoelectronic properties of organometallic halide perovskite itself, such as high absorption coefficient, long carrier diffusion length, ambipolar charge transport and solution-processability. Over 25 % of power conversion efficiency (PCE) has been achieved recently for PSCs via composition engineering, optimization of interlayer, and defect management. Aside from the high PCE, the fabrication of PSCs by scalable process in large-area is prerequisite for the PSCs to fully utilize the aforementioned advantages, so to be applied to self-powered personal mobility and electronics, smart textiles, custom-shaped building-integrated photovoltaics, and so on.

Several successful demonstrations of scalable production of PSCs have been reported. However, successful demonstration of fully scalable production of large-area perovskite solar modules (PSMs) is still lacking. The major hurdles to be jumped are uniform wet-film formation via scalable process in large-area, and complete phase conversion of perovskite precursor to photoactive phase. Therefore, reliable scalable production methods should be established including wet-film formation and phase conversion steps.

In addition, the direct integration of energy generation and storage devices have attracted a lot of interest recently in order to correspond to the fluctuation of power input from the Sun and increasing demand for self-powered electronics. However, inherent mismatch of voltage and current range for charging and discharge from PSCs to Li-based batteries is a major obstacle to realize the direct integration between them. Additionally, power output from PSCs under continuous light illumination, and storage capacity from charging-discharging cycles from Li-ion batteries should be retained.

In this work, we successfully demonstrate high-performance PSMs and solar charging batteries by integrating PSMs and Li-ion batteries in a single substrate. All the layers constituting PSMs can be fabricated via solution shearing coating, with optimized rheological and interfacial properties, at a low temperature (<160℃). An electron transporting layer (ETL) is designed to be uniform and compact in large-area, by systematically investigating the effect of leaving group in sol-gel precursor and applying an optimal tin precursor with organic crosslinkers. As a result, high-efficiency over 23% can be achieved, retaining over 80% relative efficiency compared to initial one after over 1000 h. Complete conversion of perovskite precursor to photoactive phase in a large area can be achieved via careful selection of proper antisolvent and bathing in it. PSMs are carefully designed to have a proper area and

structure to exactly match the charging voltage-current range of high-capacity Li-ion batteries. Consequently, over 20% efficiency of PSMs and over 14% of overall charging to storage efficiency can be achieved. The photo-charging can be repeatedly conducted over 30 cycles because of stable power output and storage of integrated PSMs and Li-ion batteries.

열적으로 안정하고 비할로겐 용매 가공 가능한, 트라이플루오로메틸기가 도입된 비대칭 비풀러렌 수용체 개발과 이 물질 기반 유기태양전지 특성 연구

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Thermally stable and Halogen-Free Solvent Processed Organic Solar Cells Enabled by Trifluoromethyl Functionalized Non-Fullerene Acceptors

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Abstract : For highly efficient organic solar cells (OSCs), it is essential to balance between open-circuit voltage (V_{oc})andshort-circuitcurrent(J_{sc}). The use of halogen-free and high boiling point solvents is also critical for practical fabrication. In this study, we report efficient OSCs based on halogen-free solvent processable non-fullerene acceptors (NFAs) with trifluoromethyl group-introduced asymmetric IPC1CF3-BBO-IC2F and IPC1CF3-BBO-IC2Cl. The IPC1CF3 moiety located at the end group of NFA plays a significant role in lowering highest occupied molecular orbital (HOMO) energy level of NFA, owing to the strong electron-withdrawing power of the trifluoromethyl group. Additionally, the end groups on the other side of IPC1CF3, 2-(5,6-difluoro-3-oxo-2,3-dihydro-1*H*-inden-1-ylidene) malononitrile (IC2F) and 2-(5,6-dichloro-3-oxo-2,3-dihydro-1*H*-inden-1-ylidene)malononitrile (IC2Cl) facilitate the downshift of HOMO energy level. Consequently, the large HOMO-HOMO energy level offset between the polymer donor and NFAs leads to a significant improvement in J_{sc}.On the other hand, the process ability of NFA is improved by extending the side alkyl chain in the pyrrole moiety of NFA to 2-butyloctyl, which is longer than that of 2-ethylhexylin IC2F-BEH-IC2F(Y6). We blended PM6 with NFA using *o*-xylene, one of the halogen-free solvents, to fabricate OSCs. Among them, PM6:IPC1CF3-BBO-IC2F based OSCs showed the highest PCE of 14.70%, which was significantly improved compared to symmetric IPC1CF3-BBO-IPC1CF3-based OSCs (PCE = 5.27%). More importantly, OSCs based on asymmetric NFAs exhibited excellent thermal stability, retaining more than 95% of the initial PCE at 85°C after 2000 hours. These results demonstrate that asymmetric structural modifications of NFAs are an effective approach to improve the photovoltaic performance and stability of OSCs.

Key words : Organic solar cells (유기태양전지), Non-fullerene acceptor (비풀러렌 전자 받개), Asymmetry (비대칭), Halogen-free solvent (비할로겐화 용매), Theraml stability (열 안정성)

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Surface-functionalized self-assembled monolayer for high efficiency single wide-bandgap and monolithic tandem perovskite solar cells

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Abstract : Herein, we report a facile but effective method to functionalize the surface of [2-(9H-carbazol-9-yl) ethyl]phosphonic acid (2PACz) self-assembled monolayers (SAMs), for high-efficiency wide-bandgap perovskite solar cells (PSCs). The 2PACz surface treatment with lewis base solvents improves assembly of 2PACz-SAM and leave residual surface-bound solvent molecules on 2PACz-SAM, which increases perovskite grain size, retards halide segregation, and accelerates hole extraction. The surface functionalization achieves a high power conversion efficiency (PCE) of 17.62% for a single-junction wide-bandgap (~1.77 eV) PSC. Furthermore, a monolithic all-perovskite tandem solar cell, showing high PCE of 24.66% with large open-circuit voltage of 2.008 V and high fill-factor of 81.45% is demonstrated using surface-engineered 2PACz-SAM. Our results suggest this simple approach can further improve the tandem device, when coupled with a high-performance narrow-bandgap sub-cell.

Key words : Perovskite solar cells (페로브스카이트 태양전지), all-perovskite tandem solar cells (전체 페로브스카이트 탠덤 태양전지), wide bandgap (넓은 밴드갭)

QPOD-P-22

Strategy for Reducing Non-radiative Recombination in Dye-sensitized Solar Cell

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Abstract : Dye-sensitized Solar Cell (DSSC) is one of the attractive solar cells due to its eco-friendly and transparent properties. However, commercialization of DSSCs is limited because of its limited power conversion efficiency (PCE) compared to other solar cells. Several researchers developed strategies to increase the short-circuit current density (JSC) and open-circuit voltage (VOC). However, the strategy to increase VOC is scarcely investigated. Since the VOC is mainly affected by recombination, caused by radiative and non-radiative relaxation process, these two processes should be suppressed to enhance VOC. Previous research have focused on reducing the radiative recombination, and research to reduce the non-radiative recombination are less investigated. Herein, this research propose a strategy for decreasing the non-radiative recombination by deuterium substitution for the photosensitizer. The non-radiative recombination is known to be caused by overlapping between the lowest vibrational energy state of the excited state and high-order vibrational energy state of the ground state. The deuterium substitution can decrease the vibrational energy state due to presence of heavy atoms and hence, we anticipate that the deuterium substitution can effectively decrease the non-radiative recombination by decreasing the overlap of the two vibrational energy states. We expect this work contribute to molecular strategy understanding isotope effect on recombination process.

Key words : Dye-sensitized Solar Cell (DSSC), deuterium substitution, vibrational energy, Non-radiative recombination

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확산을 통해 캐리어 이동성이 향상된 고효율 납 셀렌화물 콜로이드 양자점 태양 전지

임채연[1)2)]송정훈[3)*], 정소희[1)2)*]

High-efficiency Lead Selenide Colloidal Quantum Dot Solar Cells with Increased Carrier Mobility through Diffusion

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The efficiency of solution-treated colloidal quantum dot (CQD) thin-film solar cells has recently been greatly improved through surface chemistry treatment and a deeper understanding of bandgap. While lead sulfide (PbS) CQDs have been widely studied to achieve high-efficiency CQD solar cells, their low mobility limits the application of ideal theoretical film thicknesses for sufficient light harvesting. In this study, we developed a CQD thin-film solar cell using PbSe (lead selenide) CQDs with superior electrical and optical properties compared to PbS CQDs, resulting in improved efficiency compared to PbS CQD thin-film solar cells. This was achieved by increasing the thickness of the PbSe CQD layer, which is the active layer, during the device manufacturing process, thereby improving the short-circuit current density. PbSe CQDs are more mobile than PbS CQDs and can better transport carriers in optoelectronic devices. Consequently, the diffusion length of the PbSe CQD film is longer, enabling an increase in the thickness of the PbSe CQD layer. Furthermore, the unstable air stability, which is a fatal disadvantage of PbSe CQD solar cells, was resolved through a solution phase ligand exchange process.

Key words : Colloidal qunatum dots (양자점), Solar cells (태양전지), Lead selenide (납 셀렌화물), Mobility (이동성), Diffusion length (확산길이)

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CPEK segment improving stretchability of PEDOT:PSS as Hole Transport Layer in Organic Solar Cells

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Abstract : Hole Transport Layers (HTLs) are essential layers for connecting electrodes and active layers in Organic Solar Cells (OSCs). The most commonly used material for HTLs is PEDOT:PSS, consisting of conducting PEDOT and insulating PSS.[1] But it has a rigid property because of the high crystallinity. Therefore, we synthesized CPE based CPEK-90 composed of CPE-K and PDCA units.[2] It can improve stretchability of PEDOT:PSS, enabling noncovalent bonding between PEDOT:PSS and PDCA.[3] We mixed PEDOT:PSS and CPEK-90 materials according to the amount of PEDOT:PSS solid content and used them to fabricate OSCs devices. Although CPEK-90 was added 30wt%, the power conviersion efficiency (PCE) recorded 14.77%, which was a decrease within 10% of PEDOT:PSS. And we investigated the stretchability of HTLs measuring sheet resistance. It was confirmed that PEDOT:PSS and CPEK-90 contained 30wt% increased by 333% and 36%, respectively, during 80 cycle nubers at 100% elongation.

Key words : Stretchable organic solar cells (신축성을 갖는 유기태양전지), stretchable hole transport layer (신축성을 갖는 정공수송층), mechanical property of PEDOT:PSS (PEDOT:PSS의 물성)

Reference

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QPOD-P-25

Inverted perovskite photocathode boosting photocurrent of lignin-based bias-free solar hydrogen production

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Abstract : Perovskite solar cells have been growing as the most promising technologies to deliver low-cost, high-performance phovoltaics based on their excellent optoelectronic properties. These perovskite materials have recently emerged as the potential to photoelectrode in a process to produce hydrogen in a renewable manner, which is considered the key technology for moving toward a carbon-neutral and sustainable society. However, applying perovskite photoelectrodes for solar hydrogen production was limited so far due to the large overpotential and sluggish kinetics of the water oxidation process. Here, we present a photoelectrochemical cell with a record high photocurrent density of 19.8mA·cm^{-2} and solar-to-hydrogen(STH) efficiency of 12.3% by utilizing a long alkyl ligand-assisted stable perovskite photocathode and lignocellulosic biomass as an alternative electron source working at lower potentials. The optimized inverted perovskite solar cells with PCE of 20.6% with hydrophobic surface could offer additional stability under the harsh acidic condition, making this perovskite-based hydrogen production system stably operated without noticeable performance degradation for 20 h. Our proposed strategy provides insight into the design of an advanced solar hydrogen prodution system and broader application of perovskite photoactive materials.

Key words : Perovskite(페로브스카이트), Hydrogen-production(수소생산), Biomass(바이오매스), Passivation (패시베이션), Inverted-structure(역구조)

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Thermally stable perovskite solar cells realized by regulating additives of the thermally unstable Spiro-MeOTAD

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Abstract: Thermal stability at (over) 85 °C is important for the industrialization of perovskite solar cells (PSCs) employing the additive-contained Spiro-MeOTAD hole transport layer that is required for high efficiency but is thermally unstable. In this work, we report on effect of additives in Spiro-MeOTAD, normally LITFSI and TBP, on thermal stability of PSCs. Both of TBP and LiTFSI are found to be responsible for morphological failure in both Sprio-MeOTAD film and perovskite surface. It is found that the absence of tBP after forming the solid Spiro-MeOTAD film is problematic in thermal stability. We have developed an effective way to get rid of the residual TBP in the Spiro-MeOTAD film, where ca. 97% of TBP is removed as confirmed by GC-MS. By the proposed method, a thermally stable PSCs with maintaining ~90% of its initial performance after 1000 hours at 85℃ is realized.

Key Words: Perovskite Solar Cell, 85 degree C, Spiro-MeOTAD, Thermal Stability, LiTFSI, TBP.

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페로브스카이트 첨가제 및 조성비 조절을 통한 반투명 페로브스카이트 태양전지 성능 개선

문수지[1)*], 전남중[1)], 김범수[1)**]**

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페로브스카이트 태양전지(PSCs)는 결정질 실리콘 태양전지의 최고 효율에 근접하는 25.7%의 높은 효율을 나타내고 있으며, 이론상 한계효율에 다다르고 있다. 페로브스카이트의 밴드갭 조절이 용이한 장점을 이용하여, 실리콘/페로브스카이트 탠덤 태양전지를 통해 보다 높은 고효율 태양전지를 구현하기 위한 시도가 활발하게 이루어지고 있다. 탠덤 태양전지에 활용되는 페로브스카이트는 와이드 밴드갭을 가져야하고, 대량생산을 위해 불활성 기체 분위기가 아닌 공기 중에서 안정적인 성능 및 재현성을 보여야한다. 이를 위해 페로브스카이트 조성비 및 첨가제를 공기중에서 조절하여, 결함을 최소화하였으며, 기존 조건대비 V_{OC}의 향상을 확인하였다. 또한, 최종적으로 실리콘/페로브스카이트 탠덤 태양전지 구현에 필요한 반투명 소자 효율을 17% 이상 달성하였다.

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Polymer Electrode with High Stretchability and Conductivity Based PEDOT:PSS

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Abstract : Recently, the field of stretchable electronics is growing for their future applications such as wearable devices and artificial electronic skin. Because of their stretchability, high electrical and mechanical property, and solution processability, stretchable conducting polymer is one of the promising candidates to substitute the conventional fragile electrode. Among various conducting polymers, Poly(3,4-ethylenedioxythiophene):poly (styrenesulfonate) (PEDOT:PSS) is reported as the highest conductivity material including high stretchability. Based on these outstanding properties, many attempted approaches have been reported to improve conductivity and stretchability of PEDOT:PSS. For example, adding polar organic solvent, such as dimethylsulfoxide (DMSO) and ethylene glycol, is proposed to improve conductivity of PEDOT:PSS and ionic additives is adopted to assist stretchability of PEDOT:PSS. Herein, we propose an optimum combination of PEDOT:PSS, polar organic solvent, and ionic additives, which shows both highly stretchable and high conductive film property. As testifying materials, we selected DMSO for polar solvent and 1-Ethyl-3-methylimidazolium ethyl sulfate (EMIM ES), 1-Butyl-3-methylimidazolium octyl sulfate (EMIM OS), and 1-Ethyl-3-methylimidazolium tricyanomethanide (EMIM TCM) for ionic additives. Lastly, we fabricated organic solar cells with the proposed stretchable conductive polymer electrode and evaluated their optoelectrical performance.

Key words : Electrode(전극), Stretchability(신축성), Conductivity(전도성), Polar Organic Solvent(극성 유기 용매), Ionic Additives(이온 첨가제), Indoor Organic Photovoltaic Cells(실내 유기 광전지)

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Phase-Pure Quasi-2D Perovskite by Protonation of Neutral Amine

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Phase control of low-dimensional metal-halide perovskites (LDPs) greatly affects their optoelectronic properties, and phase-pure LDPs are desirable to achieve efficient perovskite optoelectronic devices such as solar cells and light-emitting diodes. Herein, we introduce a method to obtain phase-pure LDP by using a neutral amine, cyclohexylmethyl amine (CHMA). The incorporation of CHMA into a formamidinium lead bromide ($FAPbBr_3$) precursor solution leads to the protonation of the amine that allows the phase transition of 3D $FAPbBr_3$ to phase-pure quasi-2D perovskite (n = 2). For comparison, cyclohexylmethylammonium bromide (CHMABr), which is a conventional form of ammonium halide salt with the same organic moiety to the amine, is used, which resulted in a 2D perovskite (n = 1). The perovskite films fabricated by the two different methodologies are characterized. This study paves the way for further research on the realization of phase-pure perovskites and their relevant optoelectronic devices.

QPOD-P-30

Crystal growth control of perovskite via urea additives in vacuum-processed perovskite solar cells

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Abstract : In order to form a perovskite thin film of good quality, it is necessary to control crystal growth. The slower the crystal growth, the better-quality thin films can be obtained. This leads to an improvement in photovoltaic parameters in PSCs. In the solution process PSC (S-PSC), crystal growth is controlled by adding Lewis base such as DMSO. In this study, the crystal growth was controlled by co-evaporation of the precursors (PbI2, MAI) and urea, which is Lewis base in vacuum processed PSC (w/o urea: V-PSC, w/ urea: V-PSC-PU). After co evaporation, vacuum annealing process was performed to remove urea, and after that, it was confirmed by Scanning Electron Microscope (SEM) and Atomic Force Microscope (AFM) analysis that the perovskite grain size increased, and it was confirmed by X-ray Photoelectron Spectroscopy (XPS) that urea affected crystal growth. When the charge mobility characteristics were confirmed by measuring the TRMC analysis, the charge recombination decreased after the introduction of the urea additive. V-PSC-PU improved the open voltage (Voc) by 8.5% and the power conversion efficiency (PCE) by 7.8% compared to V-PSC. This result shows that the number of grain boundaries decreases as the grain size larges in perovskite thin film, resulting in a decrease in charge recombination.

Key words : vacuum-processed PSC, crystal growth control, Lewis base

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Non-fullerene acceptor based organic photovoltaics with thermal stability: Sequential deposition and use of quasi-orthogonal solvents

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Abstract : The development of organic photovoltaic (OPV) devices based on non-fullerene acceptors (NFAs) has led to a rapid improvement in their efficiency. However, there are still problems in terms of stability, including burn-in, which degrades stability in the initial stage. In this study, a highly stable NFA-based OPV fabricated using sequential deposition (SqD) and a quasi-orthogonal solvent is demonstrated. The quasi-orthogonal solvent is prepared by adding a small amount of 1-chloronatphtalene (1-CN) to dichloromethane (DCM). The NFA Y6 (one of efficient NFAs) is then dissolved in the quasi-orthogonal solvent and sequentially deposited on a PM6 polymer-donor layer without destroying that layer. The incorporation of 1-CN reduces the vapor pressure of the quasi-orthogonal solvent and allows Y6 to penetrate the amorphous PM6 domain to form an efficient bulk heterojunction (BHJ). The BHJ prepared using the quasi-orthogonal solvent and SqD contains more crystalline PM6 domains compared to that prepared using conventional single-step deposition (SD). The SqD-processed OPV had a PCE of 14.1%, with a PCE reduction of only 21% after thermal annealing at 80℃ for 115 h, whereas the SD-processed OPV demonstrated a reduction of 32-36% under the same conditions.

Key words : Organic photovoltaic, Sequential deposition, Non-fullerene acceptor

Self-assembled monolayer passivated on NiOx hole transport layer for p-i-n perovskite solar cells

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Abstract : Nickel oxide (NiOx) thin films were prepared on transparent conducting oxide (TCO) glass using sol-gel and nanoparticle methods. The spin-coated NiOx films were annealed at 150 °C ~ 450 °C for 30 min in an air condition. The effects of the annealing temperature on the structural and optical properties of the NiOx films were measured by x-ray diffraction, field emission scanning electron microscopy, and ultraviolet-visible spectrophotometer. In addition, electrical properties of NiOx/Perovskite, such as defect density and hole mobility, were analyzed using space-charge-limited current method in electron transport measurement. After optimizing the NiOx coating conditions, p-i-n inverted perovskite devices were fabricated to evaluate the solar cell characteristics. The NiOx thin film annealed at 350°C showed the best structural and electrical properties of the film itself, and also presented the highest efficiency when used as a hole transport layer of a p-i-n inverted perovskite solar cells. In addition, the self-assembled monolayer (SAM) material was coated on the NiOx thin films in order to improve the surface passivation. As a result, an efficiency of 19.5% was obtained in the SAM passivated on the NiOx samples.

Key words : Inverted perovskite solar cells(역구조 페로브스카이트 태양전지), Hole transport layer(정공 전달층), Spin coating(스핀 코팅), Self-assembled monolayer(자기 조립 단분자막)

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전극 형성용 Plasma Assisted Vapor Deposition(PAVD) 기술 페로브스카이트 태양전지 적용 가능성 연구

김기성[1)2)], 정경아[2)], 신재관[1)], 이강일[2)], 최용섭[2)], 양정엽[1)*]

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Abstract : 현재 인구 증가에 따른 기후변화와 탄소 중립이 화두가 되면서 전 세계적으로 에너지에 대한 관심이 높아지고 있다. 그중에서도 태양전지는 무한한 태양광 에너지를 이용하여 전기를 친환경적으로 생산하는 핵심 신재생 에너지 기술이다. 차세대 페로브스카이트 태양전지는 간단하고 낮은 온도의 공정으로 경제적인 태양전지로 관심을 받고 있다. 페로브스카이트 태양전지 구조는 Glass/투명전극/전자전달층/페로브스카이트 (광 흡수층)/정공전달층/후면전극으로 구성되어있으며 정공전달층으로 Spiro-OMeTAD, PTAA 등의 유기물 소재가 주로 사용된다. 그러므로, 금속 전극의 형성은 일반적으로 산업에서 많이 쓰이는 진공 sputtering 방법을 이용할 경우 유기물 HTL에 plasma damage가 가해지기 때문에 사용이 제한되어 physical vapor deposition (PVD) 방식 중 thermal evaporation 방법으로 공정을 수행하고 있다. 그러나, thermal evaporation 방식 역시 100% damage free한 공정 방식이 아니며, 금속 입자의 퇴적이 고르지 않아 박막의 투명도와 전도성이 떨어지는 단점이 있다. 이를 해결하기 위해 본 연구에서 plasma assisted vapor deposition (PAVD) 진공 증착 방식을 통한 유기물 소재에 damage가 free하고 high quality 저저항 Ag 전극을 형성하여 페로브스카이트 태양전지 소자를 제작하였다. 또한, 이를 통해 형성된 박막의 형태, 구조 및 전기적 특성을 PVD 방식과 비교 분석하였고, 증착 방법과 소자 특성의 상관관계에 대한 연구를 진행하였다. 결과적으로 PAVD 증착 방법을 이용하여 제작한 페로브스카이트 태양전지 소자는 PVD 증착 방법을 이용한 소자보다 태양전지 특성의 전체적인 파라미터가 개선되어 소자 성능이 1% 이상 향상한 것을 확인하였다.

Key words : Perovskite solar cells(페로브스카이트 태양전지), Physical vapor deposition(물리 기상 증착), Plasma assisted vapor deposition(플라즈마 보조 물리 기상 증착), Organic(유기물), damage free(손상 없는)

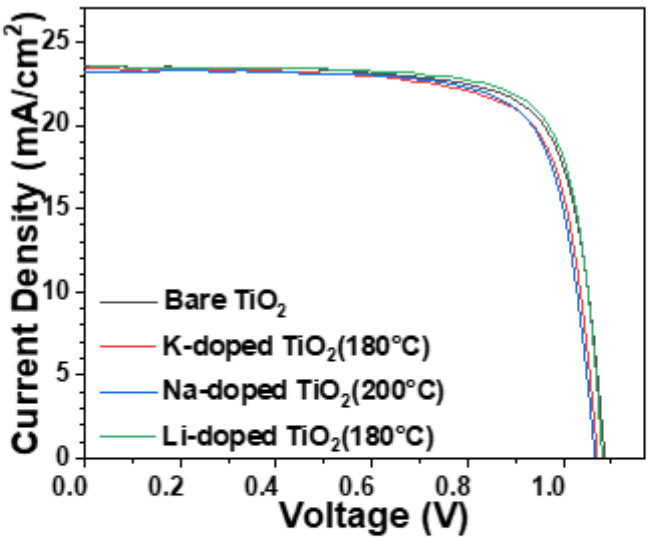
1) 군산대학교 물리학과 차세대 재료 소자 연구실
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Preparation of alkali metal-doped TiO_2 nanoparticles for application to electron transport layer of mesoscopic perovskite solar cells

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For the last decade, perovskite solar cells (PSCs) attracts variety of interests as next-generation solar cell, and TiO_2 is accepted as one of the most popular electron transporting materials. In order to modify surface structure and electron transporting property of TiO_2, alkali metals such as Li, Na, K were doped into the TiO_2 nanoparticles (NPs). Herein, alkali metal-doped TiO_2 NPs with an average size of 45 nm were synthesized by a double-step hydrothermal reaction. Surface structure of the prepared NPs and the doping level of these alkali metals were investigated by X-ray diffraction, electron transmission microscopy (TEM), energy dispersive X-ray spectroscopy (EDX), X-ray photoelectron spectroscopy (XPS), and others. Prepared various NPs were then applied as electron transport layer of mesoscopic PSCs, and their corresponding photovoltaic (PV) properties were analyzed and compared with respect to the types of alkali metals and the doping concentrations. We found that Li-doped TiO_2 provides relatively higher photovoltaic conversion efficiency (PCE) than bare TiO_2 NP or Na- and K-doped TiO_2 NPs. As a result, the PSCs with Li-doped TiO_2 NPs exhibited the PCE over 20%.



	V_{OC} (V)	J_{SC} (mA/cm^2)	Fill Factor (%)	PCE (%)
Bare TiO_2	1.09	23.54	75.94	19.43
K-doped TiO_2(180˚C)	1.07	23.38	75.45	18.89
Na-doped TiO_2(200˚C)	1.07	23.21	76.32	18.89
Li-doped TiO_2(180˚C)	1.08	23.50	77.88	19.79

공액고분자 전해질을 리간드로 사용한 페로브스카이트 박막 위의 리간드 치환 방식

김나영[1)]*, 하정민[2)], 우한영[3)]**

Ligand exchange method of perovskite nanocrystals in film using Conjugated polyelectrolytes.

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Abstract :

A long aliphatic ligand, such as oleic acid and oleyl amine used in perovskite nanocrystal synthesis, acts as insulator in perovskite LEDs (PeLEDs). Ligand engineering was studied to improve charge transfer and we introduced cationic conjugated polyelectrolytes (CPEs) as a ligand. it can be expected to improve color tuning ability and stability with a hydrophobic conjugated backbone. Therefore, we conduct a solid-state ligand exchange in film due to aggregation in solution-state. We used poly(triphenylamine-co-fluorene) based cationic CPE (TPAFA7-I) for ligand exchange. TPAFA7-I have methyl ammonium group and halide conter ion and used as ligand. After ligand exchange, red shifted peak was confirmed due to using Iodide through photoluminescence (PL) spectroscopy. In addition, poly(fluorene-co-phenylene) based cationic CPE (MP2I) was also used to compare with TPAFA7-I. Detailed optical properties depending on the CPE treatment will be discussed.

Key words : Perovskite nanocrystals(페로브스카이트 나노결정), Conjugated polyelectrolytes(공액고분자 전해질), Ligand exchange(리간드 치환).

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광활성을 σ-홀을 이용한 스마트 윈도우 태양전지

임성준[1], 윤소연[2], 권태혁[3]*

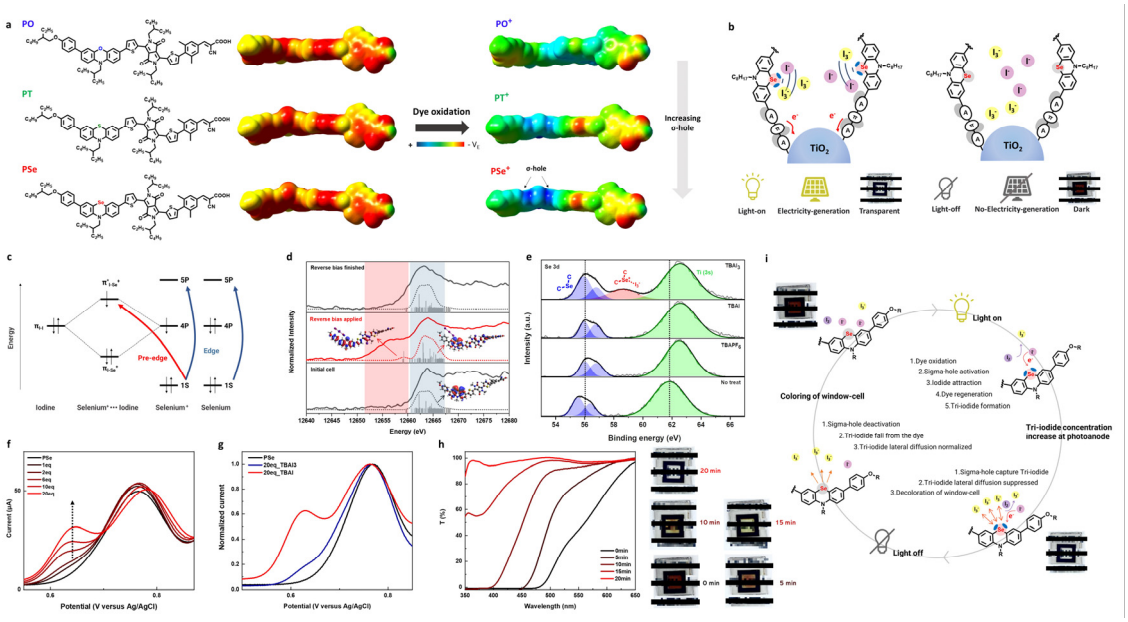
Photoactive σ-hole for smart-window photovoltaics

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Abstract : Herein, we firstly report a photoactive σ-hole, which can modulate its intensity by absorbing the light without any external bias. A homologous series of donor–acceptor–π structure of chalcogen bonding photo absorbers (ChBPAs) were synthesized, differing only in the chalcogen substituents in the donor moiety. Each ChBPAs named PCh (Ch=O, S, and Se) was immobilized on a TiO_2 to demonstrate a photo-switchable on/off σ-hole. ChBPAs are switched on by absorbing light and giving electrons to TiO_2, making the light-induced charge-separated state, $TiO_2(e^-)$/ChBPAs+. Only the photo-oxidized PSe shows the switched-on σ-hole effect because of its high polarizability and selectively attracts I^-/I_3^- electrolytes in organic solution. On the other hand, when the light is off, σ-hole is switched off, and I^-/I_3^- electrolytes no longer interact with selenium atoms. Utilizing this phenomenon, we demonstrated a photovoltaics integrated bias-free smart-window. This first photoactive σ-hole framework based on chalcogen bonds paves the way for new applications of σ-hole in photochemical and material science.

Key words : σ-hole(시그마-홀), Photoactive(광활성), Chalcogen bonding(칼코젠 결합), anion sensing(음이온 센싱)



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라만분광분석을 통한 염료감응형 광전극의 비파괴 깊이 프로파일 분석

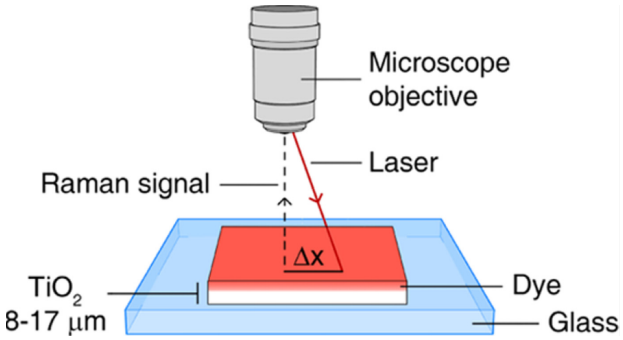
김왕효[1)]*, 윤소연[1)], 권태혁[1)]**

Non-destructive Depth Profile of Dye-sensitized Photoelectrode with Raman Spectroscopy

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Abstract : The homogeneous dye distribution within a dye-sensitized photoelectrode is a crucial feature exhibiting superior performance of dye-sensitized photon-to-electron conversion systems such as dye-sensitized solar cells (DSSCs). The chemical environments including dye distribution of the electrode have been investigated by destructive depth profiling means including cross-sectional sampling, which are inappropriate for understanding the internal systems during operations. Hence, a non-destructive evaluation of molecular changes in the devices is necessary for a non-destructive monitoring the dye depth profile. Herein, we present a conceptual demonstration of the dye depth profile within the dye-sensitized anatase TiO_2 layer of photoelectrode of DSSC using a non-destructive/non-invasive Raman spectroscopy, micro-spatially offset Raman spectroscopy (micro-SORS). The depth profile results of TiO_2 layers dye-sensitized with different sensitization conditions demonstrated that micro-SORS can unequivocally discriminate homogeneity of dye sensitization throughout the TiO_2 layers. TOF-SIMS, a representative destructive depth profiling method, exhibited the consistent result with the micro-SORS results. [1] In addition, the internal molecular behaviors in electrolyte of dye-sensitized photo-rechargeable battery (DSPB) during their charging-discharging operation have been monitored using micro-SORS, successfully evaluating changes in relative amount of redox mediator depending on the states of charge of DSPBs. This is the first demonstration of the micro-SORS in the energy conversion systems excluding modification or disassemble of energy devices.



Key words : Dye (염료), Non-destructive (비파괴), depth (깊이 프로파일), Photoelectrode (광전극)

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Enhancing photovoltaic performance by controlling crystallization kinetics of α-$FAPbI_3$

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Abstract

Formamidinium lead triiodide ($FAPbI_3$) is gaining interest due to many advantages such as high absorption coefficient, and long carrier diffusion length. Although α-$FAPbI_3$ is the most thermodynamically stable photoactive cubic phase, it can kinetically stabilize δ-$FAPbI_3$ in ambient. Many attempts were studied to stabilize the black α-phase, for example, pseudo-halide anion engineering, ionic liquid engineering, and incorporation of additives. Incorporating with methylammonium chloride (MACl) as an additive not only induces the stabilized α-$FAPbI_3$, but also affects the crystallization kinetics of α-$FAPbI_3$. Herein, we examined the crystallization process of MACl, as higher concentration of MACl induces slower crystallization kinetics. Which results in larger grain size and [100] preferred orientation in α-$FAPbI_3$ films as the the MACl concentration increased from 10 to 20, 30, and 40%. Microscopic observations, such as electron back-scattered diffraction (EBSD), confocal photoluminescence (PL), time-resolved photoluminescence (TRPL) mapping, and conductive atomic force microscopy (C-AFM), were conducted to examine the optoelectronic properties of [100] preferentially oriented grains. Reduction in the non-radiative recombination, a longer lifetime of charge carriers and less photocurrent deviation between each grain induce higher short-circuit current density (J_{sc}) and fill factor (FF) in α-$FAPbI_3$ based perovskite solar cells (PSCs) with MACl40%. Resulting the PSCs with MACl40% to attain the highest power conversion efficiency (PCE) of 22.4%. Furthermore, we confirmed these observations by enhancing the grain size and [100] preferred orientation of the MACl10% sample through a two-step heat treatment. As the lower heat treatment induced suppression of nucleation and enhancement of the crystal growth in α-$FAPbI_3$ films with MACl10%. The changes resulted in an improvement in the PCE from 18.4% to 21.8%. This indicates the impact of adding MACl to control the crystallization kinetics resulting in a preferred orientation and a large grain size, which leads to higher PCEs.

Suppressing process-dependent PbI2 residue to enhance stability of efficient perovskite solar cell

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Abstract

Excess PbI_2 has controversial roles in affecting the efficiency of the perovskite solar cells. Although the excess PbI_2 was reported to enlarge grain size and passivate defects, it requires a specific condition such as a very thin layers (~20 nm) on interfaces and/or grain boundaries. Also, with the photo-instability of the PbI_2 accelerating the perovskite degradation, many researchers have studied methods to eliminate or to redistribute PbI_2 to enhance passivation effect. Here, we investigated in revealing the formation of the PbI_2 inclusion among the surface of the perovskite. Due to fast evaporation of the precursor, residual PbI_2 clusters were found within the triple junction grain boundaries. Which is more severe on FA-based perovskite, as the fabrication requires higher temperature (~150 ℃) compared to MA-based perovskite. With this hypothesis, we suggest two strategies: the control of (1) vapor pressure and (2) stoichiometry of precursor solutions to induce sufficient reaction of $FAPbI_3$. Although both strategies successfully eliminated the residual PbI_2, by slowing down the evaporation rate, vapor pressure-control (VPC) films also resulted in larger grain size (~1,179.5 nm) with good film quality to attain the highest power conversion efficiency (PCE) of 24.5%. Which was contributed by lower trap density and suppressed non-recombination. As the insulating property of the PbI_2 which induce low photocurrent, were eliminated in VPC films. Furthermore, with photo-active PbI_2 acting as a degradation site, phase stabilization of the $FAPbI_3$ was improved in the VPC films under both dark and illumination. Considering the certified record PCE with high efficiency (>25%) in recent reports were all with FA-based perovskite, process-dependent PbI_2 residue arise to a major aspect. As $FAPbI_3$ fabrication requires higher temperature treatment compared to $MAPbI_3$. By eliminating the un-wanted extra ~2.8% of PbI_2 upon the perovskite surface, our results may provide a further boost of the device performance along with extended stability in future studies.

The Fabrication of Tin-lead Perovskite Solar Cells via Metal-assistant Precursor Solution Strategy

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Abstract : Due to their tunable bandgap and cost-effectivity, perovskite solar cells are promising photovoltaics. Among them, monolithic all-perovskite tandem solar cells can reduce thermalization loss and transmission loss using two or more light absorption layers. It is possible to overcome the Shockley-Queisser limit of single-junction solar cells. Recent research reported that high-efficiency tandem solar cells have already surpassed the efficiency of 25.7%, the highest efficiency of single-junction solar cells. However, in terms of further improving the performance of monolithic all-perovskite tandem solar cells, there are still challenging issues in the narrow-gap subcell. For example, Sn^{2+}, which is used in the narrow-gap subcell, is easily oxidized, it produces Sn vacancies leading to low efficiency. The Sn vacancies induce an increment of the electron trap density, which results in a reduction of lifetime and diffusion length. In order to produce high-efficiency monolithic all-perovskite tandem solar cells, it should solve the oxidization of Sn^{2+} and secure a high electron diffusion length. In recent studies, various methods are used to inhibit the oxidation of Sn^{2+}. Among them, tin metal is added to a precursor to induce the reduction to secure high-efficiency. Therefore, our method is applied to precursor solution with Sn oxidation-preventing metals. We observed how the method affected to narrow-gap subcell. To be specific, the effect on the thin film and the behavior of the short-circuit are analyzed following the type of metals.

Key words : Monolithic all-perovskite tandem solar cells (페로브스카이트 탠덤 태양전지), electron diffusion length (전자 확산길이)

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효과적인 플렉서블 페로브스카이트 태양전지를 위한 SnO_2-TiO_2 하이브리드 전자 수송층

백민재[1)]*, 김유영[1)], 석상일[1)]**

SnO_2-TiO_2 Hybrid Electron Transport Layer for Efficient and Flexible Perovskite Solar Cells

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Abstract : Inorganic electron transport layers (ETLs), such as titanium dioxide(TiO_2) and tin dioxide (SnO_2), are important in n-i-p structured perovskite solar cells (PSCs). In particular, the ETLs for flexible PSCs (f-PSCs) using a polymer substrate require strong adhesion with a transparent conducting oxide (TCO) and formation of a uniform thin film at a temperature below 150 ^{O}C. Hence, SnO_2 colloidal nanoparticles are primarily used to meet these demands. Nevertheless, there exist further opportunities for improvement in terms of efficiency, uniform coating, and adhesion on TCO. In this study, we prepared a SnO_2-TiO_2 hybrid electrode by adding a certain amount of TiO_2 nanosol, which functions as an inorganic binder, to a SnO_2 colloidal solution. In comparison with the SnO_2 colloid alone, f-PSC fabricated with a SnO_2-TiO_2 hybrid electrode demonstrated not only better mechanical reliability against bending due to strong adhesion to the substrate but also greatly improved efficiency because of improved energy alignment. Eventually, the SnO_2-TiO_2 hybrid electrode resulted in an efficiency of 21.02% and even an efficiency of over 16% in a mini-module (7 X 7 cm^2) due to the uniform coating over a large area. This study provides a new strategy for the ETL of high-efficiency f-PSCs.

Key words :Perovskite solar cells(페로브스카이트 태양전지), electron tranpsort layer(전자 수송층), SnO_2(산화주석), TiO_2(산화티타늄), flexible(플렉서블), Solution process(용액공정)

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금속보호층과 촉매층이 도입된 NIP구조의 페로브스카이트 태양전지를 통한 태양광 물분해

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Solar water splitting improved on Perovskite Photoanode Performance by metal protection and catalyst

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Abstract : 본 발표에서는 태양광 물분해에 적용된 페로브스카이트 태양전지에 대해 보고합니다. 일반적으로 유기 금속 할라이드 페로브스카이트는 수분에 의해 쉽게 분해됩니다. 그래서 물 분해에 적용될 때, 안정성을 향상시키기 위해 상부층을 수분으로부터 보호하는 것이 중요합니다. 이전의 발표된 논문에서 필즈금속(In-Bi-Sn 합금)은 광음극의 보호층으로서 효과적으로 페로브스카이트 태양전지를 수용액에서 보호하는데 사용되었습니다. 위 방법을 이용해 우리는 광양극의 수용액내에서 안정성을 향상 시키기 위해 사용하였습니다. 이를 통해 수용액이 페로브스카이트층을 분해하는것을 방지함과 동시에 생성된 정공이 산소발생 반응(OER)에 참여하도록 안정적으로 이동하는 전극으로 작동함을 확인하였습니다. 추가적으로 전기도금으로 Ni 금속이 필즈금속 상부에 증착되었습니다. 이때 사용되는 Ni 금속은 산소발생반응을 위한 촉매이며 결과적으로, 광전극은 중성 및 알칼리 수용액및 연속 조명(AM1.5G) 하에서 안정성과 성능을 나타냅니다.

Key words : Perovskite solar cell(페로브스카이트 태양전지), Solar water splitting (태양광 물분해), Field's metal (필즈금속), OER(산소발생반응)

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Highly Efficient and Stable Perovskite Solar Cell with 1D-3D Mixed Dimensional Perovskite

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Abstract :

Perovskite solar cells (PSCs) have shown a steep increment in power conversion efficiencies (PCEs) and it is about to be commercialized. However, stability is one of the critical issues that hinders commercialization. Low-dimensional perovskite (0D, 1D, 2D) have been studied widely due to its hydrophobicity compared to 3D perovskite. Not only the enhancement it water stability due to its large organic cation, but the wide bandgap of the low dimensional perovskite can increase open circuit voltage (V_{OC}) by approaching the quasi -fermi level splitting (QFLS) of the perovskite. Although low dimensional perovskite induces higher stability, it has a weakness in the aspect of charge extraction due to its in-plane crystal growth, especially in 2D perovskite. 1D perovskite, on the other hand, grows in out-of-plane direction which rarely hinders charge extraction. In this study, ionic liquid is selected since it can have dual role. Here in, an ionic liquid 1-Ethyl-3-methylimidazolium methane sulfonate (EMIM-$MeSO_3$) is introduced to form 1D-3D mixed dimensional perovskite. 1-Ethyl-3-methylimidazolium cation ($EMIM^+$) forms stable 1D perovskite interacting with PbI_2. In addition, methane sulfonate anion ($MeSO_3^-$) effectively passivate the defect sites on the perovskite surface, owing to the Lewis base characteristic of oxygen. With both benefits from low dimensional perovskite formed by cation, and passivation ability of anion, EMIM-$MeSO_3$ treated PSCs has reached a champion efficiency up to 22.54% and enhance long term stability.

Key words : Perovskite, Solar cell, Low-dimensional perovskite, 1D perovskite, Ionic liquid

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Interfacial Hydrazine Derivatives for High Voltage Tin Lead Alloyed Perovskite Solar Cells

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Abstract : Sn-Pb alloyed perovskite materials capable of regulating optical band-gap in the range of 1.1~1.3 eV are promising candidates not only for high efficiency single junction perovskite solar cells (PSCs) but also for super high efficiency tandem PSCs. However, Sn-contained perovskites are likely to suffer from the loss of open-circuit voltage (V_{oc}) due to oxidation of divalent tin, leading to short carrier lifetime and high trap density. Here, we report high V_{oc} and stable Sn-Pb PSCs via interfacial hydrazine derivatives. Steady-state photoluminescence intensity at 986 nm is enhanced after forming the interlayer, which indicates that non-radiative recombination is decreased. The hydrazine derivative interlayer formed on top of the Sn-Pb perovskite film acts as an electron acceptor to facilitate charge transfer, as confirmed by the time-resolved photoluminescence study. As a result, power conversion efficiency (PCE) is increased from 18.43% to 20.66% after post-treatment with hydrazine derivatives due mainly to the significant improvement of V_{oc} from 0.7551 V to 0.8214 V. Furthermore, the interlayer hydrazine derivative improves stability, where 90% of initial PCE is maintained after 500 hours.

Key words : Sn-Pb alloyed perovskite (납-주석 합금 페로브스카이트), post-treatment (후처리), perovskite solar cell (페로브스카이트 태양전지), hydrazine derivative (하이드라진유도체), high voltage (고전압)

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Unassisted photoelectrochemical water splitting with coupled lead halide perovskite photoelectrodes

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The use of lead halide perovskite (LHP) based photoelectrodes for photoelectrochemical (PEC) water splitting has the potential to significantly increase the efficiency and cost-effectiveness of hydrogen production. The two types of monolithic LHP-based PEC devices for hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) offer a new approach to efficient and unbiased hydrogen production. By integrating the two monolithic LHP-based photoelectrodes, we were able to achieve an impressive solar-to-hydrogen conversion efficiency of 10.64% and photocurrent density of 8.65 mA/cm2. This development offers a promising future prospect for sustainable fuel with boundless opportunities. With the use of cost-effective water splitting catalysts and the integration of LHP-based photoelectrodes, the production of hydrogen as a clean and sustainable energy source could become a more viable option for large-scale energy production.

단일체 페로브스카이트 기반 광전기화학전지를 이용한 9.16% 광-수소 전환 효율 달성

김태균[1]*, 박종혁[1]**

Achieving 9.16% Applied Bias Photon-to-Current Efficiency with monolithic lead halide perovskite photoelectrochemical cell

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Abstract

In spite of lead-halide perovskites (LHP) solar cells can be connected with water electrolysis externally for solar-to-hydrogen, LHP device with a monolithic configuration for photoelectrochemical (PEC) cells is more ideal for economically viable hydrogen production. To this end, the hydrogen evolution reaction (HER)/oxygen evolution reaction (OER) catalyst decoration on the LHP solar cell terminals is a governing factor for high efficiency and stable operation. Herein, we report monolithic PEC cells with double-cation perovskite solar cell (PSC) connected with a robust 3D OER catalyst by conductive carbon powders for minimal ohmic contact loss. The monolithic PEC cell exhibits 0.56 V onset potential and maximum photocurrent density of 24.26 mA/cm^2 at 1.23 V_{RHE} with an 9.16% applied bias photon-to-current efficiency. We further achieved an enhanced stability of 48 hr in pH 14 aqueous solution under simulated solar light (1 Sun). This result will stimulate commercial level application of LHP-based PEC solar to fuel conversion with reasonable efficiency.

Key words: perovskite(페로브스카이트), photoelectrochemical cell(광전기화학전지), water splitting(물분해), oxygen evolution reaction(산소발생반응), conductive carbon powder(전도성 카본)

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High-performance Inverted Perovskite Solar Cells via Vacuum Thermally Evaporated N-type Rylene Diimide Derivatives as Cathode Interlayer

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Abstract :

The performance of inverted perovskite solar cells is significantly influenced by the choice of the cathode interlayer (PeSCs). Vacuum thermal evaporation (VTE), one of several deposition processes, is already utilized in the C_{60} electron transporting layer (ETL) and the bathocuproine (BCP), LiF, and Ca cathode interlayer in inverted PeSCs. Cathode interlayers, in particular, have already been employed to lessen the energy barrier between the ETL and cathode and to minimize interfacial resistance in inverted PeSCs.

In organic and perovskite photovoltaics, N-type rylene diimide derivatives such as perylene diimide (PDI) and naphthalene diimide (NDI) have been used to the cathode interlayer by solution processing such as spin-coating method due to their benefits of simple molecular modification, high electron mobility, and strong thermal and chemical stability.

We demonstrate rylene diimide derivatives, such as the PDI and NDI families of small molecules, as potential cathode interlayer materials in inverted PeSCs using the VTE method. Cathode interlayers made of rylene diimide have a relatively small 5 nm thickness. The underlying rylene diimide materials display various silver cathode development phenomena. By adjusting for the metal cathode's work function and the growth phenomenon by varying the amount of amine-functionalized groups in each material, we also demonstrate the effect as a cathode interlayer.

As a result, the N,N'-Bis[3-(dimethylamino)propyl]perylene-3,4,9,10-tetracarboxylic diimide (PDIN)-based PeSC has a higher power conversion efficiency (PCE) of 21.60% than PeSCs without a cathode interlayer and with an interlayer constructed of NDI-based materials. Furthermore, as compared to control PeSCs without a cathode interlayer, PDIN-based PeSC has better thermal and photo-stability. Based on the findings of this investigation, we anticipate that PDI-based materials can be changed to have superior physical and chemical properties as a cathode interlayer, resulting in larger improvements in the performance and stability of inverted PeSCs.

Key words : Vacuum thermal evaporation, Inverted structure, Cathode interlayer, Perovskite, Solar cell

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Enhancing Reverse Bias Stability of the Planar Perovskite Solar Cells by TiO_2 Hole Blocking Layer

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Perovskite solar cells (PSCs) have gained attention due to their excellent optoelectronic properties, which offer comparable power conversion efficiencies (PCEs) to silicon photovoltaic cells. However, their long-term stability under reverse bias remains a challenge. Reverse bias can cause localized shunts, leading to permanent damage and efficiency loss, especially when PV modules are partially shaded. Strategies such as using high breakdown voltage and carbon electrodes have been developed to address this issue. Additionally, PSCs undergo partially reversible efficiency decay due to accumulated mobile ions, which can be prevented by using TiO_2 hole blocking layer to prevent hole tunneling and local shunts. This study suggests that such strategies can enhance PSC stability under reverse bias, which is crucial for real-life PV operation. The continued development of PSCs with improved stability is important for the commercialization and wider adoption of this promising technology in the renewable energy sector.

Stabilizing α-$FAPbI_3$ at the $FAPbI_3/SnO_{2-x}$ Interface by Reducing Oxygen Vacancies in SnO_{2-x}

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Reducing nonradiative recombination in SnO_{2-x} has been a critical point for fabricating efficient and stable perovskite solar cells (PSCs). Controlling oxygen vacancies in SnO_{2-x} is an efficient strategy, but most research only presents the consequential results without scrutinizing the phenomenological part of the strategy. Here, we deeply examined and revealed a new beneficial effect of controlling oxygen vacancies in SnO_{2-x}. Oxygen atoms of SnO_{2-x} were responsible for retaining α-$FAPbI_3$ at the $FAPbI_3/SnO_{2-x}$ interface by controlling the formation of iodine interstitials, which are strong initiators of unfavorable perovskite phase transitions. Using crystallographic analysis, we observed suppression of these phase transitions when oxygen vacancies were mitigated in SnO_{2-x} by oxidized black phosphorus quantum dots. Furthermore, formamidinium (FA) cation retention was also observed as a beneficial effect of the strategy by introducing hydrogen bonding sources for FA cations at the interface. Our findings suggest the genuine necessity of oxygen vacancy reduction in SnO_{2-x}.

고효율 대면적 유기 태양전지를 위한 고분자 억셉터 개발

진현정[1)]*, 손해정[2)]**

Development of Alloyed Polymer Acceptor for High-Performance Large-Area Ternary Blend Organic Photovoltaics Module

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Abstract : Organic photovoltaic (OPV) research fields are received significant attention due to their attractive features such as solution processability, flexibility, and large-area devices for the next generation solar cell technology. Although significant advances in the photovoltaic performance was reported, most devices were limited to a small size device. To further improve the blend morphology in a large-area process, we designed and synthesized a polymer acceptor, PY-P2, as the third component to form alloyed acceptor domain in the photoactive layer. The polymer acceptor PY-P2 where a biphenyl linker that has high dihedral angles and forms intricate alloy-like composites in acceptor N3 domains. By adding a small amount of PY-P2 into the PM6:N3 system, PY-P2 prevented N3 acceptor aggregation and domain overgrowth during the large-area process, providing an efficient charge generation and transporting pathways. However, stiff polymer chain PY-T2 introduced bithiophene linker could not supply the phenomenon due to the limited solubility and exists separated from the acceptor domain. Therefore, the uniform and optimized active layer exhibited power conversion efficiency of 14.7% for PY-P2-based large-area module. This value was higher than that of a binary blend-based module of 11.9% and a PY-T2-based ternary blend of 11.7%. In this study, we suggested a design strategy of a third component polymer acceptor to optimize the large-area OPV module by ternary blend system.

Key words : Organic photovoltaics(유기태양전지), Large-area modules(대면적 모듈), Bulk-heterojunctions, Alloyed polymer acceptors, High-performances

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역구조 페로브스카이트 태양전지에서 자가조립단층의 알킬 사슬 길이에 따른 페로브스카이트 박막 특성

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Characteristics of Perovskite Thin Films Depending on Alkyl Chain Length of Self-Assembled Monolayers in Inverted Perovskite Solar Cells

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Abstract : 니켈산화물 나노입자는 역구조 페로브스카이트 태양전지에서 안정성, 경제성을 고려했을 때 가장 유망한 정공수송층이지만, 페로브스카이트 전구체와의 높은 반응성으로 인한 낮은 광전변환효율은 해결해야 할 문제로 지적되고 있다. 본 연구에서는 위와 같은 문제를 해결하기 위해 형성된 니켈 산화물 나노입자 박막 위에 서로 다른 알킬 사슬 길이를 가지는 (2-(3,6-Dimethyl-9H-carbazol-9-yl) ethyl)phosphonic acid (Me-2PACz), (4-(3,6-Dimethyl-9H-carbazol-9-yl) ethyl)phosphonic acid (Me-4PACz) 자가조립단층을 형성하였다. 두 SAM 물질은 P-O-M 결합을 기반으로 니켈 산화물 표면에 자가조립단층을 형성한다. 그 결과, 두 물질 모두 자가조립단층으로 인해 니켈산화물과 페로브스카이트 전구체의 직접적인 접촉을 방지함으로써 성능 향상이 있었다. 하지만 Me-4PACz는 긴 알킬 사슬 길이로 인한 낮은 젖음성으로 인해 페로브스카이트 박막과 정공 수송층 사이에 빈 공간이 생기는 등 페로브스카이트와 정공 수송층 계면에서 새로운 문제점이 생겼으나, Me-2PACz의 경우 좋은 젖음성으로 좋은 페로브스카이트 - 정공 수송층 접촉을 얻어 22.4%의 고효율 역구조 페로브스카이트 태양전지를 제작하였다.

Key words : Perovskite(페로브스카이트), Nickel Oxide(니켈산화물), Self-Assembled Monolayer(자가조립단층)

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백금복합체 기반 광하향변환 전략을 통한 페로브스카이트 태양전지의 성능 및 안정성 향상

황은혜[1)]* 및 권태혁[1)]**

Platinum(II) Complex-Based Multifunctional Photon Downshifting Materials Enhancing Performance and Stability of Perovskite Solar Cells

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Abstract : Organic-inorganic hybrid perovskite solar cells (PSCs) have been regarded as one of the most promising photovoltaics owing to the rapid growth of power conversion efficiency (PCE). For their commercialization, however, there are still challenges to achieve long-term operational stability, especially for UV and humidity, while maintaining their high device performance. Herein, to enhance stability as well as photocurrent generation efficiency of PSCs, highly luminescent and water-repellent Pt(II) complexes, **Pt-F** and **PtFM** were developed as multifunctional photon downshifting materials. The corresponding photon downshifting layers (PDLs) were fabricated on glass substrates of PSCs using the ultrasonic spray deposition (USD), which can adjust their crystallinity and photoluminescence quantum efficiency. The improvement of the performance was achieved through the PDL coating owing to the long-range energy transfer. Moreover, the long-term stability of the PDL-coated PSCs was remarkably enhanced under continuous UV irradiation. For high-performance PSCs with photocurrent density higher than 25.0 mA cm^{-2}, it was revealed that **PtFM**-based PDL hardly interferes with their superior PCE owing to its significantly blue-shifted photophysical properties compared to **Pt-F**. In conclusion, the facile and versatile fabrication of Pt(II) complex-based PDLs suggests wide ranging applicability improving the performance and stability of other optoelectronic devices.

Key words : Perovskite solar cells(페로브스카이트 태양전지), Photon downshifting(광하향변환), Platinum complex(백금복합체), Stability(안정성)

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Development of Dye-Sensitized Photo-Rechargeable Flow battery for indoor light harvesting

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Abstract

Recently, with the increase in the use of wireless sensors and Internet-of-things(IoT) systems in daily life, the demand for battery used as power sources is rapidly increasing. However, batteries have to be replaced or recharged by grid electricity after their stored energy gets exhausted. In order to overcome these limitations, batteries that can be recharged using light energy used in daily life are being developed. As a previous study, dye-sensitized photo battery(DSPB) in which a dye-sensitized solar cell and a lithium battery were combined was reported and showed energy conversion efficiency of over 10 % under 1000 lux conditions(dim-light). DSPB is the first monolithic system for low light condition. Nevertheless, its small capacity limits its practical use.

For this reason, we developed an integrated system with flow battery that is useful to increase capacity. For successful operation, we studied the mechanism of photo-charge. Then, for increasing solar to energy efficiency and capacity, we applied solid active materials. As a result, capacity increase 10 times compared to the previous study, and the efficiency achieved about 10 %.

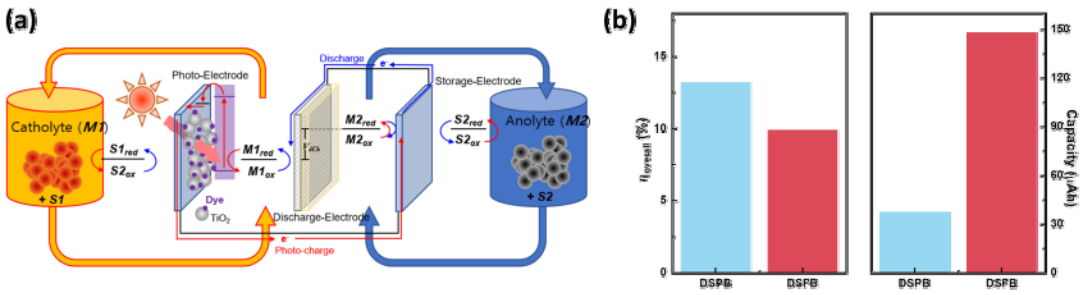


Figure 1 (a) Schematic figure of structure of DSFB (b) The result of overall efficiency and capacity

Key words : Dye-sensitized solar cell (염료감응형 태양전지), Redox flow battery (산화환원흐름전지), Solid-state redox active material (고체활물질), ndoor light harvesting(실내광에너지수확), Integrated system(일체형 구조)

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Ternary Blend Based High Performance Organic Solar Cells Under Indoor Conditions

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Abstract : Artificial light sources such as light-emitting diodes (LEDs) harvesting photovoltaic cells have attracted large attention as an off-grid power source with the development of the Internet of Things (IoTs). Indoor organic photovoltaics (IOPVs) are notable candidate for IoT applications because they have many advantages likewise cost-efficiency and environmental-friendly structure, absorption light tunability, and especially, high photon to charge conversion efficiency at low-intensity light environment. As a result of intensive studies, the power conversion efficiency (PCE) of organic photovoltaic cells have improved considerably (PCE ＞ 30%). To achieve high-efficient IOPVs, controlling trap-assisted recombination and leakage current is highly important due to low current density generated by low incident light intensity. In this work, our ternary blends system showed improved PCE using advantages which are complimentary absorption and low recombination induced by ternary blends. We testified various combination of third component ($PC_{71}BM$, Y7, Y6-derivative, etc) based on PM6:FCC-Cl blend and compared their optoelectrical performance under indoor conditions.

Key words : Indoor Organic Photovoltaics(실내유기태양전지), Ternary Blend Solar Cells(삼원혼합태양전지), Indoor Application(실내응용장치)

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QPOD-P-55

Highly improved photocurrent density and efficiency of perovskite solar cells via inclined fluorine sputtering process

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Abstract : Increase in incident light and surface modification of the charge transport layer are powerful routes to achieve high-performance efficiency of perovskite solar cells (PSCs) by improving the short-circuit current density (J_{SC}) and charge transport characteristics, respectively. However, few techniques have been studied to reduce reflection loss and simultaneously improve the electrical performance of the electron transport layer (ETL). Herein, we propose an inclined fluorine (F) sputtering process to fabricate high-performance PSCs. The proposed process simultaneously implements the antireflection effect of F coating and the effect of F doping on a TiO_2 ETL, which increases the amount of light transmitted into the PSC due to the extremely low refractive index (~1.39) and drastically improves the electrical properties of TiO_2. Consequently, the J_{SC} of the F coating and doping perovskite solar cell (F-PSC) increased from 25.05 to 26.01 mA/cm^2, and the power conversion efficiency increased from 24.17% to 25.30%. The unencapsulated F-PSC exhibits enhanced air stability after 900 h of exposure to ambient environment atmosphere (30% relative humidity, 25 °C under dark condition). The inclined F sputtering process in this study could become a universal method for PSCs from the development stage to commercialization in the future.

Key words : Perovskite solar cells (페로브스카이트 태양전지), Fluorine plasma coating (불소 플라즈마 코팅), Antireflection (반사방지), Electron transport layer doping (전자수송층 도핑)

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페로브스카이트 태양전지의 보관 안정성과 유동이온 확산의 상관관계 해석

최승구[1], 이진욱[1]*

Interpretation on degradation mechanism of perovskite solar cells during ambient storage correlated with mobile ions diffusion

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Abstract : Typical high efficiency perovskite solar cells (PSCs) have incorporated 2,2′,7,7′-Tetrakis(N, N-di-p-methoxyphenyl amine)-9,9′-spirobifluorene (spiro-OMeTAD) as a hole transporting material. However, a chemical doping process of the spiro-OMeTAD involves corrosive tert-butylpyridine, hygroscopic lithium bis(trifluoromethyl sulfonyl)imide, and time-consuming post-oxidation, leading to defect generation, phase conversion, and consequent performance degradation. Here, we report a possible cause of PSC performance degradation even under ambient storage by analyzing the relationship between ion diffusion-induced (de)doping effects and interfacial band alignment. During the dark storage time under a dry atmosphere, n-type doping effect across the device cross section was observed using Kelvin probe force microscope (KPFM), resulting in stagnant photo-generated carriers at charge extraction interfaces. To evaluate the carrier dynamics, charge accumulation capacitance and time resolved photo-luminescence were correlated with the KPFM measurement. This work provides a importance insight towards elucidation of performance degradation mechanism of PSCs.

Key words : perovskite(페로브스카이트), solar cell(태양전지), stability(안정성), de-doping(디도핑), ion diffusion (이온 확산)

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Anti-solvent dripping에 따른 준-2차원 페로브스카이트 상 분포 분석

김가영[1] 이진욱[2]*

The investigation on the quasi-2d perovskite phase distribution with anti-solvent dripping

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Abstract : Typically, the anti-solvent assist spin-coating of perovskite film is widely used to form quasi-2D perovskite thin films. In the quasi-2d perovskite films, the phase distribution is the one of the important key factors that influences carrier dynamics. Consequently, the researchers have tried to control the phase distribution and orientation by the changing precursor solution composition or anti-solvent. However, the mechanism of film formation by the anti-solvent dripping is still vague. Here, we investigate anti-solvent dripping dependent phase distribution of the quasi-2D perovskite film during spin-coating process. We found that the PL peak position is blue-shifted, indicating change in phase distribution of quasi-2d. More interestingly, the phase orientations of the film with and without anti-solvent dripping are found to be opposite. Finally, the phase distribution was correlated with device performance of light emitting diodes.

Key words : Perovskite(페로브스카이트), quasi-2d(준-2차원), phase distribution(상 분포)

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Manipulating Trap Density with Anti-solvents for Perovskite-based Indoor Photovoltaic Devices in Self-Sustaining IoT Systems

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Abstract: Perovskite solar cells have made remarkable progress in a relatively short period of slightly over a decade, primarily due to their high efficiency, low cost, and tunable bandgap. Owing to these remarkable optoelectrical properties, indoor perovskites have attracted significant attention for their potential application in the Internet of Things (IoT) domain. Nevertheless, as indoor photovoltaics rely on weak light intensity from artificial light sources, such as light-emitting diodes (LEDs), they handle significantly lower carrier densities than those utilized in solar energy applications. This significant discrepancy in carrier densities suggests that the concentration of trap states will significantly impact the device's overall efficiency. As a consequence, antisolvent engineering was utilized to investigate trap density manipulation of the perovskite film, utilizing its intermediate phases with DMSO. Through a reduction in trap states using anti-solvent engineering, small-area perovskite solar cells attained an efficiency of over 40% and large-area perovskite with a designated area of 25 cm^2 achieved an efficiency of over 35%.

Key words : Indoor solar cell(실내등 태양전지), Perovskite solar cell(페로브스카이트 태양전지)

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Spiro-OMeTAD 정공수송층의 유기 도펀트 도입을 통한 페로브스카이트 태양전지 안정성 향상

정성광, 이진욱[1)]*

Enhancing stability of perovskite solar cells by introducing a bifunctional organic dopant in spiro-OMeTAD hole transport layer

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Abstract : 2,2′,7,7′-tetrakis(N,N-di-p-methoxyphenyl-amine)9,9′-spirobifluorene (Spiro-OMeTAD) has been commonly used as a hole transport layer for normal-structured perovskite solar cells (PSCs). Lithium bis(trifluoromethane)sulfonimide (LiTFSI) is introduced as a p-type dopant to oxidize spiro-OMeTAD that can lead to improved conductivity along with the better band alignment to enhance hole extraction efficiency. However, the lithium salt accompanies several side-effects such as Li^+ migration and accumulation, hygroscopic nature and formation of by-products, leading to performance and stability degradation of the PSCs. Herein, we suggest tetramethylammonium bis(trifluoromethane)sulfonimide (TMATFSI) as an alternative organic dopant for the LiTFSI. The bulky TMA^+ cation do not migrate toward perovskite layer, and it reacts with perovskite film surface to induce passivation effect. The TMATFSI not only induces passivation of perovskite film surface, but also enhances resistivity of spiro-OMeTAD against harsh environmental conditions such as humidity and high temperature.

Key words : perovskite (페로브스카이트), solar cell (태양전지), hole transport layer (정공수송층), dopant (도펀트), stability (안정성)

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Effective solvent recycling strategy for the eco-friendly perovskite solar cell

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Despite achieving a high photovoltaic efficiency, perovskite solar cells have a significantly shorter lifespan of 1-2 years compared to silicon solar cells with a lifespan of over 25 years, making commercialization difficult. Therefore, several researches have been conducted to recycle perovskite solar cells. However, most current recycling methods use organic solvents that can be harmful to humans and the environment, that can cause many problems during solvent treatment. In this study, we proposes an environmentally friendly and cost-effective solvent recycling method. The effects of residual substances in the recycling solvent were analyzed, and a two-step selective dissolution process was adopted to minimize the effects of these substances. The organic solvent used in the recycling process was effectively recovered and purified for reuse in the production of perovskite solar cells. As a result, the perovskite solar cells with recycled organic solvent showed a high efficiency of 25.12% to that of control perovskite solar cells. These results demonstrate the potential of an environmentally friendly and cost-effective solvent recycling method, indicating the possibility of recycling and commercializing perovskite solar cells.

Key words : perovskite solar cell(페로브스카이트 태양전지), recycling(재활용)

QPOD-P-61

Recovery of Toxic Solvents for Eco-friendly Recycling Strategy of Perovskite Solar Cells

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Abstract :Sustainable recycling technologies of perovskite solar cells (PSCs) at the end of life is inevitable for commercialization, which can reduce the environmental impacts as well as re-fabrication cost. Thus, several efforts have been made to recycle toxic Pb compounds and expensive components in PSCs. However, most recycling strategies included dissolving layers such as perovskite and charge transfer layer by using organic solvents, which can cause harmful effects on environmental, health, and safety. Nevertheless, studies related to these toxic solvents used in recycling processes have not yet been considered. Here, we report the recovery of toxic solvents used in whole PSCs recycling process. The *N,N'*-dimethylformamide (DMF) solvent, used in PSC recycling process, was recovered and purified by using hematite nanoparticles (HT NPs). The high Pb adsorption capacity and a fast equilibrium adsorption kinetics of HT NPs provide the feasibility of Pb management from PSC-dissolved solvent. Furthermore, the recycled PSCs using recovered DMF exhibits a comparable power conversion efficiency to that of control PSC, suggesting a potential of sustainable PSC recycling strategy toward practical PSC commercialization.

Key words : Perovskite solar cells, selective dissolution, solvent recycling, hematite nanoparticle, Pb removal

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Engineering Halide Perovskite-Based Green Photodetectors for Enhanced Responsivity and Detectivity by Composition, Additive, and Process Optimization

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Metal halide perovskites have emerged as highly promising optoelectronic materials for photovoltaics, light-emitting diodes, and photodetectors due to their excellent spectral tunability, superior photoelectric properties, and simple solution-based fabrication processes. In comparison, traditional photodetectors based on Si and III-V compound semiconductors (such as GaN) have demonstrated decent detection ability but require relatively expensive and complex fabrication methodologies, like metal-organic chemical vapor deposition (MOCVD) and molecular-beam epitaxy (MBE), which restrict low-cost and scalable production over a large area. Furthermore, most successful Si-based materials exhibit weak light absorption due to their low absorption coefficient, which limits their acceptable performance at low film thicknesses. Additionally, both amorphous and crystalline Si have a broad light absorption range that spans the entire spectrum, making it challenging to achieve high color discrimination due to parasitic absorption . Halide perovskite materials are being widely used to replace conventional Si in the fabrication of various photodetectors due to their direct bandgap and high absorption coefficient, allowing complete light absorption and narrow light detection with a film thickness of only a few hundred nanometers.

In this study, we investigated the impact of composition and additive engineering (at the A site) on (MA, FA)$Pb(I_{0.3}Br_{0.7})_3$ perovskite absorbers to precisely control the bandgap, defects, and crystallization process. Our focus was on optimizing the MA/FA ratio and subsequent process conditions to promote the formation of a homogeneous and large-grained film. Additionally, we studied the effects of CH_3NH_3Cl (MACl) addition to reduce the dark current and improve phase stability. Finally, we conducted space-charge-limited current (SCLC) measurements to quantify the trap density. Our results demonstrated that optimizing the cationic site composition, annealing conditions, and additive content significantly impact the perovskite film morphology, phase stability, and defect formation, ultimately enabling high-performance green PDs.

To summarize, our study demonstrated the potential of a halide perovskite film of $(FA_{0.7}MA_{0.3})Pb(I_{0.9}Br_{2.1})$ as a promising material for green-light photodetectors with high detectivity and responsivity. We found that controlling the cation composition, adding MACl, and optimizing annealing conditions significantly impacted the perovskite phase evolution, defect density, and optoelectronic properties. Specifically, the annealing conditions played a crucial role in promoting low defect density and large-grained perovskite films by affecting the phase evolution, nucleation, and growth kinetics. As a result, the optimized perovskite-based green PD exhibited superior responsivity (55.24 A/W at 7.17×10^{-7} W/cm), comparable to commercial Si-based photodetectors, providing a sound strategy for future perovskite-based PD commercialization.

비대칭 단분자 어셉터를 이용한 대면적 유기태양전지 개발

이진형[1)]*, 손해정[2)]**

Development of Large Area Organic Solar Cells Using Asymmetric Small Molecule Acceptor

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Abstract : In this poster, we reported two different asymmetric small molecular acceptors (SMAs), called as A1-D-A2 and A1-D-A3, and used as acceptor materials for fabricating high efficiency large area organic solar cells (OSCs). This SMAs consist of a weak electron-donating core (D) with resonance and strong electron-withdrawing groups with high electron affinity (A1, A2 or A3). D group increases crystallinity because D group assists molecular packing though resonance conjugation system compared of the A1, A2 or A3 group. Because of their asymmetric molecular structures, the synthesized A1-D-A2 and A1-D-A3 has stronger exciton dissociation probability than A1-D-A1 by its strong dipole moment, thereby improving charge transfer and transport. We also synthesized a new block co-polymer, named PBDB-T55, to tune the energy level, and used as a donor polymer with the above asymmetric SMAs. Large-area (1 cm^2) inverted OSCs were fabricated by blade coating technique and among three devices, PBDB-T55:A1-D-A2-based OSC demonstrated the best power conversion efficiency (PCE) of 14.1%, which is better than that of PBDB-T55:A1-D-A3-based OSC of 13.1% PBDB-T55:A1-D-A2-based OSC has the improved short-circuit current density and fill factor Because the D unit provide high crystallinity and A2 provide high electron affinity. We also fabricated the PBDB-T55:A1-D-A2-based OSC module, and the module rendered a remarkable PCE of 11.28%, which is the best among the recently reported binary OSC modules with active areas over 50 cm^2. This result demonstrate that asymmetric structure SMAs are an effective way for improving performance and stability of OSCs

Key words : High Power Conversion Efficiency(높은광전환효율), large area photovoltaics(대면적 태양전지), Organic photovoltaics(유기 태양전지)

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Enhanced Reproducibility of Tin-based Perovskite Solar Cells Using 2D Material as a Cathode Interfacial Layer

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Abstract

Perovskite solar cells (PSCs) have attracted attention from many researchers due to the rapid rise of their efficiency to 25.7% in the past decade. However, the high efficiency has been achieved by the lead based perovskites. Alternatives have been sort to replace the toxic lead, and tin is the most promising due to its comparable electronic properties as lead. The performance of tin-perovskite solar cells still stands at 14.8%; this low performance is mostly due to poor reproducibility and poor stability of the tin-based perovskite solar cells. In this study, we show that 2D organic as a cathode interfacial layer can improve the reproducibility of tin-perovskite solar cells. We also employ copper electrode to improve the stability of the devices due to its non-corrosive nature with iodine from the perovskite degradation. Using 2D organic as a cathodic interfacial layer, we were able to fabricate devices with efficiencies above 10% and with good reproducibility.

QPOD-P-65

Improved performance and stability of perovskite solar modules by interface modulating with multifunctional ligand

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Abstract : Perovskite solar cells (PeSCs) using FAPbI3 perovskite films often exhibit unfavorable phase transition and defect-induced non-radiative interfacial recombination, which result in considerable energy loss and impair the performance of PeSCs in terms of efficiency, stability, and hysteresis. In this work, we report a facile interface engineering strategy to control the surface structure and energy-level alignment of the perovskite film by tailoring the interface between the FAPbI3 film and the hole-transporting layer using 4-hydroxypicolinic acid (4HPA). According to density functional theory studies, 4HPA has prominent electron delocalization distribution properties that enable it to anchor to the perovskite film's surface and facilitate charge transfer at the interface. By enabling multiple bonding interactions with the perovskite layer, including hydrogen bonds, Pb-O, and Pb-N dative bonds, the 4HPA passivation has significantly reduced the trap density and efficiently suppressed non-radiative recombination. The obtained perovskite films had superior optoelectronic properties with improved crystallinity, pure α-phase FAPbI3 and favorable energy band bending. Following this strategy, 4HPA post-treatment PeSCs achieved a champion PCE of 23.28% in 0.12 cm2 cells and 19.26% in 36 cm2 modules with excellent environmental and thermal stabilities.

Key words : Perovskite solar cells(페로브스카이트 태양전지), Solar modules(태양광 모듈), Interfacial engineering(계면 공학), Multiple bonds effect(다중결합 효과)

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Atomic Layer Deposition of Vanadium Containing Hole Transport and Passivation Bi-Functional Layer for Highly Efficient and Stable α-$FAPbI_3$ Perovskite Solar Cells (>23%)

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Perovskite Solar Cells (PSCs) have emerged as a promising technology for next-generation photovoltaic devices due to their high power conversion efficiency (PCE, certified >25%), low-cost fabrication, and tunable bandgap. However, one of the main challenges hindering their commercialization is their stability issues. The ionic bonding and low formation energy of perovskite materials, it is an advantage in terms of easy fabrication at relatively low temperature but also acts as disadvantage in stability issue under various environmental conditions, such as moisture, oxygen, and heat. The material′s stability itself is more severe in case of $FAPbI_3$(Formamidinium lead tri-iodide), which has wider absorption spectrum due to lower band gap compared to before mainstream composition $MAPbI_3$(Methylammonium lead tri-iodide). In addition to perovskite material′s inherent properties, organic transporting layers used for Electron/Hole Transporting Layer (ETL and HTL respectively) are also one of the factors that lowers PSCs stability. For example, 2,2',7,7'-tetrakis[N,N-di(4-methoxyphenyl)amino]-9,9'-spirobifluorene (Spiro-OMeTAD, here after Spi) which is mainly used as HTL in *n-i-p* normal structure PSCs suffers from dopant ion diffusion problem and metal ion penetration from electrode even to ETL substrate. Several approaches have been proposed to enhance the stability of perovskite solar cells, including interface engineering with 2D cation, doping, encapsulation, and device architecture optimization. These strategies aim to improve the perovskite material's intrinsic stability, reduce defects and trap states, and extrinsically protect the device from external degradation factors. However, the interfaces or multi-layer stacks can cause unwanted interfacial defects or increasing resistance of devices. Motivated from here, we aim to deposition bi-functional layer with hole transporting and device passivation properties. We adopted Atomic Layer Deposition (ALD) of transition metal oxide at low temperature to not damaging underlying perovskite materials or Spi. The ALD layer of Vanadium Oxide(V_2O_{5-X}) was successfully deposited and hole transporting through the defect energy level was confirmed by Metal-Insulator-Metal ohmic contact and Photoluminescence (PL) spectroscopy. The stability test under ambient, high humidity and heat stress was conducted and enhanced stability of α-$FAPbI_3$/Spi/V_2O_{5-X} was observed. Finally, highly efficient and stable perovskite solar cells with almost pure α-$FAPbI_3$ of PCE over 23% was fabricated and shows enhanced device life time was measured by max power point tracking and dark stored condition.

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QPOD-P-67

Achieving long-time operational perovskite solar cells through multifunctional additive engineering

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Abstract : Fabricating high-quality perovskite films with large grain sizes and low defect densities is critical for developing efficient and stable perovskite solar cells (PeSCs). Herein, we report a simple and effective multifunctional additive engineering strategy for producing high-quality perovskite films. By including 2-hexyl-thiophene (2HT) with a thiophene electron-pair donor and a long hydrophobic alkyl chain as an additive in the perovskite precursor solution, we successfully obtained a perovskite film with high crystallinity, decreased trap density, and hindered ion migration. These features are attributed to the strong coordinative interaction between the sulfur atom in 2HT and Pb2+ in the perovskite film. The long alkyl chain of the 2HT additive assisted the production of a superior perovskite film with enlarged grain size, smooth surface topography, and hydrophobicity. Consequently, improved efficiency and prolonged operational stability are realized simultaneously for an inverted MAPbI3 PeSC with the 2HT additive. The device with 2HT delivers a higher power conversion efficiency of 20.61% compared with that of the control device (18.65%) and exhibits negligible hysteresis. Moreover, the stability of the device with the 2HT additive is superior to that of the control device under various testing conditions.

Key words : Defect passivation(결함 부동태화), Crystallization modulation(결정조정), $MAPbI_3$ Perovskite ($MAPbI_3$ 페로브스카이트)

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근적외선 흡수 스펙트럼을 통한 고성능 페로브스카이트/ 유기 하이브리드 태양전지

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High Performance Perovskite/Organic Hybrid Solar Cells with Extended Absorption Spectra to Near-Infrared

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Abstract : Perovskite solar cells have been drawing attention because of their excellent performance exceeding the efficiency of first-generation crystalline silicon solar cells, light weight and low cost. With the excellent photovoltaic properties including the high absorption coefficient and high carrier mobilities in perovskite, performance of perovskite solar cells has significantly increased from 3.8% to 25.7% within about 10 years. Unfortunately, the performance has almost reached to the Shockley-Queisser limit which the theoretically calculated through the bandgap of the photo-active layer. For exceeding the Shockley-Queisser limit, additional photon absorption should be needed in perovskite solar cells. In this study, we proposed the perovskite/organic hybrid structure having complementary absorption. These perovskite/organic hybrid solar cells allows to extend the absorption from visible to near-infrared by introducing the organic materials having the infrared absorption spectra.

Key words : Perovskite(페로브스카이트), organic bulk heterojunction(유기 벌크 이종접합), hybrid(하이브리드), complementary absorption(보상 흡수), crystallinity(결정성), optical simulation(광 시뮬레이션)

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QPOD-P-69

Impact of passivation of SnO_2 film surface on efficiency and stability of perovskite solar cells

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Abstract : Most of high nefficiency perovskite solar cells (PSCs) have used a SnO_2 thin film as an electron transport layer (ETL) formed by chemical bath deposition (CBD) method. Although SnO_2 has advantage of photocatalytic inactivity due to wide band gap and high electron mobility, surface defects of the SnO_2 films have detrimental effect on both efficiency and stability. In this study, we report on an effective way to reduce the surface hydroxyl defect of the CBD-grown SnO_2 via post-treatement using functional molecule. X-ray photoelectron spectroscopy and X-ray absorption near edge structure studies confirmed the reduction of surface hydroxyl groups. The hydroxyl group was found to act as a defect site because the post-treatment improved the interfacial charge transfer and carrier lifetime of perovskite. As a results, power conversion efficiency (PCE) increased from 21.20% to 23.09% due to the improvement of fill factor (FF) from 75.75% to 80.60% with a slightly increased short-circuit photocurrent density (J_{sc}) and open-circuit voltage (V_{oc}). Furthermore, the stability of the PSCs was significantly enhanced after modification of SnO_2 film with 4-fluorothiophenol, showing that 90% of initial PCE was maintained after 500 hours.

Key words : perovskite solar cell(페로브스카이트 태양전지), SnO_2(산화주석), chemical bath deposition(화학조증착), 4-fluorothiophenol(사플루오르 티오페놀), stability(안정성)

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Pseudo-bilayered inverted organic solar cells using Marangoni effect

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Vertically separated donor and acceptor (pseudo-bilayer; PB) structures in organic solar cell (OSCs) have been suggested as alternatives to the bulk-heterojunction for easier charge extraction and morphological stability. However, sequential solution-coating for the PB structure significantly limits the choices of solvents and materials to prevent the destruction of bottom layers. Herein, we construct a Y7-BO/PM6 bilayer structure using a small-molecule (Y7-BO) as a bottom layer, extremely vulnerable to solvent. The PM6 layer is formed using the Marangoni phenomenon on water and transferred onto the Y7-BO layer. To develop the PB architecture, we add a solvent with low volatility to the PM6 solution and let the additive reside within the bilayer, intermixing the donor/acceptor interfaces. An appropriately small amount of chloronaphthalene optimizes the intermixing and reinforces the face-on molecular orientation. Consequently, a PCE of 17.12% in the OSCs with the inverted PB architecture is achieved, higher than that of the BHJ counterpart.

QPOD-P-71

비금속 프탈로시아닌을 이용한 고효율/고안정성 페로브스카이트 태양전지

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페로브스카이트 태양전지(PSCs)는 단결정 실리콘 태양전지에 가까운 25% 이상의 높은 전력 변환 효율(PCE)을 달성하였다. 그러나 상용화를 위해서는 PSCs의 열 안정성과 정공 수송 물질의 높은 비용이 해결되지 않은 상태로 남아 있다. 우리는 PSCs의 안정성을 개선하기 위해 H_2-Phthalocyanine을 정공 수송 물질로 도입하였다. 또한 H_2-Phthalocyanine의 pyrrolic nitrogen은 페로브스카이트 박막 표면의 배위하지 않은 Pb^{2+} 이온과 반응하여 passivation agent 역할을 하였다. 이 passivation 효과로 인해 metal-Phthalocyanine을 사용한 PSCs와 비교하였을 때 PSCs의 개방 회로 전압(V_{OC})이 향상되었다. 또한, H_2-Phthalocyanine을 사용한 PSCs는 20.1%의 높은 효율과 더불어 85°C/85% RH 고온/습윤 환경에서 1000시간 이상의 높은 안정성을 보였다.

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발광 태양 집광기를 이용한 염료감응형 태양광결합의 전력변환효율 향상

아쇼크 쿠마르 칼리아무르티[1)*], 센틸쿠마르 무투[1)], 파하드 마테인[2)], 강형철[1)], 프란시스 곽우아시암[1)], 류준영[1)], 유기천[1)], 홍성규[2)], 이재준[1)**]

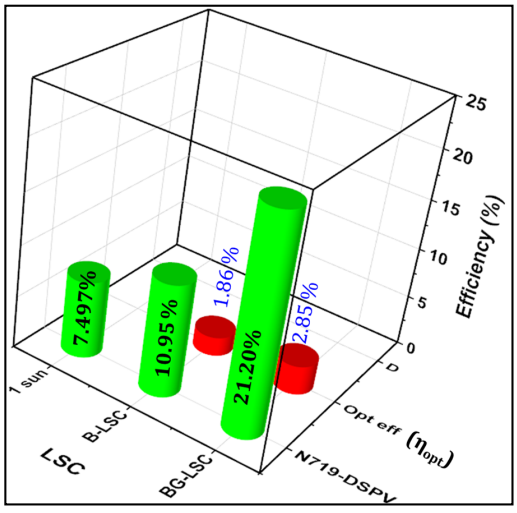
Enhancing the Power Conversion Efficiency of Dye-sensitized Photovoltaics Coupled with Luminescent Solar Concentrator

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Abstract : Luminescent solar concentrator (***LSC***) is the promising technology to generate selective and intense light wave guide with a narrow band energy which could be effectively considered for the photovoltaic (***PV***) application that operates under low intensity conditions. In this study, we characterized a highly efficient ***LSC*** containing a tetraphenylethene (TPE) and tetraphenylpyrazine (TPP) as an organic luminophore material with the emission maximum (λ_{em}) at 473 (*B-* ***LSC***) and 487 nm (*BG-****LSC***), respectively. Based on the spectral matching, the designed ***LSCs*** were integrated with standard dye-sensitized photovoltaics (**DSPV**) fabricated using N719 dye (N719-**DSPV**) and exhibited a very high optical efficiency (η_{opt}) of 1.86 and 2.85%, respectively for *B-****LSC*** and *BG-****LSC***. Considering the edge emission of ***LSC*** as input power, the power conversion efficiency (PCE) of the device N719-**DSPV** integrated with *B-****LSC*** and *BG-****LSC*** was estimated to be 10.95 and 21.20%, respectively which was approximately 1.46 and 2.82-fold higher than the device PCE (7.497%) under 1-sun condition. The present work emphasizes the substantial prospect for the rational design of hybrid ***LSC***-DSPV systems for the viable prospects of future BIPVs.

Key words : Luminescent Solar Concentrator, Dye-sensitized Photovoltaics, LSC-DSPV, and optical efficiency.



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MAPbI3 페로브스카이트 태양전지의 매립 계면을 위한 A-π-D-π-A 구조의 효율적인 다기능 패시바이터

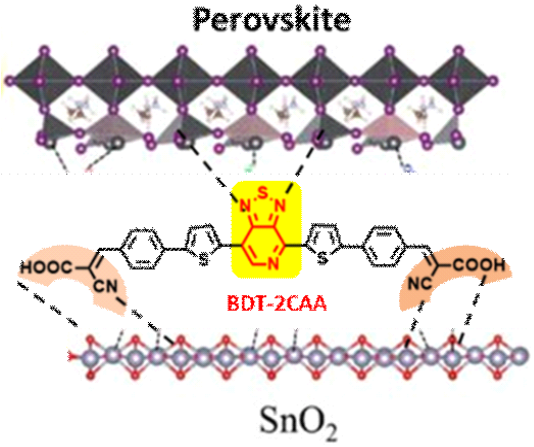
봄바라보니 야다기리[1)*], 산제이 산두[1)], 아쇽 구마 칼라무리트[1)], 이재준[1)**]

An Anchoring Type A-π-D-π-A Structured Efficient Multifunctional Passivator for The Buried Interface in MAPbI3 Perovskite Solar Cells

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Abstract : Most of the methodologies applied for modifying perovskite solar cells (PSCs) focus on either the perovskite active layer or the electron transport layer (ETL). To systematically improve device performance, a dual-functional passivation method that simultaneously passivates trap defects in both the perovskite and ETL films is the most effective approach. Here, we proposed an acceptor-spacer-donor-spacer-acceptor (A-π-D-π-A) denoted as **BDT-2CAA**. The sulfur (S) and nitrogen (N) at BT promote the passivation of Pb^{2+} via Lewis acid-base interactions (Pb-S/O) and reduce trap densities at the grain boundaries, which can dramatically elevate the open-circuit voltage (Voc) of PSCs. The CN and COOH interact with Sn^{4+} and improve electron mobilities exhibiting the best performance and operational stability. The hydrophobic fused rings (BDT, phenyl, and thiophene) increase moisture stability.



Key words : **Passivation** (패시바이터), Buried interface (매립 인터페이스), Perovskite solar cells (페로브스카이트 태양전지)

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평탄한 표면의 고효율 페로브스카이트 태양전지 제작을 위한 고온 반용매 처리법

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Pre-annealing method via heated antisolvent treatment for efficient and surface-uniform perovskite solar cells

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Abstract : Recently, perovskite solar cells have received substantial attention, because of their attractive characteristics such as tunable bandgap, flexible material property, low fabrication cost. In order to improve perovskite film quality, there have been many efforts up to now. Especially, antisolvent treatment during perovskite film formation has been the most widely used method for facile formation of pinhole-free and uniform perovskite film.

In this work, we studied a more effective antisolvent treatment method for much more uniform and pinhole-free perovskite film using heated antisolvent. We observed poor coverage of intermediate phase perovskite film after room-temperature antisolvent treatment. After annealing on a hot plate, the poor coverage induced some pinholes and craters on the final perovskite film. On the other hand, the heated antisolvent treatment was able to help forming full-covered intermediate phase by pre-annealing effect. The full-covered intermediate film easily formed pinhole-free and uniform perovskite film after final annealing. Consequently, power conversion efficiency was enhanced from 15.53% to 16.72%. We further analyzed characteristics of the heated antisolvent treated perovskite solar cells by electrochemical impedance spectroscopy, space-charge-limited current, etc. This method will further improve antisolvent engineering methods, and contribute fabricating much more high quality perovskite films.

Key words : perovskite solar cells, antisolvent engineering, heated antisolvent

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대면적 OSC용 고결정성 레지오레귤러 폴리머 반도체

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High Crystalline RegioregularPolymer Semiconductor for large area OSCs

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Abstract : The study aimed to improve the efficiency of regioregular conjugated polymer by fluorination. A new polymer, PDBD-2FBT, was synthesized by incorporating an additional fluorine atom compared to the base material, difluorobenzo thiadiazol, to address the low VOC problem of PDBD-FBT. The PDBD-2FBT:Y6-HU blend-based device exhibited an increased VOC of 0.79 V, resulting in an photo conversion efficiency of 9.87% due to low JSC and FF values. However, by improving the blend morphology through TA treatment, a higher photo conversion efficiency of 14.14% was achieved, even with a photoactive layer thickness of 400 nm. The heat treatment effect was confirmed through GIWAXS and AFM analysis, and a 3600 mm2 module was fabricated using a bar-coating method, achieving a PCE of approximately 10%.

Key words : regioregualr polymer(레지오레귤러 폴리머), thickness tolerance(두께 공차), large area module (대면적 모듈)

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Improved photovoltaic performance due to the introduction of quinoxaline-based polymeric donors through engineering of non-fullerene backbones for organic solar cells

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Abstract : We demonstrate a simple technique to convert low-energy converting quinoxaline-based polymers into efficient polymer donors for non-fullerene acceptor-based organic solar cells. Alternating copolymers, namely P(BDTSi-DTfQ), incorporating electron-rich 4,8-bis(triisopropylsilylethynyl)-benzo[1,2-b:4,5-′]dithiophene (BDTSi) and electron-deficient 2,3-didodecyl-6-fluoro-5,8-di(thiophen-2-yl)quinoxaline (DTfQ) units were synthesized. We analyzed the properties of P(BDTSi-DTfQ) and compared them with those of a reported polymer composed of BDTSi and 2,3-didodecyl-6,7-difluoro-5,8-di(thiophen-2-yl)quinoxaline(DTffQ) units, namely P(BDTSi-DTffQ). Polymer P(BDTSi-DTfQ) exhibited a lower bandgap (Eg) and higher highest occupied and lowest unoccupied energy levels (HOMO and LUMO) than P(BDTSi-DTffQ). The NFA-OSC made with P(BDTSi-DTfQ) as a donor and one of the NFAs, ITIC, as an acceptor, provided a power conversion efficiency (PCE) of 3.68%. This is significantly higher than the PCE (~0.75) obtained in the case of OSCs prepared using the P(BDTSi-DTffQ):ITIC blend. Noticeably, the energy levels of P(BDTSi-DTfQ) were found to be favorable for efficient charge separation when it was blended with ITIC. This mixture allowed better charge separation at the donor/acceptor interface as well as significantly lowered bimolecular recombination. The overall effect was to provide a higher PCE. However, P(BDTSi-DTffQ) showed mismatched energy levels with ITIC resulting in a higher bimolecular recombination and lower PCE.

Key words : Quinoxaline-based donor(퀴녹살린 기반 공여체), Non-fullerene acceptor(비풀러렌 수용체), organic solar cell(유기태양전지), Backbone engineering(백본 엔지니어링)

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습윤성 차이를 활용한 Sn-Pb 기반 저밴드갭 페로브스카이트 패터닝 및 8 by 8 crossbar array 근적외선 검출기 개발

이상헌[1),]홍윤화[2)], 김창용[1)], 이혜민[1)], 강석범[1)], 임서현[1)], 윤주웅[1)], 허광[2)], 김동회[1)*]

Fabrication of 8 by 8 cross bar array near-infrared radiation(NIR) photodetector with all patterned Sn-Pb based narrow bandgap perovskite via wettability difference

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Abstract :

Perovskite with ABX_3 structure, has various photo-electrical advantagessuch as low-cost solution process, long diffusion distance, great absorption coefficient in all wavelength bands, and tunability of band gap through composition changes. So, it has been actively studied for various photoelectric conversion devices. Especially in the case of narrow bandgap perovskite with tin and lead mixed cations used on the B site of perovskite, light absorption can be expanded up to the near-infrared region, making it possible to manufacture a NIR photodetector which has been considered one of the important sensors nowadays. Consequently, recently, the narrow bandgap perovskite has been considered more and more important in the field of perovskite photodetectors. Another important thing for photodetectors is pixelation. Therefore, the patterning technology of the narrow bandgap perovskite is as necessary as the high-quality perovskite fomation process.

This study introduces the patterning technique of narrow bandgap perovskite which can improve the photo-detection properties via perovskite's property, which can be selectively deposited depending on the difference in wettability of the substrate. As a result, we have succeeded in fabricating the 8 by 8 crossbar array NIR photodetector with all patterned Sn-Pb based narrow bandgap perovskite.

Key words : Photodetector (광 검출기),Near-Infrared radiation (근적외선), Perovskite (페로브스카이트), Narrow bandgap perovskite (저밴드갭 페로브스카이트), Patterning (패터닝), Wettability difference (습윤성 차이)

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$CsPbBr_3$ 페로브스카이트 태양전지 제조를 위한 양이온 교환 전략

박진호[1)]*, 김진영[1)]**

Cation Exchange Strategy for Fabrication of CsPbBr3 Perovskite Solar Cell

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Abstract : All-inorganic $CsPbBr_3$ perovskite solar cell is attracting attention due to its high voltage output and negligible level of stability against humidity and temperature compared to organic-inorganic perovskite solar cells. However, the limited solubility of CsBr remains an obstacle for the production of $CsPbBr_3$ films intended for use in perovskite solar cells. In this study, we present a cation exchange strategy for the synthesis of all-inorganic $CsPbBr_3$ films. By exploiting the high solubility of CsAc (Cesium Acetate) in methanol, we have achieved the conversion of the organic $DMA_{0.3}MA_{0.7}PbBr_3$ film (DMA = Dimethylammonium cation, MA = Methylammonium cation) to an all-inorganic $CsPbBr_3$ film by facile two-step spin coating. Therefore, a high-quality $CsPbBr_3$ film featuring a uniform, flat, sizable grain structure, and minimal secondary phase was successfully produced. The material property of the as made $CsPbBr_3$ film is studied. And its formation mechanism is proposed. Moreover, as an application, a perovskite solar cell is realized using the $CsPbBr_3$ film, demonstrating an efficiency as high as 5.9% with remarkably high V_{oc} (1.4 V).

Key words : $CsPbBr_3$, solubility (용해도), solar cell (태양전지), perovskite (페로브스카이트), two-step method, Cesium acetate.

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혼합 할로겐 페로브스카이트에서의 광유도 할로겐 편석 In-situ 관측

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In-situ Observation of Photo-induced Halide Segregation in Mixed Halide Perovskite

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Abstract :

Mixed-halide perovskites have shown potential as attractive candidates for both single-cell and tandem photovoltaic applications due to their easily adjustable optical properties. However, the separation of phases induced by light still poses a challenge for their use in solar cells. In this study, we conducted measurements at both the bulk and nanoscale to investigate the mechanism behind halide ion migration, which causes the segregation of phases. Through the use of Kelvin probe force microscopy (KPFM) under illumination, we observed the time-dependent movement of ions to and from grain boundaries that matched bulk photoluminescence spectra of lead halide perovskites with a wide range of band gaps (1.67 ~ 1.88 eV). By analyzing changes in band bending at the grain boundaries, we deduce that iodide ions predominantly cause halide segregation, as they migrate more quickly in perovskite materials with a higher iodide content. Moreover, we confirmed that the rate of change in band bending at the grain boundaries is in agreement with the rate of emergence of the I-rich perovskite phase, indicating that the migration of iodide ions towards the grain boundaries influences the transition to an I-rich phase. Our findings may help elucidate the mechanisms underlying light-halide ion segregation and interactions and contribute to the development of more efficient strategies for controlling phase segregation at grain boundaries, thereby enhancing the stability of wide-bandgap perovskites.

Key words : Wide Bandgap Perovskite(고 밴드갭 페로브스카이트), Stability(안전성), In-situ Atomic Probe Force Microscopy(In-situ 원자간력 현미경)

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Self-assembled electron transport layer in polymer solar cells using Indolocarbazole-based conjugated small molecular electrolytes

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Abstract : IIndolocarbazole (Ic) - based conjugated small-molecular electrolytes (CSMEs) with different numbers of amine groups were designed and synthesized. CSMEs are used to form an electron transport layer (ETL) via spontaneous phase separation in bulk-heterojunction (BHJ) solar cells. The self-assembled bilayer with a BHJ active layer on top and a CSME layer on bottom is generated by a single coating step of one solution of CSME and BHJ active layer materials, CSME:PTB7-Th:$PC_{71}BM$. The location of CSME layer is confirmed by time-of-flight secondary ion mass spectroscopy (TOF-SIMS). The CSME layer plays a role as ETL, which reduces the work function (WF) of ITO effectively and leads to high power conversion efficiency (PCE) of the CSME modified PSC. We also use the X-ray photoelectron spectroscopy (XPS) to test the relative intensity of hydrogen bonds between the CSME and ITO. With the increased relative intensity of hydrogen bonds between the CSME and ITO, more effective spontaneous phase separation of the CSME/BHJ bilayer can be formed to generate the CSME layer on top of ITO, and the photovoltaic performance of the PSC enhanced. Out of synthesized series of CSMEs (IcL4N, IcL6N, IcL8N, IcL10N and IcB8N), IcB8N based device shows the highest relative intensity of hydrogen bonding and the highest PCE with a value of 7.09% without using any other ETL materials, which is the highest PCE value without using any other ETL in a separate processing step, in I-PSCs utilizing PTB7-Th/$PC_{71}BM$. This study provides new strategies for the design of ETL molecules that can reduce the number of processing steps required for device fabrication.

Key words : Conjugated small molecular electrolye, electron transport layer, single-step solution processing, spontaneous phase separation, interfacial layers

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전기증착으로 만든 염료감응형 태양전지용 효요적이고 투명한 FeNiCoSe상대전극

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Electrodeposition of FeNiCoSe on fluorine-doped tin oxide as an efficient and transparent counter electrode for dye-sensitized solar cells

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Abstract : Multiple transition metal selenides have recently emerged as excellent dye-sensitized solar cell (DSSC) counter electrode (CE) materials due to their low cost and high catalytic activity. At present, the synthesis of multiple transition metal selenides is mainly done by hydrothermal method. It is important to develop the corresponding DSSC counter electrodes by electrodeposition technology. Herein, we deposited FeNiCoSe quaternary nanomaterials on fluorine-doped tin oxide (FTO) glass by using a potential-reversal electrodeposition technique. The optimal FeNiCoSe loading at 16 cycles was confirmed by adjusting the electrodeposition cycles. Scanning electron microscopy (SEM) showed that the FeNiCoSe nanoparticles were uniformly deposited. Benefiting from the synergistic effect among the elements and the large number of active sites, FeNiCoSe-16 exhibits excellent electrocatalytic activity towards I^-/I_3^- redox couple and has a good transmittance(78.85%). The power conversion efficiency(PCE) of DSSCf abricated with FeNiCoSe-16 CE reached 6.917%, which is higher than that of Pt-based devices(6.517%) and NiCoSe-based devices(5.586%). Compared to conventional platinum counter electrodes, FeNiCoSe counter electrodes deposited by potential-reversal electrodeposition do not require high-temperature treatment, hence a simple fabrication process, which makes them excellent replacements for Pt in DSSCs.

Key words : Counter electrode(상대전극), Dye-sensitized solar cells(염료감응형 태양전지), Electrodeposition(전기 증착), Transition metal selenide(전이금속 셀렌화물), Transparency(투명)

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In-situ intramolecular synthesis of tubular carbon nitride S-scheme homojunctions with exceptional in-plane exciton splitting and mechamism insight

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Abstract : Constructing tubular graphitic carbon nitride homojunctions is an attractive endeavor to accelerate the dissociation of its Frenkel excitons and charge transfer dynamics, but the realization of this strategy remains a major challenge. Herein, carbon nitride homojunction with open tubular interior, porosity and interconnected feature has been developed via one-step pyrolyzing urea and L-cysteine. The experimental results and DFT calculations indicate that such unique tubular S-scheme homojunctions not only apparently boost in-plane exciton dissolution and suppress the inversive charge recombination via built-in electric field, but also decrease Gibbs free energy of intermediate hydrogen absorption. Thus, the tubular carbon nitride homojunctions display an excellent hydrogen production (4548.4μmol/g/h), which is 35-fold improvement than that of pristine carbon nitride, outperforming the most reported donor-acceptor-based carbon nitride homojunctions and tubular carbon nitride.

Key words : Tubular carbon nitride(튜브형 질화탄소), S-scheme homojunction(S 방식 동종접합), Exciton dissolution(엑시톤 용해), Charge transfer pathway(전자 이동 경로), Intermediate hydrogen absorption(중간 수소 흡수)

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기능성 유기 분자의 정공수송층 표면처리를 통한 고효율 저밴드갭 페로브스카이트 태양 전지 개발

안유진[1)]*, 박익재[2)], 김진영[3)]**

Highly Efficient Low Bandgap Perovskite Solar Cells by Surface Treatment of a Hole-transporting layer using Functional Organic Molecules

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Abstract : Organic-inorganic halide perovskite solar cells (PSCs) have been attracting considerable attention as next-generation solar cells due to their excellent photovoltaic properties, cost-effectiveness, and scalable manufacturing capability. The record power conversion efficiency (PCE) of PSCs has recently reached over 25% in single-junction solar cells, which is based on the 1.5-1.6 eV bandgap perovskite absorber. To extend the light absorption region and increase the efficiency, lead-tin mixed low-bandgap perovskite solar cells have been extensively investigated due to their ability to lower the bandgap down to 1.17 eV. Moreover, they can be used in all-perovskite tandem solar cells, which also have the potential to exceed the efficiency limits of single-junction devices.

High-efficiency mixed lead-tin halide perovskite solar cells have mainly used poly(3,4-ethylene dioxythiophene) polystyrene sulfonate (PEDOT:PSS) as the hole transport layer(HTL). However, it is known that their hygroscopic characteristics lead to fast degradation of the perovskite absorber layer and thus adversely affect the long-term stability of the devices.

In this study, we introduce a strategy that passivates interfacial defects using a functional organic molecule by surface treatment of the HTL. This organic species facilitates electron extraction at the HTL and low bandgap perovskite interface, thus improving electrical properties. As a result, the device based on the surface-treated HTL exhibits higher Jsc compared with the control device, and we achieved PCE of over 20%.

Key words : Perovskite Solar Cells(페로브스카이트 태양전지), Hole Transport Layer(정공수송층), Interface Engineering (계면 엔지니어링)

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상분리 억제를 통한 고안정 페로브스카이트/페로브스카이트/실리콘 삼중접합 탠덤 태양전지

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Suppressing Phase Segregation of Mixed-halide Perovskite for Highly Light-Stable Perovskite/Perovskite/Si Multi-junction Tandem Solar Cells

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Abstract : Up to now, organic-inorganic hybrid halide perovskite has received much attention as an absorber material for next-generation photovoltaics because of its excellent optoelectronic properties for solar cells. The power conversion efficiency (PCE) of single-junction perovskite solar cells has achieved 25.7% in a short period. In addition, double-junction tandem solar cells with perovskite materials such as perovskite/Si, perovskite/CIGS, perovskite/perovskite and perovskite/organic have been developed so far. The monolithic perovskite/Si tandem solar cells with double-side textured Si substrate have recorded the highest certified PCE of 32.5% recently. However, realizing efficient and stable perovskite-based triple-junction tandem solar cells remains challenging despite their high theoretical PCE (~49%). One of the most critical issues is the poor stability of perovskite solar cells because wide bandgap perovskite (over 1.9 eV) with mixed-halide composition could be easily segregated to I-rich and Br-rich phases under continuous light illumination condition.

Here, we report a highly durable wide bandgap (1.9 eV) perovskite solar cell. Perovskite absorber containing triple cation (FA/MA/Cs) was prepared by two-step sequential deposition method. We added trimethylolpropane triacrylate (TMPTA) as an additive into the perovskite layer and cross-linked it by annealing process. By photoluminescence and X-ray diffraction analyses, we confirmed that TMPTA additive retarded the phase segregation of the mixed-halide perovskite. We assumed that the additive prevents the ion migration at the grain boundaries, which improves the light stability. As a result, the devices with the additive-added perovskite exhibited outstanding stability under continuous light illumination with negligible PCE drop during 1 hour in ambient condition. Finally, we successfully fabricated solution-processed perovskite/perovskite/Si triple-junction tandem solar cells on one-side textured Si substrates.

Key words : Tandem Solar cells, Light Stability, Halide Segregation, Additive Engineering

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광전자분석을 이용한 HTL 두께에 따라 달라지는 광전하 특성

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Hole Transport Layers Thickness and Light Intensity Dependent Photometric Characteristic Analysis for Efficient Perovskite Solar cells

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Abstract : Many studies are being conducted to improve the efficiency and stability of perovskite solar cells. Among them, photoelectronic analysis is essential to foresee electronic transfer in perovskite films.

The photoluminescence(PL) and time-resolved photoluminescence(TRPL) are representative spectroscopic methods that can observe the time and quantity of electrons excitation from valence band to conduction band. and when they recombination again using the phenomenon that it is emitted in the form of the light.

In recent studies, most measurements were made using one power according to the lab. However, according to our research it can be seen that even the same substrate has different forms of PL and TRPL graphs depending on the different excitation power. Besides, there is an experiment depending on the energy of the light.

As the results, the power conversion efficiency (PCE) gap between the different conditions also different. Therefore, in accordance with this, we want to present a more accurate and reliable result using the appropriate excitation laser power depending on the experimental environment.

We believe that simple and fast spectroscopic measurements can get more accurate and reliable data

Key words : Spectroscopy (분광분석), hole transport layer (정공전달층), electron mobility (전자 이동성), reproducibility (재현성), solar cells (태양전지)

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SCLC 방법을 사용한 하이브리드 페로브스카이트 박막의 전하 이동 양상과 결함 밀도 규명

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Revealing Charge Carrier Mobility and Defect Densities in Hybrid Perovskite Films via Space-Charge-Limited Current Measurements

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Abstract : The Space-charge-limited current (SCLC) characterizations have been employed widely to investigate the trap density and charge-carrier mobility in perovskite solar cells (PSCs). However, its applications among metal halide perovskites are quite complicated because of the electronic and mixed ionic nature of these materials. Herein, we used Pulsed Voltage Space Charge Limited Current (PV-SCLC) method to eliminate the impact of mobile ions and to obtain the accurate electric values. We investigated that hybrid perovskite thin-films with the composition of $Cs_{0.17}FA_{0.83}Pb(I_{0.77}Br_{0.23})_3$, undergoes forward and reverse scans without any hysteresis. Moreover, this study also clarifies that a trap-filled voltage increases linearly as the film thickness increases. Therefore, we believe that PV-SCLC measurements is one of the novel methods for the accurate investigations of the intrinsic transport characteristics of the metal-halide perovskites.

Key words : SCLC (space-charge-limited-current), trap density (트랩 밀도), electrical conductivity (전도도), hysteresis (히스테리시스), charge carrier mobility (전하 이동도)

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QPOD-P-87

첨가물 작용기에 따른 페로브스카이트 광 안정성 향상 및 passivation 특성 분석

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Importance of Functional Group Additives to Improve the Photostability of Highly Efficient Perovskite Layers

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Abstract : Long-term stability, especially the photostability of organic-inorganic perovskite solar cells (PSCs), is the most critical parameter for commercialization. However, continuous irradiation of UV light causes a decrease in PSCs efficiency because of the perovskite degradation and ions escaping from the perovskite. Therefore, in this study, we employ the anti-solvent additive for ions passivation in the grain boundary. The anti-solvent additive method can effectively passivate grain boundary and does not change perovskite composition. As we employed functional groups have lone pair electrons and those electrons can passivate by ionic bonding with Pb^{2+}, I^- and preventing decomposition. Moreover, We have used extensive advanced spectroscopic characterization such as steady-state photoluminescence spectroscopy (SSPL), time-resolved photoluminescence spectroscopy (TRPL), and pulsed voltage space-charge limited current (PV-SCLC) for revealing the mechanism of photostability.

Key words : perovskite solar cells (페로브스카이트 태양전지), anti-solvent additive (안티 솔벤트 첨가물), passivation (패시베이션), photostability (광안정성), spectroscopy (분광학)

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Efficient Monolithic Perovskite/Perovskite/Si Triple Junction Tandem Solar Cells with an Efficiency over 20%

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Abstract :

Halide perovskites (PVSK) are promising materials for absorber in solar cells based on their superior optoelectronic properties, and already 25.7% of certified power conversion efficiency (PCE) was achieved in single-junction solar cells. Especially, because of easy bandgap controllable characteristics, PVSKs are proper to be employed in tandem for overcoming the Shockley–Queisser limit of single junction that already 32.5% of PCE was certified in PVSK/Si tandem. Until now, however, most of studies about PVSK-based tandems are focused on double junction, and so reports about further stacked configuration such as triple junction tandem is hard to find although their higher theoretical maximum PCE. The main obstacle is the inferior properties of wide bandgap (~1.9 eV) PVSK solar cells. Thus, quality improvement of wide bandgap PVSK materials should be addressed for realization of efficient PVSK-based triple tandems.

In this study, we adopted urea, as additive, to enhance the quality of MA-based triple halide PVSK films. From optical analysis with UV-Vis spectroscopy, we observed enhanced stiffness in band-edge region, showing improvement of perovskite crystallinity according to the addition of urea. Consistently, enhanced crystallinity and enlarged grain size of PVSK were confirm by X-ray diffraction (XRD) and scanning electron microscopy (SEM) analysis, respectively. In addition, performances of PVSK solar cells were examined and over 13% of PCE could be obtained with ~1.9 eV PVSK by additive engineering. Finally, we fabricated a Si/PVSK/PVSK triple junction tandem with developed wide bandgap PVSK, and 20.3% of PCE was obtained which is higher than the highest efficiency of Si/PVSK/PVSK tandem reported so far.

Key words : Perovskite(페로브스카이트), Solar Cell(태양전지), Wide bandgap(넓은 밴드갭), Triple junction(삼중접합), Tandem(탠덤)

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닥터블레이드 공정으로 제조된 대면적 유기태양전지 모듈

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Large-Area Organic Solar Cell Modules Fabricated by a Doctor Blade Coating Process

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Abstract : Despite recent breakthroughs in the fabrication of spin-coated small-area devices (≤0.1 cm2) with power conversion efficiencies (PCEs) of more than 17%, printed large-area organic solar cells (OSCs) are significantly less efficient because of the intrinsic differences between the coating dynamics of the two types of OSCs. The PCEs of printed large-area (～100 cm2) OSCs have typically been decreased compared with those of small-area spin-coated devices. In this work, an efficient low-temperature printing method to fabricate high-efficiency large-area nonfullerene-based OSC modules is successfully demonstrated. A systematic study of the relationship between the concentration of the photoactive solution and the resulting film properties reveals that the large-area modules (85 cm2) produced in this work deliver excellent performance, yielding PCEs of up to 8.18% with a geometric fill factor of 85%. These novel OSC modules are ～87% as efficient as smallarea printed single cells (cell PCE ～9.43% with 1 cm2).

Key words : Organic solar cell modules (유기태양전지 모듈), Printing process (인쇄공정),

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$MA_{1-x}GA_xPbI_3$ 페로브스카이트 태양전지의 결정립내 구조 제어 효과

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The Effects on Intragrain Structure Control in the $MA_{1-x}GA_xPbI_3$ Perovskite Solar Cells

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Abstract : Metal halide perovskites are promising photovoltaic materials due to their excellent optoelectronic properties like high absorption coefficient, low exciton binding energy, and long diffusion length, and single-junction solar cells consisting of them have shown a high certified efficiency of 25.7%. Despite rapid improvement, the observation of the intragrain structures which are generally influential in the optoelectronic properties of materials has been challenging due to their weakness on electron beam. In this study, the intragrain domains were observed by using a low-dose transmission electron microscopy technique with a dose rate of ~1 $e^-/Å \cdot s$. we controlled the tetragonality (t) by regulating the Guanidinium (GA) substitutional ratio in $MA_{1-x}GA_xPbI_3$ (x=0-1). We demonstrate that carrier lifetime and perovskite solar cell performance correspond with the presence of $\{112\}_t$ ferroelastic twin domains ($0<x<0.15$) and $\{111\}_c$ ($x>0.20$) stacking faults. The best performance was found when no intragrain defects were obvious. These results suggest that intragrain structures control can propose an essential factor of photovoltaic performance.

Key words : Perovskite solar cells (페로브스카이트 태양전지), Intragrain structure (결정립내 구조), twin domain (쌍정 도메인), stacking fault (적층 결함)

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Air-stable $CsPbI_2Br$ Perovskite Solar Cells Introduction of MACl Additives

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Abstract: Until now, many effective strategies such as compositional engineering, interface engineering, solvent engineering, surface passivation, and thermal gradient annealing method have been introduced to fabricate high-performance $CsPbI_2Br$-based perovskite solar cells (PSCs), resulting in the significant improvement of photovoltaic properties. However, most of the high-performance $CsPbI_2Br$ inorganic PSCs have been using the hole transporting layer (HTL) with hygroscopic additives such as bis(trifluoromethane) sulfonimide lithium salt (Li-TFSI) and 4-tert-butylpyridine (tBP) to enhance hole conductivity of HTL, however, it is not suitable for commercialization of the PSCs due to worse stability. In addition, in terms of commercialization of the PSCs, it is vitally required to fabricate the air-stable $CsPbI_2Br$ PSCs. The bulk defects of $CsPbI_2Br$ such as cation vacancy, anion vacancy, and grain boundary trigger the phase transformation from α-phase $CsPbI_2Br$ to δ-phase $CsPbI_2Br$ in air. Therefore, it is essential to control the crystallization and passivate the trap sites of perovskite film for efficient and air-stable $CsPbI_2Br$-based PSCs without hygroscopic additives, which is suitable for commercialization of the single-junction and tandem solar cells. Herein, we report efficient and air-stable $CsPbI_2Br$ PSCs by introducing methylammonium chloride (MACl) additive. MACl effectively controlled the crystallization of $CsPbI_2Br$ films in air, resulting improved the crystallinity and air stability. The best-performing MACl-incorporated $CsPbI_2Br$ PSCs exhibited the signigicantly improved power conversion efficiency (PCE) of 15.33% compared with the control device. Therefore, the MACl additive plays a crucial role in fabricating the high quality and air-stable $CsPbI_2Br$ film.

Key words : Halide perovskite, Inorganic solar cells, Methylammonium chloride

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금속유기골격체(Metal-organic Frameworks)를 사용한 역구조(p-i-n) 페로브스카이트 태양전지 안정성 향상

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Enhancing the Stability of Inverted Perovskite Solar Cells Using UiO-66 MOFs(Metal-organic Frameworks)

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Abstract : Inverted perovskite solar cells have drawn much attention due to their reduced hysteresis, low-temperature processability, and as a suitable structure for perovskite/silicon tandem solar cells. However, just as conventional perovskite solar cells, their long-term stability remains a major challenge for commercialization, since they are extremely vulnerable to the degradation accelerated by environmental factors such as moisture, air and light. In this study, we explored the use of UiO-66 metal-organic frameworks (MOFs) as a means of improving the stability of the inverted perovskite solar cells. UiO-66 is a Zirconium-based metal-framework with terephthalic acid organic linkers, known for its high chemical stability and absorption of ultraviolet (UV) light, which is harmful to the operation of perovskite solar cells. We found that incorporating UiO-66 interlayer between the hole-transporting layer, poly[bis(2,4,6-trimethylphenyl)amine] (PTAA), and perovskite layer improved the stability of inverted perovskite solar cells, especially against continuous light irradiance. The device achieved the efficiency of 17.8%, which showed a slight increase from 17.6% of the control device, and maintained higher than 98% of the initial efficiency under 1200 seconds of 1 sun irradiance. In addition, we found that the hydrophilic property of UiO-66 improved the wettability of the PTAA surface, which has a hydrophobic nature and is normally incompatible with hydrophilic perovskite layers. This improvemnet in wettability of perovskite on the PTAA surface could have significant implications for large-scale perovskite solar cell fabrication, as it could increase the surface coverage, efficiency, and reproducibility of inverted perovskite solar cells. Our findings suggest that UiO-66 metal-organic frameworks could be a promising strategy for enhancing the stability of inverted perovskite solar cells, making them a more attractive structrue for perovskite/silicon tandem solar cells.

Key words : Perovskite Solar Cells(페로브스카이트 태양전지), Inverted Perovskite Solar cells(역구조 페로브스카이트 태양전지), Stability(안정성), Metal-organic Frameworks(금속유기골격체), Large-scale perovskite solar cells (대면적 페로브스카이트 태양전지)

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Maximizing Photoluminescence Quantum Efficiency of stacked halide layer via combination of bulk and interface engineering

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Abstract : To further approach the theoretical limit of perovskite solar cells (PSCs), it is cucial to analyze and interpret the external photoluminescence quantum efficiency (PLQE) of a light-absorbing halide layer stacked with charge transporting layers (CTLs) rather than solely as a halide layer. Here, we propose the next phase research direction for reaching radiative limit of PCE by maximzing PLQE of the stacked halide layer. We demonstrated that controlling the bottom charge transporting layer (CTL)/perovskite interface is a main factor to maximize PLQE in full device stack. On combining interface and bulk engineering, the FTO/bottom CTL/halide structure and full device stack exhibited an enhanced external photoluminescence quantum efficiency (PLQE) of 40.67% and 15.57%, respectively. As a result, the device combined with the interface and bulk engineering showed an improved reverse-forward average power conversion efficiency (PCE) of 25.64% and certified quasi-steady-state (QSS) efficiency of 25.06%. The certified open-circuit voltage (V_{oc}) of 1.18 V is 94.93% of the radiative limit V_{oc} of 1.243 V, the highest value among certified QSS V_{oc} of PSCs. Moreover, the device maintained 80% of its initial PCE for 500 hours under 10% relative humidity at 85℃ without any encapsulation. This research approach provides a promising direction for reaching the theoretical limit of PSCs by maximizing PLQE.

Key words : PLQE, Interface engineering, Bulk engineering, passivation

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광흡수층 상부 고상 계면 처리를 통한 무기 페로브스카이트 태양전지의 안정성 향상에 관한 연구

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A study on the Stability Improvement of Inorganic perovskite solar cells through solid-state in-plane growth (SIG)

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Abstract : 고효율 페로브스카이트 이중접합 태양전지 소자에 사용되는 와이드 밴드갭 페로브스카이트(~1,8eV) 조성의 경우 밴드갭 증가를 위해 주로 할로겐 이온의 비율을 조절하는 방법을 사용한다. 하지만 이러한 높은 비율에 브로민이 포함된 박막은 빛이 조사되었을 때 이온 이동(ion migration)으로 인한 할라이드 상분리(halide segregation)가 발생한다. 할라이드 상분리 현상으로 인해 와이드밴드갭 페로브스카이트 소자의 개방전압 손실뿐만 아니라 광안정 저하의 문제를 야기한다. 최근에는 대표적인 무기 페로브스카이트 물질인 $CsPbI_3$는 휘발성, 흡습성의 유기물을 포함하지 않아 많은 연구가 진행되고 있다. 특히 $CsPbI_3$는 단일 할로겐 이온을 포함하기 때문에 광유도 할로겐 분리가 일어나지 않는다. 그러나 $CsPbI_3$의 입방상(cubic phase)은 고온에서만 안정하기 때문에 주변 환경에서 안정하지 못하다. 따라서 일반 유·무기물 혼합 페로브스카이트 소재보다 상안정성이 떨어지는 단점을 가지기 때문에 결함 농도, 결정성 향상, 결정화 속조 제어를 위한 조성 제어, 첨가제 도입, 계면처리 등의 상안정성을 높이는 연구가 진행되어야 한다.

본 연구에서는 무기 페로브스카이트 단점인 상안정성을 높이기 위해 표면 및 계면 결함 제어 대한 방법으로 고상 계면 처리 방법을 고찰하였다. 고상 계면 처리는 3D 페로브스카이트 층 위에 2D 페로브스카이트 층을 올려 효율성과 안정성을 개선하는 방법이다. 따라서 무기 페로브스카이트 박막의 입자 성장을 제어하고, 상부 고상 계면 처리를 통해 안정성을 가지는 무기 페로브스카이트 박막 및 효율을 향상하는 연구를 수행하였다.

Key words : 무기 페로브스카이트 태양전지, 고상 계면 처리

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Extraction method of mobile ion density for organic-inorganic halide perovskite solar cells

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Abstract : 할로겐화 납 페로브스카이트의 효율과 안정성이 10년 동안 크게 향상되었다. 이는 페로브스카이트 박막의 트랩 밀도와 계면을 이해하는 다양한 패시베이션 및 표면 처리에 의해 달성되었다. 그러나 페로브스카이트는 할로겐 원소 및 유기분자 이온들이 연속적인 전기장에 의해 주변 캐리어와 섭동을 일으키는 특이한 광전 거동에서 여전히 광전 특성화에 한계가 있다. 암흑 전류 분석은 일반적으로 Space Charge Limited Current(SCLC)의 다양한 적합 공식에 의해 분석된다. 또한, 정전용량-전압(C-V)을 측정함으로써 charge carrier, depletion region, built in potential (Vbi), 나아가 소자 내부의 트랩 밀도를 추출할 수 있다. 그러나, 상술한 측정 방법은 일반적으로 연속 전압 하에서 이온 이동으로 인해 부정확한 측정값을 갖는다. 펄스 전압원 및 페로브스카이트 필름위에 Ag를 증착하여 할로겐 원소의 이동을 제한하고, 비정상 상태인 페로브스카이트 필름 내부를 정상 상태로 변화시켜 측정할 수 있다. $MAPbI_3$의 경우, 연속 측정 중에도 동일한 Vbi를 얻을 수 있다. 저온 C-V의 특성으로부터 도출된 트랩 밀도는 $3.7x10^{16}$ cm^{-3}으로 측정되었다. 이 값은 동일한 펄스 전압에서 SCLC가 측정한 MAPbI3와 동일한 값을 나타냅니다. 여기서, 우리는 페로브스카이트의 비정상적인 광전 거동의 원인인 할로겐 물질의 요오드를 제어하기 위해 펄스 전압을 사용하여 암전류와 정전용량-전압에 대한 정확한 분석 도구를 제공한다.

Key words : Perovskite solar cells(페로브스카이트 태양전지)

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상온 및 25% 습도 조건에서 가스 퀜칭 기법을 이용한 넓은 밴드갭 페로브스카이트 태양전지의 재현 가능한 제조 방법 개발

김성룡[1)*], 우문영[1)], 노준홍[1)2)3)**]

Development of a Reproducible Fabrication Method for Wide Band Gap Perovskite Solar Cells using Gas Quenching Technique under Room Temperature and 25% Humidity Conditions

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Abstract : 페로브스카이트 태양 전지(PSC)는 높은 효율과 낮은 생산 비용으로 인해 차세대 태양광 장치의 유망한 후보로 부상하여 활발히 연구가 되고 있다. 특히 A site와 X site의 조성을 변화시켜 밴드갭을 조절(1.2eV~2.5eV)하는 능력으로 인하여 차세대 적층형 태양전지로서 상당한 관심을 끌었다. 그러나 페로브스카이트 박막을 제조함에 있어 기존의 Anti-solvent공법은 연구자의 숙련도에 따라 소자 성능이 편차가 크게 나타나기 때문에 재현성이 떨어지며 독성 용매를 사용하기 때문에 친환경적이지 못하다. 더욱이 과량의 Anti-solvent의 사용과 적용 가능한 기판 크기의 제한 때문에 상업화와 대면적화에 어려움이 있다. 이 연구에서는 페로브스카이트/페로브스카이트 적층형 태양전지를 위한 p-i-n 구조의 wide bandgap FACsPbIBr 구성을 갖는 페로브스카이트 태양전지의 X-선 회절(XRD) 분석을 통하여 PbI_2 의 억제를 확인하고 재현성 있는 Gas quenching 방법을 연구하였다.

이번 연구의 소자는 다양한 압력과 기체를 사용하며 상온, 25% 상대습도 환경에서 Gas quenching 방법으로 제작되었다. 페로브스카이트 박막의 구조적 및 광학적 특성은 각각 XRD 및 SEM으로 분석되었다.

페로브스카이트 박막의 XRD 분석에서 Gas quenching 방법이 PbI_2 형성을 효과적으로 억제한다는 것을 밝혀 내었다. 페로브스카이트의 결정성 향상은 가스 압력과 상관관계를 가짐을 알 수 있었고 최적의 압력을 도출해 낼 수 있었다. 본 연구를 통하여 높은 수준의 박막 품질 제어와 재현성을 가진 gas quenching 방법이 1.8eV의 높은 밴드갭을 갖는 페로브스카이트 박막에 적용 가능함을 증명하였고, 이는 적층형 태양전지 상용화에 대한 새로운 통찰력을 제공할 것이다.

Key words : Perovskite(페로브스카이트), Gas quenching(가스 담금질), Wide bandgap(넓은 밴드갭), p-i-n perovskite solar cell(p-i-n 구조 페로브스카이트 태양전지)

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Spatial and Energy Trap Distribution of Wide-bandgap $MAPbBr_3$ Perovskite Thin Film

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Abstract : 유무기 하이브리드 페로브스카이트 태양 전지 (perovskite solar cells, PSC)는 광대역 투명성, 잠재적 유연성을 가진다. 이러한 이유 때문에 결정성 실리콘 태양전지에 비해 유리하다. 그러나 PSC는 물에 쉽게 녹기 때문에 습기를 피하기 위해 일반적으로 글로브 박스 내부에서 제조 공정을 수행한다. 본 연구에서는 PSC의 제조 환경 습도에 따라 페로브스카이트 박막의 공간,에너지 트랩분포를 측정하였다. 제조 환경에 따라 트랩 밀도는 건조 N_2, relative humidity (RH) 25%, RH 50% 및 RH 80%에서 5 - 1000배 측정되었으며 최소값은 $3.7x10^{14}cm^{-3}$이며 트랩 밀도의 대부분은 페로브스카이트 박막의 인터페이스에 위치한다. 특이하게도, RH 25% 로 제작된 $MAPbBr_3$ ($CH_3NH_3PbBr_3$) 태양 전지는 습기가 없는 건조한 N_2 주변보다 낮은 트랩 밀도와 높은 장치 성능을 보였다. 이러한 이유는 대부분의 트랩밀도가 인터페이스에 밀집되어있고 이는 습도의 영향이 박막의 형성메커니즘에 큰영향을 주는 것으로 보인다.

Key words : Perovskite solar cells(페로브스카이트 태양전지)

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디바이스 구동조건에서의 혼합 양이온 FA 기반 페로브스카이트 태양전지의 열화 메커니즘

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Degradation mechanism of mixed-cation FA-based perovskite solar cells under device driving conditions

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Abstract : Organic cation-based metal halide perovskites have difficulty in stability under device driving conditions due to volatile material decomposition. Formamide-based perovskite solar cells (PeSC) have been widely studied, showing efficient power conversion efficiencies (PCEs). Despite the high PCE, FA-based perovskites have quite uncertain degradation mechanisms related to stability. In this study, we compared two different stability systems by introducing inorganic and organic cations to FA-based perovskite. To evaluate the device operational stability, we examined the difference in the phase transition of inorganic-mixed and organic-mixed FA perovskites film under 1 sun illumination at 60 ◦C in ambient air. Morphological and structural characterization was collected to determine whether the degradation of perovskite plays a major role in the perovskite grain boundary or grain surface depending on the type of secondary cation. While the PCEs of the two device systems were similar, the degradation mechanism varied significantly according to the chemical properties of the perovskite components.

Key words : Perovskite(페로브스카이트), Solar Cell(태양전지), Formamide-based perovskite solar cells(Formamide 기반 페로브스카이트 태양전지), Degradation(열화)

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Band-Aligned and Defect-Suppressed Interlayers for High-Efficiency Indoor Organic Photovoltaics (〉33%)

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Abstract : With the recent advent of the Internet of Things (IoT), interest in using organic-based artificial light cells (OALC) to harvest ambient light energy is increasing. This study achieved a record power conversion efficiency (PCE) exceeding 33% under a light-emitting diode lamp (19500 lx; light intensity IL = 4.5 mW/cm2) by applying atomic layer deposition (ALD)-processed vanadium oxide (V_2O_5) hole-transport-layers (HTLs) to non-fullerene acceptor-based OALC. The most widely used material for HTLs is poly(3,4-ethylenedioxythiophene) : poly(styrenesulfonate) (PEDOT:PSS). OALCs with ALD-processed V_2O_5 HTLs considerably outperform those with PEDOT:PSS HTLs because they have excellent hole selectivity, remarkable electron-blocking, a smaller interfacial area, and significantly enhanced step range which substantially suppresses charge recombination. In addition, the suggested V2O5 based OALCs have diffusion-free characteristics into the photoactive region and exhibit superb performance stability, maintaining a PCE of 92 % after 1000 h under ambient conditions.

Key words : Indoor organic photovoltaic(실내유기광전지), V_2O_5(산화 바나듐(V)), High power conversion efficiency(높은 전력 변환 효율), Long-term stability(장기 안정성), Charge selectivity(전하 선택성)

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QPOD-P-100

Stable Methylammonium-Free Wide Bandgap Perovskite for Efficient Photovoltaics

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Recently, wide-bandgap perovskites based on iodide-bromine mixed halide composition would suffer from light-induced halide segregation. In addition, MA cations, which are widely used as organic cations in wide-bandgap perovskites, show low thermal stability.

In this work, we fabricate wide-bandgap pure-iodide FA-based perovskite that is substantially more stable upon light soaking and thermal stress than those mixed halide perovskites.

High Cs^+ content is needed for pure iodide wide-bandgap perovskite but the secondary phase is inevitable for high Cs^+ content perovskites, even though the tolerance factor is within the appropriate range through replacement of the A-site cation.

Using partial substitution of the large A site cation and volatile additive can change the tolerance factor and crystallization mechanism on high Cs^+ content perovskite. It can affect phase stability and maintain black photoactive perovskite while suppressing the formation of the secondary phase(hexagonal, orthorhombic phase)

Our pure-iodide perovskite(1.65 eV) presents promising materials for various wide-bandgap applications, especially for Si-perovskite and CZTS-perovskite tandem solar cells.

Key words : Perovskite, Wide-bandgap, Tandem solar cells, Halide segregation

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Double layer를 도입한 $CsPbI_3$ perovskite solar cell의 성능 개선

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Enhanced Performance of $CsPbI_3$ Inorganic Perovskite Solar Cells with Double Electron Transport Layers.

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Abstract : Perovskite solar cells (PSCs) have emerged as promising candidates for next-generation photovoltaic technology due to their high power conversion efficiencies and low production costs. However, PSCs suffer from issues related to their stability, which hinders their long-term performance and practical applications. To address this issue, researchers have explored various approaches to improve the stability of PSCs. One such approach involves the use of two electron transposing layers (ETLs) that can enhance the charge transport and extraction properties of the device, thus improving its overall efficiency and stability.

Key words : Perovskite solar cell (페로브스카이트 태양전지), electron transporting layer (전자수송층), double layer (이중층)

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$Mn(TFSI)_2$을 도판트로 이용한 정공수송층의 즉각적인 계면 처리로 효율적이고 안정적인 무기 페로브스카이트 태양전지 제조

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Immediate Interface Engineering for Spiro-MeOTAD Using $Mn(TFSI)_2$ as Dopant Afford Efficient and Stable Inorganic Perovskite Solar Cells

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Abstract :

Inorganic $CsPbI_3$ perovskite has attracted attention for next generation perovskite solar cells (PSCs) because achieving suitable optical band gap and high thermal and chemical stability, Especially, Cubic $CsPbI_3$ perovskite could potentially serve as top cells in tandem devices with silicon solar cells because they have 1.73 eV bandgap. However, it quickly turns to an undesired non-perovskite yellow phase at room temperature when they absorbs light, So it is important to stabilize the phase by reducing the defect density act as non-radiative recombination center at the interface of each layer. In here, we present an efficient interface engineering method without additional surface treatment such as annealing or coating. We directly mix dopant, $Mn(TFSI)_2$ instead of Li-TFSI into HTMs. As a result, the interfacial defect between perovskite and HTL is diminished when using $Mn(TFSI)_2$, reducing non-radiative recombination and increasing lifetime of the carrier. Also the power conversion efficiency (PCE) improves from 16.5% for the control device using conventional Li-TFSI to 17.6%. Moreover, Mn $(TFSI)_2$ used device shows superior long-term stability for 1000 h under ambient conditions without encapsulation, reserving 95% efficiency compared to the initial performance.

Key words : Surface engineering(개면 개질), Hole transport layer(정공수송층), Perovskite solar cells(페로브스카이트 태양전지)

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Improving Interfacial Recombination of Heterojunction Electron Transport Layer via Defect Engineering for Efficient Perovskite Solar Cells Over 23%

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Abstract : Electron transport layer (ETL) is pivotal to charge carrier transport for PSCs to reach the Shockley-Queisser limit. This study provides a fundamental understanding of heterojunction electron transport layers (ETLs) at the atomic level for stable and efficient perovskite solar cells (PSCs). The bilayer structure of an ETL composed of SnO_2 on TiO_2 was examined, revealing a critical factor limiting its potential to obtain better performance.Alteration of oxygen vacancies in the TiO_2 underlayer via an annealing process is found to induce manipulated band offsets at the interface between the TiO_2 and SnO_2 layers. In-depth electronic investigations of the bilayer structure elucidate the importance of the electronic properties at the interface between the TiO_2 and SnO_2 layers. The apparent correlation in hysteresis phenomena appears as a function of the type of band alignment. The formation of cascade band alignment via control over the TiO_2 underlayer enhances device performance and suppresses hysteresis. Optimal performance exhibits a power conversion efficiency (PCE) of 23.45% with an open-circuit voltage (V_{OC}) of 1.184 V, showing better device stability under maximum power point tracking compared with a staggered bilayer under one-sun continuous illumination.

Key words : Oxygen vacancy engineering(산소 결함 공학), perovkskite solar cell(페로브스카이트 태양전지), heterojunction electrion transport layer(이종 전자수송층).

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고효율의 단분자 기반의 유기 태양전지 및 탠덤 태양전지를 위한 염소화 전략의 도입

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Abstract : 단분자는 고분자 사슬의 무정형 성질을 가지고 있지 않아, 트랩 사이트로 작용할 수 있는 무질서 영역을 가지고 있지 않다. 또한 단분자의 분자 디자인 용이성은 유기 태양전지의 상업화에 효과적으로 작용하고 있다. 단분자 구조의 디자인 전략으로는 BDT기반의 골격을 사용하여 강력한 분자 간 상호작용을 유도하는 것과 전자 받개-주개-받개 구조를 도입하는 것이 있으며, 이들은 최근 13.6%의 높은 효율을 보고하였다. 본 논문에서는 매우 평평한 골격과 효율적인 전하 이동을 위하여 2차원 구조의 BDT와 끝 그룹에 ID를 사용하여 단분자를 제작하였다. 더욱이, ID에 서로 다른 종류의 할로겐 원소를 도입 및 비교를 통하여 염소를 치환하였을 때에 가장 작은 π-π 거리와 결정형이 가장 높은 비율로 기판과 평행하게 존재하는 것을 확인하였다. 최종적으로 제작된 소자에서는 할로겐 치환 중 염소를 치환하였을 때에 PCBM과의 벌크 이종 접합 구조의 유기 태양전지에서 10.5%의 PCE를 보였으며, 더욱이 탠덤 태양 전지에서는 15.1%의 높은 PCE를 보였다. 이를 통하여 할로겐 치환이 미래의 고효율의 유기 태양전지 및 탠덤 태양전지를 위한 효과적인 전략임을 보였다.

Key words : 단분자, 탠덤 태양전지, 할로겐 치환, 벌크 이종 접합

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화학양론적으로 제어된 콜로이드 코발트 황화물 나노 입자에 기초한 페로브스카이트 태양전지 성능 향상

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Enhanced Perovskite Solar Cell Performance based on Stoichiometrically controlled Colloidal Cobalt Sulfide Nanoparticles

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Perovskite solar cells (PSCs) have emerged as promising next-generation photovoltaic devices because of their superior optical and electronic properties. In recent years, organic hole transporting material (HTM) based PSCs have been reported with remarkable increase in the photovoltaic performance. As power conversion efficiency (PCE) of PSCs with organic HTM has dramatically increased, expectations toward commercialization of PSCs rised. However, traditional organic HTMs are often several times expensive than the price of novel metals due to complicate synthesis process. In the view of this limitation, we investigated the new p-type inorganic HTM. Cobalt sulfide compounds are the most notable materials for HTMs of PSCs which are less expensive and earth-abundant. Nevertheless, synthesis of cobalt sulfide was difficult in that impurities with non-stoichiometry materials disturbed separating pure compounds. Here, we synthesized novel inorganic HTMs as a stoichiometrically adjusted p-type cobalt sulfide nanocrystals (Co_xS_y NCs). Hole transporting layers (HTLs) based on cobalt sulfide nanocrystals showed the excellent hole transport ability owing to its high conductivity and suitable energy levels for hole extraction. Co_xS_y NCs HTLs-based PSCs exhibited power conversion efficiency (PCE) nearly comparable to dopants-free spiro-OMeTAD HTM-based PSCs. Especially, the PSCs with mixed Co_xS_y NCs (with undoped Spiro-OMeTAD) HTLs exhibited PCE of 20.48 % which is the high-performance reported for such ionic additive-free HTMs. Furthermore, the cobalt sulfide HTM-based PCS showed an initial efficiency of 92 % even after exposure to 70 % relative humidity for 1000 hours. These new p-type Co_xS_y NCs promises to support environmentally and economically sustainable development of PSC and diverse optoelectronic area.

효율적인 패시베이션을 위한 페로브스카이트 태양전지에서 (α-Methylguanido)acetic Acid의 최적 위치 탐구

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Abstract : 페로브스카이트의 결함은 트랩 보조 비방사성 재결합을 유도하고 열화를 가속화하여 장치 효율과 안정성에 큰 악영향을 미친다. 따라서 트랩 패시베이션은 효율성과 안정성을 동시에 향상시키는 효과적인 방법이다. 이 연구에서는 크레아틴이라 불리는 (α-methylguanido)acetic acid를 두 가지 방법으로 도입하였다. 흥미롭게도 페로브스카이트층 위에 캡핑층을 증착했을 때는 bulk에 첨가제로 도입했을 때와는 다르게 2차원 페로브스카이트층이 형성되었음을 확인했다. 2D 캡핑층을 형성하기 위한 활성화 에너지는 3d 페로브스카이트가 먼저 형성된 후 2d 페로브스카이트층이 형성되기 때문에 더 작아서 극복할 수 있다. 2d 캡핑층은 페로브스카이트 표면의 불안정한 결함을 2d 페로브스카이트로 효과적으로 변환할 뿐만 아니라 에너지 준위를 적절하게 정렬하여 정공 추출 능력을 향상 시킨다. 그 결과, 크레아틴 2d 캡핑층을 갖는 페로브스카이트 태양전지는 전력 변환 효율 (PCE)의 22.6%를 나타냈고 상온 N2 조건에서 250시간 동안 초기 PCE의 거의 80%를 유지했으며 80 °C의 열 조건에서 N2 조건에서 120시간 동안 초기 효율의 66%를 유지했다.

Key words : perovskite (페로브스카이트), passivation (패시베이션), perovskite solar cells (페로브스카이트 태양전지)

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페로브스카이트 태양전지 정공수송층에 사용되는 아민 기반 랜덤 공중합체의 합성

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Synthesis of Amine-based Random Copolymer for Hole Transporting Layer in Perovskite Solar Cells

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Abstract : 페로브스카이트 태양전지의 구성 요소 중 정공수송층은 그 특성이 태양전지의 성능과 직결되기 때문에 이를 이루는 물질 개발에 관한 연구가 중요하게 이루어진다. 오늘날에 많이 사용되는 정공수송물질로는 spiro-OMeTAD, PTAA, D-A형 고분자 등이 존재하는데, 특히 PTAA의 경우 간단한 합성과정 등의 장점이 있어 주목을 받는다. 본 연구에서는 이러한 아민 기반 고분자의 전하 이동도를 높이기 위해 평면 구조의 단량체를 도입하였다. 이는 비닐 작용기를 주사슬에 가지고 있어 비정질 고분자에서의 분자 간 상호작용 및 전하 이동에 도움을 준다. 또한, 고분자의 용해도를 유지하기 위해 신규 단량체에 가지 달린 알킬기를 도입하였고, 랜덤 공중합 방식으로 합성하였다. 이를 위해 기존의 PTAA 변형 고분자들의 합성에서 채택하는 Suzuki 반응, Yamamoto 반응이 아닌, Buchwald-Hartwig 반응으로 중합을 진행하였다. 서로 다른 신규 단량체 비율의 랜덤 공중합체를 합성하였으며, 그 특성들을 기존 PTAA와 비교하였다.

Key words : PTAA, random copolymer(랜덤 공중합체), Buchwald-Hartwig reaction(부크발트-하트위그 합성), hole transporting layer(정공수송층), perovskite solar cells(페로브스카이트 태양전지)

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무기 페로브스카이트 태양전지 안정성 향상을 위한 3차원 양쪽성 이온 도입

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Abstract : 완전 무기소재 기반의 $CsPbI_3$ 페로브스카이트 태양전지는 비교적 안정성에 취약한 유기성분을 대체함으로써 태양전지의 안정적인 성능을 구현하기 위한 유력한 후보로 손꼽히고 있다. 그러나 안정적이고 효율적인 $CsPbI_3$ 페로브스카이트 태양전지를 위해서는 α phase-$CsPbI_3$가 빛에 반응하지 않는 γ phase--$CsPbI_3$로 변하는 문제를 해결해야 한다. 본 연구에서는 페로브스카이트 전구체 용액에 3차원 양쪽성 이온을 도입하여 매우 안정적인 $CsPbI_3$ 페로브스카이트 태양전지를 개발하였다. 양쪽성이온은 페로브스카이트 결정화 과정에서 γ phase 형성을 효과적으로 억제하고 안정적인 α phase-$CsPbI_3$를 구현하였다. 양쪽성 이온의 SO3-는 산소의 비공유 전자쌍을 Pb2+의 빈 오비탈에 채움으로써 양쪽성이온과 페로브스카이트가 화학적으로 결합하였음을 XPS와 1H-NMR을 통하여 밝혀냈다. 그 결과 3차원 양쪽성이온을 적용한 페로브스카이트 태양전지는 높은 재현성을 보이며 18.4%의 광전환효율을 달성하였다. 봉지 과정 없이 상온, 상대 습도 25%±5%에서 25일 후 초기 효율의 98%를 유지하였고, 100°C의 높은 온도에서 우수한 안정성을 보였다.

Key words : Perovskite(페로브스카이트), Stability(안정성), Three dimensional Zwitter ion (3차원 양쪽성 이온)

1) 포항공과대학교

라미네이트된 동질 접합 정공 수송층을 이용한 실내 광전지의 획기적인 성능 향상

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Improved Performance of Indoor Organic Photovoltaics with Laminated Homojunction Hole-Transport Layer

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Abstract : The use of Internet of Things (IoT) devices in semipermanent indoor power systems has gained significant attention in recent years. Organic photovoltaics (OPVs), with their unique optoelectronic properties under dim illumination conditions, are particularly suitable for indoor energy-harvesting systems. In this paper, we introduce an additional PTQ10 homojunction hole transport layer (HTL) into PTQ10:Y6 OPVs using a simple and effective transfer lamination method. The HTL significantly reduces defect densities and maximizes quasi-Fermi level splitting, resulting in a dramatic improvement in indoor performance, with the power-conversion efficiency (PCE) increasing by over 25%. Optimized indoor OPVs equipped with the proposed HTL demonstrate an improvement in PCE by 26.5% under a 1000 lx LED and an output power density of 413 μW cm−2 under 1000 lx halogen conditions, the highest recorded values to date. These results demonstrate the practical potential of using the proposed architecture to operate low-power indoor electronic devices.

Key words : indoor organic photovoltaics(유기물 실내 광전지), homojunction hole-transport layer(동질 접합 정공 수송층), suppressed recombination(재결합 억제), shunt resistance (션트 저항), quasi-fermi level splitting (준-페르미 레벨 분할)

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Preparation and Characteristic of $Cu_{2-x}S$ on Nickel thin layer as a counter electrode for quantum dot sensitized solar cells

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Quantum-dot-sensitized solar cell (QDSSC) has been considered as an alternative to new generation photovoltaics, but it still presents low stability. Besides the continuous effort on improving photoanodes and electrolytes, the focused investigation on charge transfer at interfaces and rational design for counter electrodes are recently receiving much attention. The development of a stable counter electrode (CE) for quantum dot sensitized solar cells (QDSSCs) is still challenging. In this work, a Cu/Ni film has been pre-prepared via a novel redox reaction between Ni foam and Cu ions. Further, a $Cu_{2-x}S$/Ni CE was fabricated by sulfidation of the Cu/Ni film. A improved photovoltaic conversion efficiency for a ZCISSe QDSSCs composed of the $Cu_{2-x}S$/Ni CE was obtained, with the performance being attributed to the improved catalytic activity, high conductivity and good adhesion between $Cu_{2-x}S$ and FTO glass

친환경 유기태양전지에 적합한 신규 랜덤 공중합체 신규 도너 개발

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Developing a newly designed random copolymer donor suitable for green solvent processable organic solar cell

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Abstract : A new benzodithiophene (BDT) building block, 4,8-bis(5-(2-ethylhexyl)-3-fluoro-4-hexylthiophen-2-yl)benzo[1,2-b:4,5-b']dithiophene (3-FBDT) is designed by tailoring the position and number of alkyl and F substituents with adjustment of a torsional energy barrier of a BDT core. Incorporation of 3-FBDT into a representative BDT-based polymer donor (PBDB-T-2F) yields a new photovoltaic copolymer (PBDB-T-2F(3/4)) with decreased valence band level and dramatically improved solubility in non-halogenated and non-aromatic solvent, i.e., tetrahydrofuran (THF). Although PBDB-T-2F shows a significant drop in power conversion efficiencies (PCEs: 17.46 to 9.73%) due to serious aggregation by replacing chloroform with THF as a processing solvent, a THF-processed PBDB-T-2F(3/4) devices maintain a high PCE (13.86%) with no detrimental effect. By analyses of charge carrier dynamics and film morphology, the electronic and morphological properties of PBDB-T-2F(3/4) are proved to be mainly governed by the PBDB-T-2F blocks. The damage in the optical and photoelectrical properties is not significant by incorporation of a small amount of 3-FBDT into PBDB-T-2F. Benefitting from its high solubility and outstanding photoelectrical properties, PBDB-T-2F(3/4) was also employed to fabricate the THF-processed flexible, semi-transparent, and large-area devices, successfully demonstrating its great potential for non-aromatic/non-halogenated solvent-processible solar cells. Incorporation of the 3-FBDT building block into various BDT-based photovoltaic polymers can be effective strategy to improve the processibility in green solvents without significant disruption in their photoelectrical properties.

Key words : eco-friendly solvent(친환경 용매), polymer solar cells(고분자 태양전지), power conversion efficiency(광전변환 효율), new donor polymer(신규 도너 고분자)

에탄올 기반의 α-formamidinium lead triiodide 페로브스카이트 층의 친환경 용액 공정

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Abstract : 에탄올 기반의 α-formamidinium lead triiodide 페로브스카이트 층의 친환경 용액 공정용액가공 페로브스카이트 태양전지의 대량 생산에는 무독성 또는 저독성 용매의 사용이 필수적이다. 그러나 할라이드 페로브스카이트는 일반적으로 대부분의 무독성 용매에 완전히 용해되지 않는다. 여기서 우리는 에탄올 기반 용매에 용해된 페로브스카이트 전구체 용액을 사용하여 조밀하고 균일한 α-formamidinium lead triiodide(α-FAPbI3) 필름의 증착을 보고한다. 이 공정에서는 anti-solvent 적하 공정을 필요로 하지 않는다. N,N-dimethylacetamide (또는 dimethylsulfoxide)와 같은 루이스 염기성의 극성 비양성자성 용매와 에탄올, 염화 알킬암모늄(RNH3Cl)의 조합은 FAPbI3의 안정적인 용매화를 가능케한다. FAPbI3 전구체 용액에 첨가된 RNH3Cl은 dimethylacetamide(또는 dimethylsulfoxide)와 배위 된 H-DMAc-PbI3 및 DMAc·HCl과 같은 아이오딘화플럼베이트(plumbate) 착물을 통해 스핀 코팅 및 고온 어닐링 중에 제거됩니다. 여러 유형의 RNH3Cl을 결합하여 매우 조밀하고 균일한 높은 결정성을 가진 α-FAPbI3 페로브스카이트 막을 형성할 수 있었다. TiO2 전극을 사용하여 24.3%, SnO2 전극을 사용하여 25.1%의 전력 변환 효율을 얻었다.

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Understanding the Synergistic Influence of Propylammonium Bromide Additive and Erbium Doped $CsPbI_2Br$ for Highly Stable Inorganic Perovskite Solar Cells

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Abstract:

Inorganic cesium lead halide perovskites have gained more attention to boost photovoltaic performance and device stability. Nevertheless, the photoactive to photo-inactive phase transition in ambient conditions hamper its further enhancement. Here, we varied the various amounts of propylammonium bromide (PABr) additive in the γ-$CsPbI_2Br$ perovskite and further varied erbium (Er^{3+})-doping in the γ-$CsPb_{1-x}Er_xI_2Br$ perovskite. Further, in the optimized ($CsPb_{0.97}Er_{0.03}I_2Br$) composition, we studied the influence of various amounts of PABr additive. Our results clearly show the PABr additive added film results in high-quality surface morphology, high crystallinity and decreased trap-state density. Accordingly, our champion $CsPb_{0.97}Er_{0.03}I_2Br$ + 2 mg ml^{-1} PABr (CsEr-PA)-based inorganic perovskite solar cells (IPVSC) device showed 16.74 % power conversion efficiency (PCE), which is much higher than bare (13.20 %) and $CsPb_{0.97}Er_{0.03}I_2Br$-based perovskite devices (15.73 %). In addition, the CsEr-PA-based IPVSC device reveals increased long-term stability, which maintains 90 % of its initial PCE at 65 °C thermal stress in ambient conditions over 400 h. These dual stabilization strategies cover a new way to increase the photovoltaic performance of IPVSCs.

Keywords: Inorganic halide perovskites, Erbium doping, Propylammonium bromide additive, Ultra-high grain size, Stability.

RF-마그네트론 스퍼터링을 이용하여 증착된 산화주석 박막의 전기적, 광학적 특성 연구

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Effect of Sputtering Power on Optical and Electrical Properties of Tin oxide Electron Transport Layer Deposited by RF-magnetron Sputtering

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Abstract : The electron transport layer (ETL) is a crucial component of solar cells, and the electrical properties of the ETL are critical for efficient energy conversion. In this study, we synthesized SnO2 ETLs with various sputtering power levels (30-60W) using radio-frequency (RF)-magnetron sputtering and characterized their properties using ellipsometry and UV-vis spectrometry, I-V curve measurement. Due to the limitations of 2-terminal IV measurements, we qualitatively analyzed the electrical properties of the SnO2 thin films by considering the current flow in the thin film and multiplying and dividing by the thickness. Our results showed that the sputtering power had a significant effect on the properties of the SnO2 ETLs, including thickness, which affected the current flow and resistance of the thin films. Our findings suggest that the optimization of sputtering power is essential for the synthesis of conformal SnO2 ETLs with desirable electrical properties for efficient solar cells.

Key words : Perovskites(페로브스카이트), Electron transport layer(전자전달층), SnO2(산화주석)

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진공증착한 페로브스카이트 전구체 특성 분석 및 용액 공정을 통한 변환

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Characterization of vacuum-deposited perovskite precursors and conversion through the solution process

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Abstract : Perovskite solar cells have many advantages, such as low price and excellent performance. Recent research has focused on upscaling perovskite solar cells. Radio frequency (RF) magnetron sputtering can be used to deposit uniform lead iodide films on large area substrates. A perovskite layer can be prepared by the sequential interaction of lead iodide films with methylammonium iodide (MAI). In this study, high-quality sputtered PbI_2 thin films were fabricated by controlling the sputtering conditions. The relationship between power density and properties of sputtered PbI_2 thin films is described and compared to spin-coated equivalents. The sputtered PbI_2 film presents a uniform and uniform layer with excellent step coverage regardless of the substrate showing the advantages of sputtering. In addition, the conversion process of perovskite from the sputtered PbI2 thin film was investigated.

Key words : Perovskite(페로브스카이트), Sputtering(스퍼터링)

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페로브스카이트 태양전지의 2차원 광 발광 이미지 분석

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Two-dimensional analysis by photoluminescence imaging technique of perovskite solar cells

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Abstract : 페로브스카이트 태양전지(Perovskite solar cells)는 실리콘 태양전지의 효율 한계를 뛰어넘는 산업에의 응용 가능한 차세대 태양전지로 현재까지 많은 주목을 받고 있다. 하지만, 대량생산을 위해서 태양전지의 특성 중 하나인 전압-전류 곡선을 측정하는 데 히스테리시스(hysteresis)가 발생하여 정확한 효율 평가의 어려움이 있다. 이번 연구에서, 등가회로 모델을 기반으로 한 입자 군집 최적화(particle swarm optimization) 알고리즘을 사용하여 페로브스카이트 태양전지의 신뢰할 수 있는 태양전지 인자(효율, 곡선인자, 개방전압, 단락전류 등)을 빠르게 얻는 방법을 소개한다. 우리는 시뮬레이션 할 태양전지 등가회로 내에서 커패시터의 위치(병렬 및 직렬, 이중 다이오드 모델)에 따라 전류-전압 곡선의 특성을 탐구하고 실험 결과와 일치하는 피팅 곡선을 얻었다. 피팅 매개 변수를 사용하여, 히스테리시스가 나타나지 않는 전류-전압 곡선과 그에 해당하는 태양전지 인자를 추출했다. 이 접근법을 광 발광 이미징(photoluminescence imaging) 기술과 결합하여, 우리는 공간적으로 해결된 태양 전지 특성을 성공적으로 시각화했다. 본 연구는 페로브스카이트 태양전지의 공정개발을 위한 기본적인 분석틀과, 대량생산을 위한 빠르고 신뢰할 수 있는 분석방법을 제공할 것으로 기대된다.

Key words : 페로브스카이트 태양전지, 광 발광 이미징, 히스테리시스, 입자 군집 최적화 알고리즘, 전류-전압 곡선

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Metal ion doping and quantum dot passivation approach for stabilizing γ-$CsPb(I_{1-x}Br_x)_3$ inorganic perovskite solar cells

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Abstract : Realizing photoactive and thermodynamically stable inorganic halide perovskites is challenging task. Here, we employed a dual strategy for realizing efficient inorganic mixed halide perovskite photovoltaic devices based on metal ion doped γ-$CsPb(I_{1-x}Br_x)_3$ absorber, which undertakes a quantum dot based bulk and surface passivation treatment to maintain a photoactive phase under ambient conditions and with significantly improved operational stability. Devices fabricated from these air-processed perovskite thin films exhibit an air-stable power conversion efficiency (PCE) that reaches 17.51% with negligible hysteresis and maintain >90 %of the initial efficiency when operating for 600 h under harsh environmental conditions, stemming from the combined effects of the dual-protection strategy. This approach is further examined within large-area perovskite solar module (PSM) (19.8 cm^2 active area) to realize 10.94% PCE and > 30 ambient stability, as well as within low-bang gap γ-$CsPbI_{2.5}Br_{0.5}$ (Eg=1.73 eV) composition, yeilding 19.01 % PCE.

Key words : Inorganic perovskites, metal ion doping, quantum dot passivation, module scale device fabrication.

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Non-fullerene Acceptors with Alkylthiothiophene Side Chains for Efficient Non-halogenated Solvent Processed Indoor Organic Photovoltaics

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Abstract : Organic photovoltaics (OPVs) are regarded as promising energy sources for powering internet of things devices under indoor conditions. Indoor OPVs (IOPVs) have achieved power conversion efficiencies (PCEs) of 25-30%, due in part to the discovery of wide band gap non-fullerene acceptors (NFAs) (>1.7 eV). However, this requires the use of halogenated solvents that are harmful to human health and the environment. Therefore, halogen free solvent processing with the deliberate designing wide band gap NFAs is required to demonstrate the feasibility and environmental compatibility of NFA-based IOPVs. Herein, we designed two NFAs, ITIC-Th-s and ITIC-Th-s-me, composed of an ITIC core and four 5-thioalkylated-2-thienyl groups as out-of-side chains with methyl groups attached to the conjugated end units. The substitution of electron-donating methyl in the end group is expected to increase an open-circuit voltage, which is beneficial to IOPV applications. They were then blended with a polymer donor (PM6) to obtain a photoactive layer with an absorption spectrum similar to that of indoor light sources. Xylene:1,8-octanedithiol (XO) and chlorobenzene:1,8-diiodooctane (CD) were used as non-halogenated and halogenated solvents, respectively. XO-based devices exhibited competitive PCEs relative to CDs; PM6:ITIC-Th-s and PM6:ITIC-Th-s-me yielded PCEs of ~19% and ~22%, respectively, under common white light emitting diode illumination. Specifically, PM6:ITIC-Th-s-me processed from XO solvents achieved a PCE of 22.38% at 550 lux, which is the best-performing binary material system based IOPVs processed from a non-halogen solvent mixture. The presented approach highlights several useful design strategies for the development of indoor NFAs for efficient non-halogenated IOPV applications.

Key words : organic photovoltaics, nonfullerene-acceptors, indoor OPVs

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Advances in Tandem Solar Cell : Perovskite/Silicon Triple-Junction with Transparent Conductive Adhesive Lamination Process

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Organic-inorganic hybrid perovskite solar cells (PSCs) are expected to become future renewable energy sources among the emerging photovoltaics. Perovskite materials are very promising for the tandem solar cells due to the largely tunable band gap energy (E_g). Recently, PSCs based multijunction solar cells are intensively and extensively investigated to achieve higher performance over Si solar cells. For the fabrication of tandem, conventional vacuum deposition methods have been widely used even though the high-cost and their applications to fabricate multijunction solar cells. However, to realize the simple process to reduce total fabrication cost, simple fabrication process is highly required. Here, we developed a transparent conductive adhesive (TCA) based lamination method for the fabrication of the multijunction solar cell, which is comfortable and cost-effective method. Based on low-temperature and low-pressure lamination conditions, we achieved over 2.2 V open-circuit voltage and 11.16 % power conversion efficiency in perovskite/perovskite/silicon triple-junction solar cells. The TCA lamination method developed through this study is expected to present a new horizon in future research and industrialization of multijunction solar cells.

Understanding the Degradation Effect of Potential-Induced Degradation (PID) in Perovskite Solar Cells

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Abstract : In recent years, perovskite solar cells have attracted significant attention due to their excellent optical properties, including a high absorption coefficient, broad absorption spectrum, high charge carrier mobility, and high defect tolerance. Perovskite solar module research is actively being pursued to commercialize these promising devices, with the current state of the art for large-area perovskite solar cells being a module with an aperture area of 802 cm^2. However, a key challenge in the development of perovskite solar cells for commercial use is potential-induced degradation (PID), which can occur when high voltage is applied to the device, leading to decreased performance and efficiency over time. Ensuring PID voltage stability is essential for modularization and large-scale deployment of perovskite solar cells.

In this work, we investigate the effect of high voltage on perovskite solar cells through PID testing and analyze the recovery effect after the PID test. Our goal is to develop strategies to enhance PID stability and facilitate the production of perovskite solar cells for commercial applications.

Key words : perovskite(페로브스카이트), Potential-Induced-Degradation(PID)

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Optimization of Nickel Oxide Films using vacuum process and oxidation process for p-i-n perovskite solar cells

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Abstract : Over the past 12 years, perovskite solar cells (PSCs) have demonstrated rapid growth in power conversion efficiency (PCE), reaching a record high of 25.7%. This progress in PCE is critical for the development of tandem solar cells, which have the potential to achieve even higher PCEs of up to 31.25%. However, the commercialization of PSCs has been hindered by their weakness to degradation due to humidity, light, and temperature, particularly in the case of solution-processed spiro-OMeTAD hole transport layers. As an alternative, vacuum-processed inorganic materials such as NiOx have been investigated as hole transport layers for their improved stability and uniform deposition on textured silicon bottom cells.

In this study, we optimized the evaporated NiOx hole transport layer by exploring various process parameters such as deposition thickness, annealing temperature, and additional interlayer in order to applying these conditions to tandem solar cells. We analyzed the structural properties of the thin film using X-ray diffraction (XRD) and characterized the optical properties by measuring absorbance and quantum efficiency. The energy conversion efficiency of the tandem solar cell was measured using a solar simulator with a glass/FTO/NiOx/MAPbI3/C60/PCBM/Au structure, and the stability of the thin film under different conditions was evaluated. Our results indicate that the evaporated NiOx hole transport layer could be a promising approach for improving the efficiency and stability of PSCs, paving the way for their wider commercialization.

Key words : Perovskite solar cell(페로브스카이트 태양전지), Nickel oxide(니켈옥사이드), Thermal evaporation (열진공증착법), Rapid thermal process, Stability(안정성)

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Fabrication of Pinhole Free Perovskite Films in Ambient Humidity Condition Using Diethyl Ether as Antisolvent

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Abstract : Recently, perovskite solar cells have shown remarkable improvements in power conversion efficiency (PCE), with a record of 25.7%. These high-efficiency solar cells have been produced using a one-step spin coating method with anti-solvent, resulting in uniform and pin-hole free perovskite films. The choice of anti-solvent is crucial, as its chemical properties can affect the morphology of the perovskite film. Therefore, it is necessary to optimize the dripping process of the anti-solvent to achieve a high-coverage and uniform perovskite film, particularly considering the humidity conditions. Previous studies have mostly focused on depositing the perovskite film under controlled humidity conditions (< RH 20%) in a glove box. In this study, we propose using diethyl ether as an anti-solvent to form uniform and pin-hole free perovskite films in ambient humidity conditions (< RH 50%). The resulting films were characterized using UV-vis absorption, scanning electron microscope, and X-ray diffraction spectra to analyze their optical properties, film morphology, and crystallinity.

Key words : Perovskite(페로브스카이트), Film morphology(박막 형상), Anti-solvent(반용매)

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실버 나노와이어를 상부 전극으로 한 바코팅 공정의 양면 황화납 양자점 태양전지

이혜진[1)]*, 할릴 세틴[2)], 임지석[3)], 한동휘[4)], 유형근[5)]**

Printed bifacial collodial lead sulfide quantum dot solar cell with silver nanowire for top electrode

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Abstract : Lead sulfide quantum dots (PbS QDs) are a potential type of optoelectronic materials that have attracted a lot of interest. Their electronic band gap tunability and cost-effective synthetic techniques, in especially, enable the flexible construction of solar energy harvesting cells, leading to optimal device performance. However, the main method for fabricating the QD layer in solar cells is still the inefficient spin-coating approach, which makes it difficult to produce solar cells on a large scale due to thickness un uniformity. In this work, main coating was employed as the bar coating and the top electrodes were coated by spray coating rather than vacuum deposition. Additionally, we employed PbS-PbX_2 and PbS-CTA (X=I^-, Br^-, CTA is cysteamine) as a n-type and p-type semiconductor property to create QD bulk homojunction films. And this enhanced transport of photoexcited carriers along unique physical pathways increased carrier diffusion length and resulted in greater efficiency. And we discovered that the efficiency of devices made with spin coating against bar coating approaches was 9.33% and 9.03%, respectively, which was just as effective as spin coating. Efficiency was 5.12% when Ag nanowires(AgNW) was employed as the top electrode. Although the device performance was obviously inferior compared with Au top electrode, we saw the possibility of manufacturing the top electrode by a solution process. AgNW's transparency made it possible to determine that it functions as a bifacial solar cell and can generate electricity even when exposed to light coming from the top electrode.

Key words : Lead sulfide quantum dots (황화납 양자점), Bar coating (바 코팅), Solution procedure(용액 공정)

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계면 및 벌크 결함 제어를 통한 고효율 및 밝은 페로브스카이트 태양전지

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Eliminating bulk and interface traps for realizing efficient and brigh perovskite solar cells

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Abstract:

Lead halide perovskite solar cells are an emerging technology that can be solution processed to yield low-cost, light weight, and flexible photovoltaics. Much of the early work has been focused on developing device structures and processing techniques to improve light absorption and eliminate detrimental traps within the bulk of the perovskite active layer. As a result, the power conversion efficiency (PCE) of perovskite solar cells has improved from ~3% up to ~20% in less than a decade. However, the device efficiency of perovskite solar cells still needs to be much improved in order to compete with traditional photovoltaic technologies, such as Silicon and GaAs, and to ultimately realize the theoretically determined Shockley-Queisser efficiency limit.

I will present our work on developing high quality electron transport layer (ETL) and a new perovskite composition to further improve the device performance. A chemical bath deposition (CBD) was used for the synthesis of a tin dioxide (SnO_2) ETL. We found the pH of the reaction solution is identified as the key parameter for the CBD of SnO_2 that controls the morphology and optoelectronic quality of the SnO_2 ETL.

In addition, to improve the optoelectronic properties of the perovskite active layer, $MAPbBr_3$ is significantly reduced to minimize the band gap penalty, which also resulted in improved effective carrier mobility. $MAPbBr_3$ is commonly added to the perovskite composition to stabilize the α-phase $FAPbI_3$ but results in an increase in the band gap. Addition of 0.8 mol% of $MAPbBr_3$ to the FAPbI3 perovskite resulted in much improved carrier lifetime and effective mobility, compared to conventionally added 10 mol%.

Together with the new SnO_2 and the perovskite active layer, a record setting and certified PCE of 25.2% is achieved, which translates to 80.5% of the SQ limit for its band gap. In addition, due to low open-circuit voltage (V_{OC}) loss, the newly developed devices exhibit an electroluminescence (EL) efficiency up to 17.2% and an EL wall-plug efficiency up to 21.6%.

페로브스카이트 태양전지의 산화주석에 대한 전기적 특성 강화를 위한 염화물 수동태화

정석현[1)]*, 이원규[1)], 이솔희[1)], 이상원[1)], 황재근[1)], 이해석[2)], 김동환[1)], 강윤묵[2)]**

Chloride Passivation to Enhance Electrical Properties for Tin Oxide of Perovskite Solar Cells

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Abstract : Perovskite solar cells have shown significant improvements in power conversion efficiency (PCE), reaching 25.7%. Tin Oxide (SnO2) has been utilized as an electron transfer layer (ETL) due to its favorable properties such as wide bandgap, high electron mobility, and easy fabrication via spin coating at low temperatures. Previous research has demonstrated that modifying the surface of SnO2 with alkaline halide materials improves the electrical properties by altering the band alignment with perovskite. In this study, the researchers propose using an organic halide interlayer, specifically methylammonium chloride (MACl), to enhance the electrical and optical properties of the device. The MACl interlayer reduces oxygen vacancies on the surface of SnO2 and promotes the growth of perovskite grains in the following process, resulting in a perovskite solar cell with an increased fill factor of 81% and PCE of 21%.

Key words : surface passivation(표면 수동태화), perovskite solar cells(페로브스카이트 태양전지), tin oxide(산화 주석), electron transport layer(전자전달층)

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Structural modulation of Zn doped Sn-based perovskite solar cells

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Abstract : Sn-based perovskites have intrinsic defects, such as Sn vacancies, oxidised components (Sn^{4+}), and local lattice strain in the perovskite crystalline structure. In this study, Zn metal powder (Zn^0) was introduced to reduce Sn oxidation in the solution step based on the redox potential difference. Additionally, Zn^{2+} was introduced in the perovskite precursor, which decreased the intrinsic defects and lattice strain of the perovskite films. The diffusion length, particularly that of the hole, increased with a reduction in the lattice strain, and Zn doping led to interfacial energy-level alignment of the perovskite and hole-transporting layers. The reduced lattice strain decreased the defect density and charge carrier recombination of perovskite devices. The power conversion efficiency of the Zn-doped Sn-based perovskite solar cell was improved to 11.39% compared to the 8.56% of the reference device.

Key words : Sn-based perovskite solar cells, Zn ion doping, Strain relaxation

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페로브스카이트 태양전지의 부동화를 위한 요오드화 페닐트리에틸암모늄 후처리

스리칸타 팔레이[1)], 김형우[1)], 서관용[1)*]

Phenyltriethylammonium Iodide Post-treatment for Passiviation of Perovskite Photovoltaics

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Abstract : Organic-inorganic hybrid perovskite (OIHP) photovoltaics have been highlighted as a promising energy devices and the power conversion efficiency (PCE) has surpassed 25%. Although the OIHP photovoltaics have high PCE, the stability of OIHP is issued owing to the ionic segregation, surface defects, water intrusion, and so on. To prevent those stability degradation factors, the introduction of surface passivation layer is an effective method. This passivation layer nullify the ionic defects and protect the OIHP surface from the moisture. Here in, we have passivated the OIHP surface with a phenyltriethylammonium iodide (PTEAI) by simple post-treatment. The PTEAI has the halide components that passivate the anion defects and the carbon chain with benzene ring protect the surface from moisture. Also, the PTEAI having low number of H-bonding donors and small topological polar surface enhances the OIHP stability. The PTEAI-treated OIHP photovoltaics show an increased PCE over 20% with pen-circuit voltage (Voc) and fill factor (FF) enhancements. Furthermore, the PCE of the OIHP photovoltaics retain 92% of intial PCE after 500 hour in ambient air.

Key words : Perovskite (페로브스카이트), Phenyltriethylammonium iodide(요오드화 페닐트리에틸암모늄), Photovoltiacs (태양전지), Passivation (부동화), Stability (안정성), Defects (결함)

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루이스 산-염기 부가체를 통한 페로브스카이트 결정립 크기 조절 및 페로브스카이트 태양전지 효율 향상

김형우[1], 서관용[1]*

Perovskite Grain Size Control and Efficiency Enhancement of Perovksite Photovoltaics via Lewis Acid-Base Adduct

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Abstract : Organic and inorganic hybrid perovskite (OIHP) photovoltaics have high potential owing to its high power conversion efficiency (PCE), simple solution process, and low fabrication cost. For the high-efficiency OIHP photovoltaics, the formation of large grain size OIHP layer is essential to reduce the charge recombination at the grain boundary. Here in, we enlarge the OIHP grain size by forming the Lewis-base adduct in lead iodide (PbI_2) precursor via solvent additives. The Gutmann donor number (D_N) which is an interaction force of PbI_2-solvent additives adduct affect to the recrystallization of PbI_2 precursor layer. After the chemical reaction to organo-ammonium halide (mixture of FAI, MABr, and MACl), the OIHP grain size is different depending on the D_N of solvent additives. Among the solvent additives, dimethylsulfide (DMS) which has a high D_N of 40.0 kcal·mol^{-1} derives large OIHP grain size and high electrical properties. The PCE of OIHP photovoltaics using DMS achieves a 21.2% under AM 1.5G illumination. This work sheds a new light on the effect of solvent additives for OIHP grain growth mechanism and improvement of OIHP photovoltaics.

Key words : Organic-inorganic hybrid perovskite (유-무기 하이브리드 페로브스카이트), Solvent additives (용매 첨가제), Lewis acid-base adduct (루이스 산-염기 부가체), Photovoltaics (태양전지), Donor number (도너 수), Grain size (결정립 크기)

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Improved Performance and Stability of Organic Solar Cells Enabled by Interface Engineering

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Keywords: Organic solar cells, ZnO, surface modification, UV resins, Stability

Abstract

Organic solar cells (OSCs) have realized a high power conversion efficiency (PCE) greater than 19%. However the stability of many reported OSCs has remained a key challenge to their commercial applicability. Poor contact between the organic photoactive layer and the inorganic electron transport layer (ETL) hinders the stability of OSCs. Herein, we developed inverted OSCs by employing ZnO ETL modified with ultraviolet (UV) Curable resins and significantly enhanced the stability and performance of the OSCs based on PM6:Y6-BO system. Specifically, the inverted OSCs based on UV resins modified ZnO exhibited higher PCE (14.62% & 14.57 %) as compared to 13.59% of OSCs based on ZnO only ETL. Furthermore, the OSCs based on ZnO modified ETLs retained higher percentage of their initial PCE upon thermal and light soaking tests for 200 and 1000 hours respectively as compared to the OSCs with unmodified ZnO ETLs. These results provides an effective scheme to modify ZnO surface and also show prospects for application of UV curable resins in photovoltaic devices.

Simple approach for an electron extraction layer in an all-vacuum processed n-i-p perovskite solar cell

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*Corresponding authors

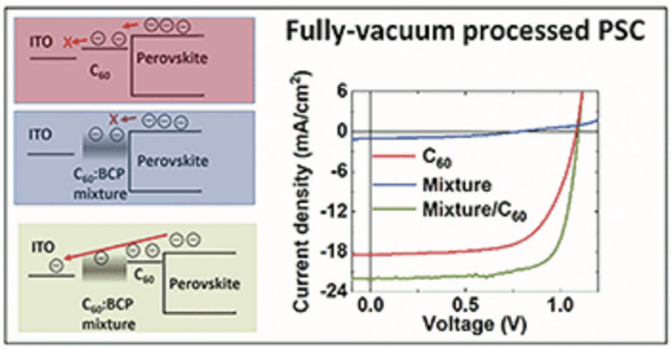
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Vacuum processing is considered to be a promising method allowing the scalable fabrication of perovskite solar cells (PSCs). In vacuum processed PSCs, the n-i-p structure employing organic charge transport layers is less common than the p-i-n structure due to limited options to achieve an efficient electron extraction layer (EEL) on indium tin oxide (ITO) with vacuum thermal evaporation. There are a number of specific applications where an n-i-p structure is required and therefore, it is of interest to have alternative solutions for the n-type contact in vacuum processed PSCs. In this work, we report an efficient vacuum deposited EEL using a mixture of conventional organic small molecules, C_{60} and bathocuproine (BCP). Incorporation of BCP into C_{60} does not result in conventional n-doping; however, we observed enhanced charge extraction, which significantly increased the power conversion efficiency (PCE) from 13.1% to 18.1% in all-vacuum processed PSCs. The C_{60}:BCP mixed (co-sublimated) film most likely results in shifted energy levels leading to better alignment with the electrodes.



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에폭시 접합 기반 Mechanical Stacked III-V/Si 탠덤 태양전지 소자의 상부 InGaP/GaAs 2J 셀 효율 개선

장승훈[1], 김나영[1], 정철[1], 이욱철[1], 신현범[1], 한승용[2], 김영국[2], 이준신[2] 강호관[1]*

Development of InGaP/GaAs 2J Top Cell on epoxy bonded Quartz substrate for Mchanical Stacked III-V/Si Tandem Solar Cell

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실리콘 기반 고효율 탠덤 태양전지 관련 연구와 사업화의 필요성은 이론적 한계치에 도달한 실리콘 단일 접합(single-junction) 태양전지 효율 정체 및 산업적 측면에서의 30% 이상 변환 효율 갖는 초고효율 저가형 태양전지 수요에 기인한다. 최근 이와 같은 결정질 실리콘 태양전지와 탠덤 구조를 이루는 상부셀로 페로브스카이트(Perovskites) 또는 Ⅲ-V 태양전지가 고효율 확보, 밴드갭 조절 용이성, 소자 구현 가능성 측면에서 가정 적합한 소재로 그 가능성을 인정받고 있다. 그러나 페로브스카이트 소재는 신뢰성 확보 및 대면적 소자 구현 측면에서, Ⅲ-V 소재는 저가화 측면에서 극복해야 할 큰 단점을 가지고 있다. 본 연구는 저온 에폭시 접합과 투명 기판을 적용하여 기존 결정질 실리콘 셀 위에 Ⅲ-V 상부 셀을 적층하는 방법으로 양산 가능한 저가형 Ⅲ-V/Si 탠덤 태양전지 개발을 시도하였다. 그림 1은 각각의 결정질 실리콘 태양전지와 Ⅲ-V 태양전지 사이에 Quartz 기판이 광학적 투과층과 전기적 절연층으로 동작하며, Mechanical stacking 방식으로 결합된 4-terminal 소자의 모식도이다. 4-Terminal 탠덤 태양전지는 2-Terminal 소자와 달리 하부 실리콘 셀의 독립적인 효율 기여와 전류 매칭이 불필요하다는 장점 외에도 추가적인 Wafer Bonding 또는 실리콘 기판 위에 Ⅲ-V 에피층을 성장해야하는 어려움을 피할 수 있는 장점이 있다.

첫 번째 단계는 상부셀 제작 단계로 Quartz기판 위에 역방향 성장된 InGaP/GaAs 2J 에피층 구조와 Quartz 위에 에폭시 접합 및 기판 제거 방법을 이용하여 그림 2와 같이 상부셀을 제작하였다. 이때 에폭시 접합은 Lamination 공정을 이용하여 압력, 온도, 시간을 최적화함으로써 120℃이하의 저온 void free 접합이 가능하였다. 두 번째 단계는 그림 3과 같이 Qaurtz 위에 기존 Ⅲ-V 태양전지 제작 공정을 이용하여 1×1cm^2 크기의 상부셀을 제작하였으며, 마지막 세 번째 단계로 결정질 실리콘 하부셀에 Ⅲ-V/Quartz/c-Si 구조로 에폭시를 이용하여 접합함으로써 탠덤태양전지를 완성하였다. 본 연구에서 Quartz 위에 제작된 InGaP/GaAs 2J 셀의 경우 탠덤공정을 고려한 ohmic 층 등 에피 최적화와 그리드 전극 최적화 등이 완료되지 않은 상태에서 15.7%의 효율을 보여주었으며, 기존 정상적인 2J 셀(효율 27.4%) 적용 시 Ⅲ-V/Si 탠덤 태양전지 최종효율은 32%(하부 Bifacial 실리콘 태양전지 고려 시) 이상 얻을 수 있을 것으로 예측된다.

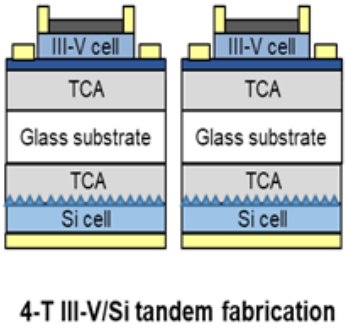
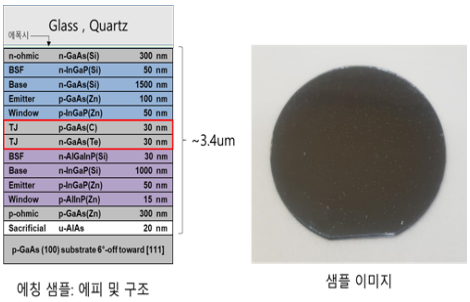


그림 1. 4-Terminal Ⅲ-V/Si 탠덤 태양전지



에칭 샘플: 에피 및 구조

샘플 이미지

그림 2. 2J InGaP/GaAs 셀와 Quartz기판 위에 접합된 에피층(기판 제거 후)

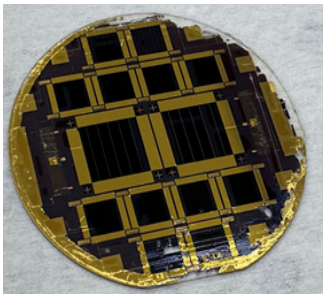


그림 3. 투명기판 위에 제작된 1×1cm^2 크기

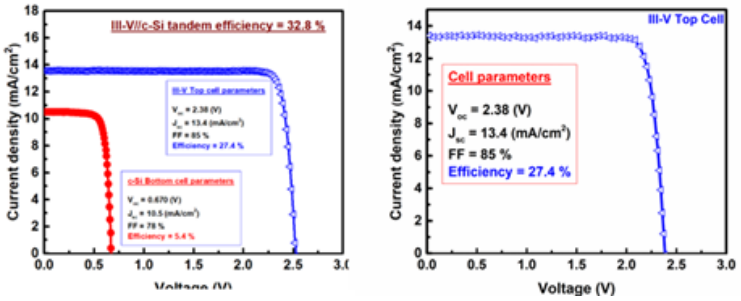


그림 4. 4-T Ⅲ-V/Si 탠덤태양전지 예상 효율 결과 InGaP/GaAs 2J 상부셀

Key words : Ⅲ-V/Si 탠덤 태양전지, InGaP/GaAs 2J, 4-터미널 소자 ,에폭시 접합

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나노폴리스텔린 구체를 이용하여 성장한 InP III-V 나노로드의 전기적 특성

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Electrical properties of InP III-V nanorods grown using Nanopolystyrene Spheres

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Abstract

우리는 나노 폴리스틸렌 구체 (PS)를 이용하여 형성된 InP 나노로드의 전기적 특성에 대하여 연구하였다. 성장방법은 기판위에 형성된 Au 나노구조체를 이용하여 Au 촉매방식의 vapor-liquid-solid (VLS) 방법으로 성장하였다. 나노 PS를 이용하여 InP 기판위에 증착된 30~40 nm 의 Au 박막을 에칭할 경우 Au colloid를 이용한 것 보다 정렬된 고밀도의 Au 나노구조를 형성할 수 있다. 또한 에칭가스를 이용하여 PS의 지름을 변경 시킬 수 있으므로 나노로드의 지름을 조절할 수 있다. 본 연구에서는 PS의 지름을 변경하였을 경우 InP 나노로드의 성장조건 변화에 대하여 조사하였고, Au colloid 로 형성된 InP 나노로드 구조와 전기적 특성을 비교하였다. 나노로드의 전기적 특성은 측정된 전류-전압곡선을 통해 Rectification Ratio 와 Ideality factor로 분석하였다.

Key words : Nanopolystyrene spheres(나노폴리스틸렌 구체), III-V nanorods(III-V족 나노로드)

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플라즈마 활성화에 의한 역방향 III-V족 이중 접합 태양전지와 실리콘 웨이퍼의 직접 웨이퍼 접합 공정

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Direct wafer bonding process of inverted III-V double junction solar cell and silicon wafer by plasma activation

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Abstract

우리는 GaAs 기판에 역방향으로 성장된 III-V족 이중접합 태양전지와 실리콘 웨이퍼를 접합하는 공정연구를 진행하였다. 접합공정은 실온에서 아르곤 가스를 사용한 플라즈마 활성화 웨이퍼 접합공정을 통해 III-V족 화합물과 실리콘 웨이퍼를 접합하였다. 접합된 III-V/Si 태양전지는 안정적인 셀 제조 공정 진행을 위해 100℃ ~ 200℃에서 어닐링 공정을 통해 접합면을 강화하였다. 전자주사현미경을 통해 접합면이 약 10nm 이하 두께의 비정질 접합층을 확인하였으며, 최종적으로 안정적인 접합을 위한 플라즈마 처리 조건과 어닐링 조건에 따라 III-V/Si 웨이퍼 접합 태양전지의 특성을 비교 측정하여 최적의 제조 공정 조건을 설정하였다.

Key words : III-V solar cell(III-V족 태양전지), Wafer bonding process(웨이퍼 접합 공정), Plasma-activated wafer bonding (플라즈마 활성화 웨이퍼 접합)

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See-Through Flexible Photovoltaic Modules of Ultrathin Silicon Solar Microcells Enhanced by Synergistic Luminescent and Reflective Near-Infrared Backplanes

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Abstract

Ultrathin single-crystalline silicon solar microcells assembled into see-through and flexible modules have exhibited broadly applicable cost-effective photovoltaics with reliable durability and efficiency. However, their module output power has suffered from inherent limitations caused by the inferior photon absorption property and the inactive see-through windows. Herein we present a strategy to enhance the performance of see-through flexible ultrathin silicon microcell modules by employing visibly transparent but near-infrared-manipulatable optical backplanes, such as a luminescent waveguide gathering near-infrared photons and a backside reflector mitigating near-infrared photon escape. Simultaneous integration of these near-infrared backplanes provides more photovoltaic gains to silicon solar modules than the sum of each backplane capability, which synergy is due to the promoted properties of the photoluminescence process and waveguiding. The experimental module with ~3- m thick silicon solar microcells can achieve up to ~40%-boosted output power generation when assisted by these backplanes. Detailed studies of optical and photovoltaic characterizations for near-infrared backplanes and their integration modules elucidate the effectiveness of designed backplanes for see-through flexible silicon photovoltaics.

건축물 태양광에서의 MLPE 인버터 및 스트링 인버터 운전사례 비교 연구

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A Comparative Study on MLPE Inverter and String Inverter Operation Cases in Building PV Power System

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Abstract : 박공형 지붕 건물의 정면에 부착된 간판에 의해 음영이 발생하는 건물의 남서향(방위각 240도) 지붕면에 설치된 95.76kW 스트링 인버터 태양광발전시스템과 반대편 북동향(방위각 60도) 지붕면에 설치된 74.52kW MLPE 인버터 태양광발전시스템의 남면 간판 음영에 따른 출력, 발전량 변화를 모니터링하고 두 종류 인버터의 최대 출력 추종 성능을 비교 연구하였다.
스트링 인버터에서는 음영에 따른 모듈 출력 불일치로 바이패스 다이오드가 작동하여 스트링의 발전량 손실이 발생하였을 뿐 아니라, 스트링 최대 출력 추종 실패로 인해 추가적 발전량 손실이 발행하였다. 이에 비해 MLPE 인버터에서는 모듈 단위에서 최대 출력 추종이 되면서 동시에 스트링 단위에서 동일 전류를 맞추어 주어 최대 출력 발전이 구현되었다. 1년간의 모니터을 통해 정량적 발전량 손실을 분석하였다.

The changes in power and generation amount of a 95.76kW string inverter PV power system installed on the southwest (240 degrees in azimuth) roof and a 74.52kW MLPE inverter PV power system installed on the opposite side, northeast (60 degrees in azimuth) roof of a building shaded by a signboard attached to the facade of the gable roof building according to the shade of the southern signboard were monitored and the MPPT performances of the two types of inverters were compared and studied.

In the string inverter, the bypass diode operates due to the module power mismatch due to the shade, resulting in loss of power generation of the string, and additional loss of power generation due to the failure of the string MPPT has occurred. On the other hand, in the MLPE inverter, the maximum power generation was realized by the MPPT in the module level and matching the same current in the string level at the same time. Quantitative generation loss was analyzed through monitoring for one year.

Key words : MLPE Inverter(MLPE 인버터), String Inverter(스트링 인버터), Building PV(건축물 태양광), Module Level Power Electronics(모듈 단위 전력 전자), MPPT(MPPT), Maximum Power Point Tracking(최대 출력 추종)

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p-PERC 갈륨 태양전지 모듈 대상 광열화 현상 회복 과정의 화학 반응 동역학 분석

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Chemical reaction kinetics of healing process on light-induced degradation for p-PERC module with gallium doped wafer

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Abstract : The light-induced degradation (LID) phenomenon in solar cells reduces power generation output. Previously, a method was developed to prevent LID where a group III impurity that can replace boron is added to the silicon wafer. However, in a subsequent study, performance degradation was observed in gallium-doped solar wafers and cells, and a degradation pattern similar to that occurring in light and elevated temperature-induced degradation (LeTID) was reported. In this study, a 72-cell module was fabricated using gallium-doped PERC cells, and the treatment of the LID process for carrier injection in the range of 1 to 7 A at 130 degreeC was analyzed using kinetic theory. We selectively heated only the solar cells inside a 72-cell module using a half-bridge resonance circuit for remote heating. To monitor the treatment of LID process in real time, a custom multimeter manufactured using an ACS758 current sensor and a microcomputer was used. Least-squares curve fitting was performed on the measured data using a reaction kinetics model. When the carrier-injection condition was applied to the gallium-doped PERC solar cell module at a temperature of 130 degreeC, the observed degradation and treatment pattern were similar to LeTID. We assumed that the treatment rate would increase as the size of the injected carrier increased; however, the 5 A condition exhibited the fastest treatment rate. It was deduced that the major factors of change in the overall treatment of the LID process vary depending on the rate of conversion from the LID state to the treatment state. In conclusion, it can be expected that the deterioration state of the gallium-doped solar cell module changes due to the treatment rate that varies depending on the carrier-injection conditions. This work was supported by the Korea Evaluation Institute of Industrial Technology (KEIT) (20015765, Technology development of the surface polishing equipment for passivation of large areas (M10-M12) p-PERC cell) funded by the Ministry of Trade, Industry and Energy (MOTIE, Korea), and conducted under the framework of the Research and Development Program of the Korea Institute of Energy Research (C2-2402).

Key words : Light-induced degradation(광열화), p-PERC(p-PERC), Chemical reaction kinetics(화학반응동역학)

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Monolithic pattern 구조의 대면적 perovskite 모듈을 위한 RF reactive sputtered-TiO_2 전자 전달층 연구

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Abstract : 페로브스카이트 태양 전지는 최근 빠른 효율 성장으로 큰 관심을 받고 있다. 페로브스카이트 태양 전지는 간단한 공정으로 제작할 수 있으며 전자전달 층으로 TiO_2가 많이 연구되었다. TiO_2는 화학적 안정성이 우수하고 가격이 저렴하다는 장점이 있다. TiO_2는 스핀 코팅 공정으로 간단히 얻을 수 있으며 단점으로는 대형화 및 두께 조절이 어려워 대면적 및 양산화가 어렵다. 또한 TiO_2는 anatase 구조가 선호되는데, 이는 450℃ 부근에서 생성되어 온도에 민감한 기판은 선택되기 어렵다는 단점이 있다. 본 연구에서는 이러한 단점을 보완할 수 있는 sputtering 방법을 사용하여 Indium Tin Oxide(ITO) 기판 위에 TiO_2를 증착하였고, 비싸고 깨지기 쉬운 단점이 있는 TiO_2 target보다 Ti 타겟을 RF 전원을 사용하여 reactive sputtering(RFRS)으로 박막을 제작하였다. TiO_2 박막은 XRD를 통해 구조를 분석하였으며 SEM으로 표면 특성을 확인하였다. 광학적 특징은 UV-visible spectroscopy로 측정하였으며 원소 비율을 XPS로 정량 분석하였다. 또한 태양 전지 소자는 15mmx15mm에서 성능을 비교하였고 50mmx50mm에서 미니 모듈을 제작하였다.

Key words : perovskite solar cells(페로브스카이트 태양 전지), TiO_2 thin film(TiO_2 박막), ETL(전자전달층), RF reactive sputtng(RF 반응성 스퍼터링), ITO substrate(ITO 기판)

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쉥글드 디자인 고출력 양면수광형 단결정 실리콘 태양광 모듈 제작

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Fabrication of Shingled Design Bifacial c-Si Photovoltaic Modules

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Abstract : Bifacial photovoltaic (PV) technology has received considerable attention in recent years due to the potential to achieve a higher annual energy yield compared to its monofacial PV systems. In this study, we fabricated the bifacial c-Si PV module with a shingled design using the conventional patterned bifacial solar cells. The shingled design PV module has recently attracted attention as a high-power module. Compared to the conventional module, it can have a much more active area due to the busbar-free structure. We employed the transparent backsheet for a light reception at the rear side of the PV module. Finally, we achieved a conversion power of 453.9 W for a 1300 mm × 2

Key words : Bifacial solar cells(양면형 태양전지), Shingled design(쉥글드 디자인), photovoltaic module(태양광 모듈), Transparent backsheet(투명 백시트), Electrically conductive adhesive(전기 전도성 접착제)

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건물부착형 고경량 유연성 쉉글드 태양광 모듈

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Fabricationg of Lightweight Flexible c-Si Shingled Photovoltaic Modules for Building-Applied Photovoltaics

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Abstract : Lightweight and flexible photovoltaic (PV) modules are attractive for building-integrated photovoltaic (BIPV) applications because of their easy construction and applicability. In this study, we fabricated lightweight and flexible c-Si PV modules using ethylene tetrafluoroethylene (ETFE) front cover and shingled design string cells. The ETFE front cover instead of glass made the PV modules lighter in weight, and the shingled design string cells increased the flexibility. Finally, we fabricated a PV module with a conversion power of 240.08 W at an area of 1.25 m^2 and weighed only 2 kg/m^2. Moreover, to check the PV module's flexibility, we conducted a bending test. The difference of conversion power between the modules before and after bending shown was only 1.7 W, which showed a power reduction rate of about 0.7%

Key words : Lightweight(경량화), Flexible photovolaic modules(유연한 태양전지 모듈), Building-integrated photovoltaic(건물 부착형 태양전지), Ethylene tetrafluoroethylene(에틸렌 테트라플루오로에틸렌), Shingled design (쉉글드 디자인)

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샌드위치 구조의 폴리실라잔 박막과 이를 이용한 박막 봉지 기술

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Flexible Thin-Film Encapsulant Design using Perhydropolysilazane Sandwich Structures

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Abstract : Although Perovskite solar cells (PSCs) have excellent photovoltaic properties, their stability issues have hindered widespread application. Therefore, encapsulation is essential for PSCs to extend their lifetime. Our study demonstrates that using perhydropolysilazane (PHPS)-based multilayered encapsulation can enhance the lifetime of PSCs. The PHPS was converted into silica under vacuum ultraviolet (UV) irradiation to encapsulate the PSCs. The encapsulation achieved a sandwich structure of PHPS/poly(ethylene terephthalate) (PET)/PHPS, with a water vapor transmission rate (WVTR) of 0.92×10^{-3} gm^{-2} d^{-1} (at 37.8 °C and 100% relative humidity). To confirm the moisture stability of the encapsulation based on PHPS/PET/PHPS barrier films, we performed a reservoir test of the encapsulated PSCs. The results indicated that the cell lifetime remained stable even after 1000 hours of ambient-temperature operation. Finally, we evaluated the mechanical flexibility of the PHPS/PET/PHPS multibarrier through bending tests. The multibarrier demonstrated high mechanical stability, and no significant increase in WVTR was observed after bending.

Key words : perhydropolysilazane(폴리실라잔), water vapor transmission rate(수분 투과도), organic/inorganic multilayer(유/무기 다층박막), thin-film encapsulation(박막 봉지공정), solution-processable(용액공정), perovskite solar cells(페로브스카이트 태양전지)

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산화 실리콘 나노 박막 기반 태양전지 봉지 기술 개발

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Development of solar cell encapsulation technology based on silicon oxide nano-thin film

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Abstract : Perovskite solar cells (PSCs) are a promising alternative to conventional photovoltaics due to their high power conversion efficiency (PCE) of 25.7%. However, their long-term stability is a concern due to moisture instability, which needs to be addressed before commercialization. Encapsulation is essential for enhancing the long-term stability of PSCs. In this study, a room-temperature thin-film encapsulation (RT-TFE) strategy is utilized to transfer a defect-free thermally grown silicon dioxide nanomembrane (t-SiO_2 NM) onto PSCs. This encapsulation strategy effectively protects the device from the external environment while minimizing damage to the device during encapsulation. The optimized RT-TFE strategy is used for thermally unstable $MAPbI_3$/spiro-OMeTAD based PSCs, resulting in an average PCE decrease of only 0.012% with a standard deviation of 0.4249 throughout the entire encapsulation process. The t-SiO_2 NM successfully protects the PSC from external water molecules in an underwater condition for 31 days at room temperature, the longest surviving time reported for PSC encapsulation. As a result, the RT-TFE PSCs maintain more than 98% of their initial efficiency.

Key words : Perovskite solar cells(페로브스카이트 태양전지), Room-temperature encapsulation(실온 봉지공정), Thin-film encapsulation(박막 봉지공정), Water barrier(방수층), Long-term stability(장기 안정성)

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2D/3D 이중층 구조를 통한 안정적인 페로브스카이트 태양전지

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Abstract : 2D/3D 이중층 구조를 통한 안정적인 페로브스카이트 태양전지

유무기 하이브리드 페로브스카이트 태양전지는 저온 공정성, 높은 흡광계수 및 긴 전하 확산 거리 등의 장점을 바탕으로 현재 25% 이상의 고효율이 보고되었으며, 이는 기존 결정질 실리콘 태양전지의 효율과 유사하다. 하지만 유무기 페로브스카이트는 낮은 결합에너지로 인하여 쉽게 이온이 이동하거나 이탈하며 결정성이 저하되고, 산소나 수분 등에 노출될 때 더욱 빠르게 열화가 진행되는 것으로 알려져 있다. 때문에 본격적인 상업화를 위해서는 지금의 열악한 안정성을 개선할 필요가 있다.

본 연구에서는 이러한 문제점을 해결하기 위하여 일반적인 ABX3 구조의 3D 페로브스카이트에 A2BX4 구조 Ruddlesden-Popper 상의 2D 페로브스카이트를 증착하는 이중층 구조로 박막을 형성하였다. 소수성을 띄는 큰 유기 양이온으로 구성된 2D 층은 외부 산소나 수분의 침투로부터 박막을 보호하고, 내부 이온의 이탈을 막아 결정성을 유지할 수 있어 결과적으로 페로브스카이트 박막의 안정성을 향상시킬 수 있다. 이처럼 안정성이 개선된 페로브스카이트 박막은 향후 실리콘 또는 다른 페로브스카이트와 결합한 태양광 모듈 등으로 적용할 수 있을 것으로 기대된다.[1]

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ECA를 활용한 Multi-busbar HJT 모듈의 repair 공정에 관한 연구

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A study on the repair process of multi-busbar Hetorjunction technology solar module using electrically conductive adhesives

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Abstract : Heterojunction technology (HJT) solar cells have gained attention due to their high efficiency and excellent passivation characteristics. As the passivation layer of the HJT solar cell, the intrinsic amorphous silicon layer is inserted between the doped layer, which forms the electric field, and the crystalline silicon wafer to obtain a high open-circuit voltage of 730 mV or more. However, the passivation layer of HJT solar cells has a problem in which hydrogen escapes at a high temperature of 200 °C or more, leading to the deterioration of passivation performance. Because of this problem, the existing high-temperature silver paste, which requires a firing process of over 800 °C, cannot be used, and a low-temperature paste must be used instead. However, low-temperature curing silver paste has the problem of poor adhesion between the electrode and the cell after soldering, which can cause a peeling off of wire after the cell interconnection process. To overcome this issue, electrically conductive adhesives (ECAs) have been demonstrated to repair the wire detached from the electrode.

Key words : HJT solar cells(이종접합 태양전지), MBB(멀티버스바)

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Comparison of the Power Generation of Building Integrated Photovoltaics by Seasonal Change

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Key word: building integrated photovoltaics, roof system BIPV, BIPV system temperature

Abstract: BIPV application is used for specialized applications of PV systems as an intrinsic part of the building. BIPV can take part in structuring the building while generating power. PV system mainly serves as a building's façade and/or roofing system. PV can be used as a curtain, glazing, or spandrel panel for a façade system, while it is applied as a roofing tile or shingle, standing seam, or skylight for a roofing system BIPV. By replacing one functional part of a building with a working PV system, the cost offset from it will be beneficial in the long run. Roofing system BIPV is viable to be used over residential house roofs, as there are many areas of the passively-functioning roof to be replaced by PV systems. Unlike conventional solar cells, BIPV is installed on rooftops or buildings, so electricity can be generated even in small areas. In this respect, BIPV can be installed in the middle of a city with a small site area with minimum land-opening effort. This experiment was done to check the power change of BIPV according to the seasonal change, with the installed module as shown in Figure 1 being tested. As the seasons change, solar irradiation and power showed similar patterns. It was confirmed that solar irradiation and power are the highest in spring and that solar irradiation and power are the lowest in summer, and through this, it was confirmed that temperature directly affects power production rather than solar radiation.



Figure1. BIPV installed in on the roof

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Performance Evaluation of Bifacial and Monofacial PV Modules Depending on Albedo Condition

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Key word: Bifacial photovoltaics, albedo, Bifacial Gain, Irradiance

Abstract: This paper analyze and compare the performance between the bifacial and monofacial PV systems based on the test conducted at Yeungnam University, Korea. The module's performance was observed on different ground condition: standard concrete and white concrete. The rear side irradiance and bifacial energy gains were analyzed. The power output was examined for a 2 years. The experiments were conducted on three parameters that include; (1) rear irradiance gain and bifacial energy gain, (2) total irradiance and power output, (3) Albedo and solar radiation changes in a year. Based on the annual rear irradiance gain analysis, the highest gain range was found for white concrete ground surface. White ground surface generated irradiance of between 5-60% more compared to the concrete ground, leading to an extra bifacial gain of 4-10%. Through this experiment, it was found that the rear irradiance, albedo and power of the bifacial module is vary depending on the ground condition, and the performance on the white ground surface was better than that on standard concrete.

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불소계 고분자를 이용한 태양전지 전면 인쇄 은전극의 내산성 강화 방안

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A Study on the Acid Resistance Characteristics of Printed Silver Electrodes Using Fluorine-based polymer

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Abstract : 인쇄 은전극은 지정된 영역에 선택적으로 필름을 증착함으로써 에너지와 재료의 소비를 줄인 전자장치를 제작할 수 있게 한다. 또한, 전극 제조를 위한 복잡한 공정을 제거할 수 있어 시장에서의 제품 가격 경쟁력을 확보할 수 있다. 유연한 기판과 인쇄된 전자제품의 결합은 웨어러블과 곡면으로 적용이 확대되었다. 이로 인해 인쇄 은 전극은 결정질 태양전지의 전면 전극으로 많이 사용되며, 이외에도 Perovskite 나 CIGS와 같은 양면형 박막태양전지에도 많이 사용되고 있다. 높은 온도에서 동작해야 하는 태양전지의 특성상 인쇄 은전극은 다양한 화학물질이 있는 환경에서 사용될 수 있다. 특히 장시간 고온과 자외선이 조사되는 환경에서 동작하는 결정질 실리콘 태양전지 모듈에서는 절연성 및 충격 방지를 위해 사용하는 EVA의 열화로 인해 카르복실산이 만들어지게 된다. 이로 인해 은 전극과 반응할 가능성이 높아지고 전극이 손상되거나 저항이 증가하는 snail-trail 현상이 발생한다. 따라서 결정질 태양전지 전면 전극으로 많이 사용되는 은 인쇄 전극은 취약할 수밖에 없고 그에 따라 적절한 필름으로 보호할 필요가 있다.

보호층의 바람직한 특성은 생산에 필요한 에너지 저감을 위한 저온 공정 가능성과 태양전지의 효율 확보를 위한 투명도가 높아야 한다. 인쇄 은전극을 갖는 소자의 신뢰성을 향상시킬 물질로 상온 처리가 가능하고 화학적으로 안정한 불소계 고분자(Cyclic transparent optical polymer, CYTOP)를 사용했다. 본 연구에서는 CYTOP으로 코팅된 은전극의 신뢰성에 미치는 영향을 연구하였다. 아세트산 노출 실험은 CYTOP 층이 화학물질로부터 은 전극을 보호할 수 있는 반면, 보호되지 않은 은 전극은 아세트산과 반응하는 것을 보여주었다. 보호층이 없는 은 전극의 저항은 70℃에서 2시간 이내에 초기값에 비해 10배 이상 증가한다. 반면 CYTOP으로 보호된 은 전극의 경우 주변 온도에 상관없이 초기 저항을 2주 이상 유지하여 은 전극과 아세트산 간의 화학 반응을 효과적으로 완화시키는 것으로 나타났다. 보호층을 도입함으로써 은전극의 안정성이 향상됨에 따라, 이를 구비한 시스템이 보다 긴 시간 동안 작동하면서 줄열에 의한 전력 손실을 줄일 수 있으므로, CYTOP 보호층은 은전극이 인쇄된 시스템의 수명을 향상시키는데 기여한다.

Key words : C-Si Moudle, Front electrode, Snail trail, Silver Electrode, CYTOP

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태양광 전기에너지의 직·병렬 혼합 토폴로지로 구성된 일대다중모듈 자기공진 무선전력전송 시스템을 위한 최적화 방안

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최근 사람들의 필요와 요구에 따라 다양한 회로로 구성된 기기에 무선전력전송 방식이 상용화되고 있다. 지속 가능한 발전의 토대가 되어 줄 태양광 전기에너지를 직·병렬 토폴로지로 구성된 다중모듈 무선전력전송시스템으로 전송하기 위한 자기공진 최적화 방안은, 인체 안전성과 무선전력전송 전송 효율의 극대화 및 전송 거리의 증대라는 시대의 요구에 필수적인 연구이다. 본 연구는 직·병렬 혼합 토폴로지로 구성된 일대다 무선전력전송 시스템을 위한 자기공진 최적화 방안으로, 직·병렬 혼합 토폴로지로 구성된 다중 수신기의 모든 전격용량과 공진주파수의 인체 안정성 및 송신기의 질량 등 다수의 제한 조건을 만족시키기 위한 수 백개의 설계변수를 최적화함으로 제한조건을 만족시키는 동시에 각 기기들 간의 커플링 효과를 고려한 구조적 전기적 변수들을 최적화하여 무선전력전송 효율을 극대화시킨다. 연구방법으로는 직병렬 혼합 일대다중모듈 무선전력전송 시스템의 자기공진 최적화를 위한 최적모듈과 목표 시스템의 전자기적 및 전기적 성능을 계산하기 위한 분석모듈로 구성되어 있으며, 두 모듈의 상호작용에 의해 완성된다. 하나의 송신기와 직렬 또는 병렬로 구성된 서로 다른 여러 개의 수신기로 구성된 자기공진 무선전력전송 시스템으로 검증된다.

Key words : 무선전력전송, 다중모듈 무선전력전송시스템, 공진 조건. 직·병렬 혼합 토폴로지

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쌀 재배 농지에서 영농형 태양광발전시스템 최적 설계 방법 연구

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A Study on the Optimal Design Method of the Agrivoltaic System in Rice Paddy

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Abstract : Agrivoltaic system should consider their impact on crop production as well as electricity generation. This study implement the simulation works considering variables such as distance between rows of the PV modules, fixed or tracking PV system, and the rice growth to design the optimal agrivoltaic system. The rice paddy for demonstration site is selected, the annual electricity generation is calculated through the PVSYST 7.3 software, and the homogeneity of the irradiation under the PV modules is evaluated using the Grasshopper for Rhino 6 software. Based on this research, the optimal design method for the installation and the operation of the agrivoltaic system in the rice paddy is proposed.

Key words : agrivoltaic, APV(영농형 태양광발전시스템), light saturation point(광포화점), border effect(주연효과), irradiation under the PV modules(태양전지 모듈 하부 일조량), homogeneity(균질도)

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수상태양광 이용률 향상 검증을 위한 양면형 모듈 실증시스템 구축 및 분석

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Establishment and Analysis of Bifacial Module System for Verification of Utilization rate Improvement in Floating PV

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Abstract : 최근 기후위기 대응을 위해 국내에서는 2050 탄소중립 정책을 수립하여 추진하고 있다. 저탄소 공정발굴, 탄소 포집 등과 더불어 기존시스템의 고효율화 또한 탄소 중립 달성에 매우 중요하다고 할 수 있으며, 특히 국내 신재생에너지의 70%를 차지하는 태양광 발전의 이용률 향상은 발전밀도 향상과 탄소중립에 주요한 요소로 작용할 수 있다. 태양광 발전의 이용률 향상을 위해 많은 연구가 진행되고 있으며, 양면형 모듈 개발 및 적용 또한 그중 하나이다. 그러나 육상환경에서 양면형 모듈 실증 및 적용사례는 있으나, 수상환경 조건에서의 실증 및 검증 사례는 미미하다. 본 논문에서는 수상태양광의 양면형 모듈 효과를 검증하기 위해 충주 연구용 수상태양광에 양면형 모듈 실증시스템을 구축하고 그 운영데이터를 분석한 결과에 대해 서술한다. 실증시스템은 단면형 모듈 1매, 양면형 모듈 3매의 총 4가지 케이스로 구성되어 있으며, 각 모듈의 발전량을 비롯하여 경사일사량, 수면반사량, 온도 등 환경변수를 취득하여 비교 분석하였다. 전면일사량이 적은 오전 8~10시와 오후 4~5시에는 10~30%의 수면 반사율을 확인하였으며, 전면일사량이 증가하는 오전 10시 이후 평균적으로 수면 반사율이 2~4% 유지되는 것을 확인하였다. 결과적으로, 수상태양광에 적용된 양면형 모듈은 단면형 모듈 대비 평균 5% 정도 발전량이 향상하는 것을 확인할 수 있었다.

Key words : Floating PV(수상태양광), Renewable Energy(재생에너지), Bifacial module(양면형 모듈)

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탄소중립을 위한 경상남도 에너지자립마을 선도모델 연구

김수환[1)]*, 신승구[1)], 박종성[1)]**

A study on a leading model for energy self-sufficient villages in Gyeonam Province for carbon neutrality

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Abstract : 정부에서는 기후변화로 인한 국내 피해를 최소화하고, 국제사회의 책임있는 일원으로서 기후위기 대응을 위해, 2017년 '재생에너지 3020 이행계획', 2021년 'NDC 상향', '2050 탄소중립' 등에 따라 재생에너지 발전량 비중을 상향 조정하는 추세이다. 경남도는 정부 재생에너지 확대 정책에 동참하고자, 2020년 '제6차 경남 지역에너지 계획', 2020년 '재생에너지 보급 목표 수정 계획' 등 재생에너지 발전량 비중을 확대하였다. 본 연구에서는, 한 마을 공동체에서 목표 자립률 달성을 위해 설치해야 할 신재생에너지 발전설비(태양광, 바이오가스 시설)의 규모 및 필요한 자본 금액 예측, 또는 자본 투입량 대비 달성 가능한 자립률의 추정치를 예측하는 수학적 모델을 제시하였으며, 마을 유형에 따라 농산촌형, 어촌형, 도시형 에너지자립마을으로 구분하며, 미래 기술이 아닌 현재 바로 설치가능한 신재생에너지 설비를 중심으로 모델링하였다. 또한, 에너지자립마을의 경제성 및 파급효과 분석: 에너지원(바이오, 태양광)별 자립마을 적합도 분석, 에너지원별 발전비용 및 경제적 파급효과 분석을 통해 재생에너지 적용 가능성을 검토하였음. 또한 친환경 관광산업과 연계한 특화자원 발굴 모델을 김해시, 거제시 사례를 통해 제시하였다.

Key words : Energy self-sufficient village(에너지자립마을), carbon neutrality(탄소중립), PV system(태양광 시스템)

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신재생에너지 기반 마을 단위 마이크로그리드 비즈니즈모델 연구

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A study on Business Model in Renewable Energy based Community Microgrid

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Abstract : 마이크로그리드는 전력의 생산과 소비가 소규모로 독립적으로 이루어질 수 있어 전력 시스템의 유연성 및 중앙 집중화 해소 기술로 각광 받고 있으며, 최근들어 분산에너지 활성화, 탄소중립 극복 방안으로 연구 관심이 크게 증가하고 있다. 또한, 마이크로그리드의 확산 및 보급을 위하여, 마이크로그리드 설계, 운영 및 지속 가능한 비즈니스 모델의 연구개발의 필요성은 커지고 있다. 마이크로그리드의 성장 핵심은 전력 활용의 유연성을 높여 전력시장 참여자의 안정적인 수익 창출에 있다. 지속적이고 안정적인 수익 창출을 위해서는, 마이크로그리드의 네트워킹을 가능하게 하고, 리소스를 공유하여 부하를 최대한 활용하고, 신재생 발전의 활용도를 최대한 높여서, 에너지를 최대로 이용하는 수익 모델을 개발하여야 한다. 본 연구에서는 마을 단위 마이크로그리드 기반 에너지 공동체 운영 방안을 고찰하고, 지속 가능하고 안정적인 수익을 창출할 수 있는 비즈니스 모델을 제안하고자 한다.

Key words : Renewable energy, Microgrid, business model, DER, NET-ZERO

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색균형 다중 형광 염료를 포함하는 폴리디메틸실록산 폴리머 및 투명 발광형 태양광 집광장치 응용

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Colour Balanced Multi-Fluorescent Dye Embedded Polydimethylsiloxane Polymer for Transparent Luminescent Solar Concentrator

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Abstract : Colour balance is a critical concept in the application of functional transparent polymers from a customer's standpoint. In this study, multiple polar and non-polar fluorescent dyes are embedded simultaneously for the first time in a polydimethylsiloxane (PDMS) polymer matrix. Five dyes successfully coexist with the optimum blending ratio. Furthermore, simultaneous dispersing of polar and non-polar dyes in the polymer is achieved. Absorption and photoluminescence characteristics of multiple fluorescent dyes in PDMS medium are systemically deconvoluted and discussed. The competitive average visible transmittance and colour balance of synthesized multi-fluorescent dye embedded PDMS is demonstrated by high colour rendering index and CIE colour space coordinates close to the white point. Additionally, the luminescent solar concentrator device demonstrates improved power conversion efficiency and light utilization efficiency than the pure PDMS waveguide-based device. Moreover, the long-term storage stability is demonstrated successfully. For the advanced ongoing research, multiple-step resonance and radiative energy transfers within five dyes are under investigation.

Key words : transparent luminescent solar concentrator(발광형 태양광 집광장치), transparent colour polymer(투명 컬러 고분자), multiple fluorescent dyes(다중 형광 염료), polydimethylsiloxane(폴리디메틸실록산), energy transfer(에너지 전달)

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대면적 페로브스카이트 태양광 모듈 응용을 위한 진공 스퍼터 방식으로 제작된 SnO_2 박막 연구

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Abstract : 페로브스카이트 태양전지는 높은 효율과 간단한 제작 과정으로 주목을 받고 있다. 페로브스카이트 태양전지 제작은 비교적 저온에서 진행되며 용액 공정이 대표적으로 사용되고 있다. 전자전달 층으로 사용되는 SnO_2 박막은 스핀 코팅 공정을 사용하여 얻을 수 있으며 전도성이 높고 투과율이 좋은 특징이 있다. 또한 기존의 TiO_2보다 band aliment가 더 적합하다. 하지만 스핀 코팅 공정은 양산화 및 대면적화가 어렵다는 단점이 있다. 따라서 이 연구에서는 대면적과 양산에 더 적합한 sputtering 방법을 사용하여 SnO_2를 증착하는 연구를 진행하였다. 많은 연구에서 sputtering 방법으로 SnO_2를 증착한 페로브스카이트 태양전지는 스핀 코팅으로 제작된 태양전지보다 낮은 효율을 보이는 경향이 있다. 따라서 스핀코팅 방법으로 제작된 SnO_2와 sputtering 방법으로 제작된 SnO_2와 차이를 비교 분석하였다.

Key words : Perovskite solar cells(페로브스카이트 태양 전지), SnO_2 thin film(SnO_2 박막), ETL(전자전달층), Spin coating(스핀코팅), Sputtering method(스퍼터 증착법)

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페로브스카이트 태양전지 모듈화 공정 연구

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Research on perovskite solar cell modularization process

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Abstract : 페로브스카이트 태양전지는 기존 상용화 실리콘 태양전지와 비교하여 저온 및 용액공정이 가능하고, 제작비용이 저렴한 이점이 있어 많은 연구가 진행되었다. 특히 광학적 · 물리적 특성이 뛰어나 최근 25.8%라는 높은 효율 성장력을 보이는 태양광 소재이다. 하지만 상용화를 위한 연구로써 페로브스카이트 태양전지는 고온이나 수분 및 산소 등의 외부요인에 안정성 문제나, 셀 소자의 크기에서 모듈 크기까지 면적 증가에 따른 특성 감소 동의 문제가 존재하고 이를 해결하기 위한 많은 연구가 진행되는 상황이다. 이에 본 연구에서는 셀 크기의 소자에서 50 x 50(mm2) 크기의 페로브스카이트 태양전지 mini 모듈을 제작하는 연구를 진행하였고, 저온 밀봉 소재를 이용한 모듈화 공정 연구를 진행하였다. 태양전지 소자는 monolithic 구조로 제작하였고, mechanical scribing 방법으로 내부 셀을 isolation 하였다. 저온 밀봉 공정으로는 수분 차단 특성이 뛰어나고 물리 · 화학적 안정성이 뛰어난 butyl 소재를 사용하여 vacuum lamination 하였다. 그 결과 셀 크기의 페로브스카이트 태양전지 소자와 유사한 특성을 보이는 mini 모듈 소자를 제작하였다. 또한 85℃, 85% RH 조건에서 신뢰성 평가를 진행하였고 장기 안정성 특성의 변화를 확인하였다.

Key words : Perovskite solar cell(페로브스카이트 태양전지), Modularization process(모듈화 공정), Low temperature sealing(저온 밀봉), Mini module(미니 모듈), Long-term stability(장기 안정성),

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정확한 태양광 발전량 예측을 위한 Extreme Gradient Boosting 모델

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Extreme Gradient Boosting model for Accurate Solar Power Forecasting

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Abstract: Accurate forecasting of solar power generation is essential for effective energy management and grid integration. Traditional forecasting methods have limitations in accuracy and data quality dependency. This work describes the effectiveness of the Extreme Gradient Boosting algorithm to predict solar power generation in the Indian peninsula. A 34-day solar power dataset from two solar plants in the north part of India was used and selected the fitted hyperparameters for high accuracy. The accuracy of Extreme Gradient Boosting forecasting was better than those of traditional forecasting methods, indicating its potential for a highly accurate and reliable solar power forecasting approach.

Key words : Artificial Intelligence(인공지능), Forecasting(예측), Solar Power(태양광), Extreme Gradient Boosting(XG부스팅)

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랜덤 포레스트 알고리즘 활용한 고정확도 태양광 발전량 예측

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Unlocking Accurate Solar Power Forecasting using Random Forest Algorithm

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Abstract : Precise solar power generation forecasting is crucial for effective energy management and successful grid integration. However, the traditional methods are limited by accuracy and data quality dependence. This study aims to use Random Forest Regression (RFR) to forecast solar power generation in the Yeongam-gun region of Jeollanam-do, South Korea. The dataset used in this study was comprised of 3000 recorded PV data including regional and meteorological data from 2018 to 2019. After training and testing, the results showed that the RFR model was able to accurately predict solar power generation with an R^2 value of 0.98, suggesting a strong correlation between the predicted and actual values. This study demonstrates the effectiveness of RFR model in forecasting solar power generation and its potential application in the other renewable energy industry.

Key words : Artificial Intelligence(인공지능), Forecasting(예측), Solar Power(태양광) Random Forest(랜덤포레스트)

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물리모델과 기계학습모델을 이용한 태양광 발전성능 추정 기술

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Photovoltaic Performance Estimation Technology Using Physical model and Machine learning model

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Abstract : 본 논문에서는, 회귀 알고리즘을 이용한 기계학습 모델을 제안하여 BIPV 시스템에서의 발전 성능 출력을 추정하였다. BIPV 시스템은 컬러 모듈이 적용되어 있고 3.5 kW급 인버터의 측정 데이터를 이용하여 실험을 실시하였다. 설치된 컬러 모듈은 dot 패턴으로 컬러가 구현되어 있고 26장이 직렬로 연결되어 최대 2.5 kW 발전된다. 일사량계와 모듈 후면에 열전대 센서를 부착하여 기상환경 데이터를 수집했다. 실험은 태양광시스템의 물리모델과 제안하는 모델을 실제 측정된 발전데이터와 비교 분석을 하였다. 물리모델은 총 세 가지를 사용하였다. 일사량의 변화에 따라 효율값이 변화되는 것을 고려한 단순 효율 모델, 단순 효율 모델에서 온도 상승에 따른 열 손실의 대한 전력 손실 효율값을 추가로 고려한 온도 보정 모델 마지막으로 온도 조건 25°C에서 일사량을 200 W/m^2 씩 변화시켜 200-1000 W/m^2 까지 I-V curve를 측정하고 각 일사량에 따른 I_{MP}, V_{MP} 값을 산출하여 회귀식으로 나타낸 일사량 변화에 대한 회귀 물리 모델이다. 기계학습 모델은 회귀알고리즘을 사용하였으며 입력요소로는 물리모델의 출력 계산값, 인버터의 측정데이터인 일사량, 모듈온도를 사용하여 출력값을 도출하였다. 모델들을 결정계수, 평균 제곱근 오차(RMSE), 정확도로 평가하였으며 선형 회귀 분석을 실시하였다. 실험 결과 물리모델과 제안한 모델의 결정계수가 0.96이상으로 선형 회귀 분석을 통해 도출된 식에 적합함을 보였고 일사량 변화에 대한 회귀모델의 RMSE 값은 0.1497 kW, 정확도 값은 86.44% 로 물리모델 중 가장 정확한 모델임을 확인하였다. 제안한 모델의 RMSE 값은 0.0451 kW, 정확도 값은 96.56% 값을 확인하였다. 따라서 본 논문에서 제안한 모델은 물리모델만을 사용하여 발전량을 추정한 값보다 RMSE 값이 0.1046 kW 감소하였고 정확도 값은 10.12% 향상되어 물리모델만을 사용하여 발전량을 추정하는 기법보다 인공지능이 결합된 추정기법을 이용한다면 보다 정확한 추정 및 예측이 가능한 것을 입증하였다. 추후 제안한 모델의 정밀도를 향상시키기 위해서는 양질의 데이터를 대량으로 투입하고 더 세분화된 형태의 빅데이터를 구축한다면 보다 향상된 결과를 확인 할 수 있을 것이다.

Key words : BIPV, machine learning, physical model, root mean square error, regression algorithm

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출력복원한 에코모듈의 실증모니터링을 통한 I-V Curve 특성 분석

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Analysis of I-V curve characteristics through empirical monitoring of output restoration Eco-module

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Abstract :
에코모듈은 노후 및 불량이 발생하여, 발전소에서 직접 수거 및 점검을 통해 고장유형을 파악하고 출력을 복원시킨 모듈을 말한다.
해당 모듈을 대상으로 신뢰성 평가를 위해 10kW급의 실증 평가를 진행하였고, 출력상태(I-V Curve 및 발전량)을 확인하였다.
현장 실증에 활용한 모듈은 2종류이며, 총 3 String으로 구성하였고, 약 2개월간의 실증데이터을 수집하여 IEC 62446-1 규격지침에 따라 String별 I-V Curve 의 출력성능을 분석하였다.
분석 결과, String 구성에 따라 각각 다른 형태의 I-V Curve의 출력을 확인할 수 있었다.

Key words : Echo module(에코모듈), Failures of PV(고장 PV모듈), PV Monitoring(실증모니터링), I-V Curve(전압-전류 곡선), IEC 62446-1

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M12 태양전지를 이용한 645Wp급 대면적·고효율 양면형 태양광모듈 개발 및 필드실증

김지현[1,2)]*, 김주희[2)], 김정훈[3)], 김창헌[2)]**

Development and Field Demonstration of 645Wp calss large area&high efficiency Bifacial solar module using M12 Solar cell

Jihyun Kim[1,2)]*, Ju-Hee Kim[2)], Junghoon Kim[3)], Changheon Kim[2)]**

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Abstract : 정부의 재생에너지 3020 이행계획 보급활성화와 RE100, 그리고 최근 IEA 2050 넷-제로 로드맵에 따라 재생에너지 이하 태양광발전 기술개발이 이루어지고 있다. 이에, 태양광 모듈의 저가화로 인한 제조사들 간의 가격 경쟁력 확보를 위하여 현재 기존의 전통적인 6인치 태양전지(M0 ~ M4 Solar cell)가 적용된 태양광 모듈 제조기술에서 대면적 태양전지(M5 ~ M12)를 이용한 대면적 태양광 모듈 제조기술 분야로 급격하게 기술 트렌드가 변화되고 있으며, 태양전지의 대면적화에 따라 동일 공정에서의 생산성 향상, 생산단가 감소가 이뤄진다.

본 연구에서는 M12(210mm) 대면적 결정질 실리콘 양면 태양전지를 이용한 645Wp급 대면적·고효율 양면형 태양광 모듈을 개발하여 필드실증을 통한 성능테스트를 진행하였다.

Key words : Bifacial Solar Module(양면 태양광 모듈), Large Area(대면적), High Efficiency/High Power(고효율/고출력)

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소용량 노후 PV 모듈의 수명예측 및 고장진단 알고리즘 개발을 위한 현장시험 분석

김근호[1], 양나래[1], 임철현[1]*

Analysis for lifetime prediction and failure diagnosis algorithm of small-capacity obsolescene PV modules

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Abstract : 국내 태양광 발전 설비가 '04년경부터 보급된 이후 '30년 2만톤 그리고 '40년에 8만여톤의 폐기물(폐 모듈 등)이 발생할 것으로 예상되며, 이에 대한 폐 모듈의 재활용 및 재사용 사업이 추진되고 있으나 현재 그 효과는 아직 미미한 수준이다. 특히 기존 설치된 태양광 발전 시설의 70%이상을 차지하는 중ㆍ소형 발전설비의 발전효율, 성능유지, 내구연한 증대(관리) 그리고 자원순환 등에 대한 기술 및 관리체계가 필요하다.
본 연구에서는 소용량의 노후 태양광 설비의 ICT 안전관리 및 원격 지능형 운영·유지보수(O&M), 노후 모듈 복구 및 재활용을 위한 기술(운영 효율과 발전량 및 설비수명 10% 증대) 개발을 위해 ①송광면 정복시센터(10kW, 250W x 40매), ②용당노인복지관(12kW, 200W x 60매), ③동부노인복지관(21.5kW, 215W x 100매), ④우석어린이집(25.2kW, 300W x 84매)의 총 4개소 실증지 옥상에 설치된 소용량 노후 태양광 설비에 대한 현장 시험분석(열화상 드론 및 I-V curve 등)을 추진하였다. 각 실증지별 드론을 활용한 열화상 촬영 및 분석 결과 공통적으로 외부 시설물에 의해 발생된 음영 및 초기 설치된 장치 고장 등에 따라 일부 hot-spot 혹은 바이패스 다이오드 현상이 발견되었으며 I-V curve 등 측정한 바 사용기간 대비 최대 발전량 감소는 최대 10% 이내로 조사되었다. 위 결과를 바탕으로 ①송광면 정복시센터의 hot-spot 의심 모듈 4매 그리고 바이패스 다이오드 의심 모듈 7개 등 철거 후 EL 분석 등을 통한 노후 태양광 모듈의 고장진단 분석 및 알고리즘 개발과 모듈 수명예측 및 건전성 및 위험도 평가 추진하고자 한다.

Key words : Small-capacity obsolescene PV modules(소용량 노후 태양광 모듈), Life-time prediction(수명예측), failure diagnosis(고장진단), Thermal image(열화상), I-V curve(I-V 곡선)

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태양광발전시스템에서 부분 음영에 따른 모듈 단위 마이크로 컨버터 특성 연구

김주희[1)]*, 김지현[1),2)], 김창헌[1)]**

A Study on Module Level Micro Converter Performance in Photovoltaic Systems by Partial Shading

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Abstract : 태양광은 대표적인 신재생에너지로 많은 연구가 진행되고 있으며, 태양광발전시스템에서 발전 성능 향상을 위해 다양한 방법들이 연구되고 있다. 그중에서 모듈 단위 마이크로 컨버터는 태양광 모듈과 마이크로 컨버터를 직렬연결하며, 부분 음영, 낙엽, 먼지 등에 의한 모듈 간 또는 스트링 간 전기적 특성 차이로 인해 발생할 수 있는 전체 태양광발전시스템의 발전량 하향 평준화 현상을 모듈 단위로 개별 최대전력점추적 제어를 통하여 태양광발전시스템의 발전량 감소를 최소화 할 수 있는 장점이 있다.
본 연구에서는 Buck-Boost 타입의 직렬형 마이크로 컨버터를 태양광 모듈 단위로 직렬연결하여 부분 음영에 따른 태양광 모듈 및 스트링 단위에서의 발전 특성을 연구하였다. 나아가 모듈 단위 마이크로 컨버터 유·무에 따른 일간 발전 성능 분석을 진행하였다.

Key words : Photovoltaic System(태양광발전시스템), Partial Shade(부분 음영), Module Level Micro Converter(모듈단위전력전자소자), Power Optimizer(파워옵티마이저), Maximum Power Point Tracking(MPPT, 최대전력점추적)

후기 : 본 연구는 산업통상자원부(MOTIE)와 한국에너지기술평가원(KETEP)의 지원을 받아 수행한 연구 과제입니다. (No. 20215810100310)

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쉥글드 모듈 백 시트에서의 빛 반사 분석

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Light reflection on backsheet of shingled photovoltaic module

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Abstract : The war between Ukraine and Russia taught us that energy can be used as a weapon. This is a phenomenon that occurred because the place where energy is produced and the place where energy is consumed are different. Solar power generation is free from these problems because the place where energy is produced and the place where is consumed are the same. Also to achieve Net-zero by 2050, solar industry should grow rapidly with compound annual growth rate of 25% between 2022~2030.

In manufacturing process of photovoltaic modules, there are elements that caused decrease or increase of module efficiency. We need to eliminate the optical power loss factors and emphasize the optical power gain factors. We quantitatively calculated by adjusting the value of cell gap and string gap for 60-cell, 72-cell modules and shingled module to find the maximum output condition.

Key words : Power loss(출력 감소), Power gain(출력 증가), Reflection(반사), Module(모듈), Optics(광학)

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고출력 태양광 모듈 제작을 위한 유한요소법 기반 대면적 모듈의 처짐 현상에 관한 연구

한동운[1)]*, 김효규[1)], 김성탁[1)]**, 모찬빈[1)]**

A Study on the Deflection of Large-area Solar Modules based on Finite Element Method for Manufacturing High-power Solar Modules

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Abstract : 최근 전 세계적으로 태양전지 제조에 사용되는 웨이퍼의 대면적화를 위한 개발이 가속화되고 있다. 웨이퍼를 대면적화할 경우 단위 생산량 및 출력 증가하고, 모듈 제조 시 동일 면적을 상대적으로 적은 수의 셀로 구성할 수 있어 각 셀에 요구되는 전기부품 및 조립시간이 감소해 제작비용을 줄일 수 있는 장점이 있다. 2019년 이전 웨이퍼 시장점유율 80% 이상이 M2셀이었으나, 2021년에는 M6셀이 42%, M10셀이 27%, 2022년 2분기를 기준으로는 M10셀이 50% 이상으로 예측되면서 대형 실리콘 웨이퍼의 시장점유율이 급속하게 증가하고 있는 추세이다. 또한 웨이퍼가 대면적화 됨에 따라 고출력 모듈에 대한 수요를 맞추기 위해 대면적 태양전지를 집적한 모듈화 개발이 진행되며 모듈의 크기도 점차 증가하고 있는 실정이다.
그러나 태양광 모듈의 크기가 증가할수록 무게 또한 증가하며, 기존 알루미늄 프레임을 적용해 설치할 경우 자중 및 외압에 의해 처짐이 발생하여 셀이 하중을 받아 변형될 가능성이 있다. 하중에 의해 셀이 변형되면 셀 내부 크랙 및 파손으로 인해 데드 셀(Dead cell)이 증가하며 이는 충전율과 효율의 감소로 귀결된다.
따라서 본 연구에서는 유한요소해석을 통해 대면적 모듈의 처짐량을 분석하고 모듈 제작에 사용되는 알루미늄 프레임의 형상 및 소재를 변경함으로써 처짐량을 최소화하고자 하였다. 먼저 기존 상용 알루미늄 프레임을 적용하여, 585W급 M10셀 태양광 모듈에 자중 및 풍압, 적설압을 부과해 유한요소해석을 수행하였다. 이후 프레임 형상 인자를 변경하며 유한요소해석을 수행해 처짐량이 최소가 되는 형상 인자를 도출하였다. 또한 알루미늄 압출 소재에 대해 상대적으로 강성이 높은 소재를 적용하여 구조해석을 수행함으로써 소재에 따른 변형거동을 평가하고자 하였다.

Key words : Solar module(태양광 모듈), Solar panel frame(태양광 패널 프레임), Deflection(처짐), Finite element method(유한요소법), Finite element analysis(유한요소해석)

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FTO 박리현상을 이용한 태양광 모듈 유리 분리 및 메커니즘 확인

고종원[1)]*, 배수현[1)], 강윤묵[2)], 이해석[2)], 김동환[1)]**

Mechanism of FTO delamination for separating glass in silicon photovoltaic module

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Abstract : The growth in the installation of photovoltaic (PV) modules has raised concerns over the management of end-of-life modules, as the increasing amount of waste generated from these modules may have significant environmental and economic impacts. Current disassembly methods, such as incineration, can result in broken solar cells and the generation of harmful substances.

To address this issue, the FTO delamination method was proposed in this study, which aims to separate the glass from the module without damaging the solar cells or generating harmful substances. The proposed method was tested experimentally, with an FTO thin film deposited on glass and successfully removed through delamination. The separation of glass from encapsulant was also confirmed using two types of encapsulants, EVA and POE. Moreover, a small silicon module structure was developed and tested to confirm the feasibility of the FTO delamination method.

In addition, XRD and SIMS measurements were performed to confirm the delamination mechanism of FTO, which further supports the potential effectiveness of the proposed method.

Key words : Photovoltaic modules(태양광 모듈), FTO delamination(FTO 박리), Glass separation(유리 분리), delamination mechanism(박리 메커니즘)

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Bifacial p-PERC 태양광 모듈에서의 PID로 인한 polarization effect 연구

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A study on polarization effect due to PID in bifacial p-PERC solar modules

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Abstract : Bifacial solar cells, with their ability to absorb light from both sides, are gaining traction as an efficient and cost-effective solar technology. Currently, bifacial solar modules account for nearly 30% of the global solar market and are expected to surpass 60% by 2032. Among the bifacial solar cells, bifacial p-PERC solar cells have been commercially available since 2017 and are in mass production. However, potential-induced degradation (PID) caused by exposure to high temperatures and humidity can occur in some cells within the module, leading to reduced efficiency. This degradation is known to occur more severely at the back side than the front side of the solar cell. In previous studies, PID-s (shunting) at the front and PID-p (polarization) degradation at the rear have been observed, but the mechanism behind the rear polarization remains unclear. In this study, we fabricated a bifacial p-PERC solar module and conducted PID and recovery experiments, analyzing its characteristics through various measurements such as light J-V, dark I-V, and electroluminescence (EL) imaging. Our results shed light on the degradation mechanism in bifacial p-PERC solar cells and can potentially lead to the development of solutions to mitigate PID, increasing the efficiency and longevity of bifacial solar modules.

Key words : Bifacial solar cells, Potential-induced degradation (PID), p-PERC solar cells

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PCM을 적용한 ESS 배터리 함체의 온도관리에 관한 수치해석 연구

지형용[1)]*, 이대규[2)]

Numerical study on thermal management of ESS battery chamber using PCM

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Abstract : PCM(phase change material) play a role of the absorb and release for a heat load, it can realize uniform temperature control, has a long lifespan, and is also relatively inexpensive. Due to the this reason, PCM are many studied applied to BTMS(battery thermal management system) for the various battery type. The main function of BTMS-applied PCM is that PCM absorbs heat at ambient temperatures higher than the phase change temperature range and dissipates heat at low temperatures, controlling the temperature and having the shifting effect of the thermal load peak range. Currently, the studies of BTMS-applied PCM is main contents for that to analyze thermal characteristics when charge/discharge by directly contacting PCM with battery cells and packs units, in order to increases thermal conductivity of PCM. However, there is no research on applying PCM to a large-capacity ESS with battery racks installed. In this work, the thermal properties numerically was analyzed for air inside ESS chamber according to without and with PCM placing. Figure 1 is the temperature distribution for ESS chamber according to without and with PCM module, under outside temperature of 35℃. The ESS chamber has a size of WDH 2,400 × 2,100 × 2,400 mm, and four battery racks of about 250 kWh was installed. The air temperatures of middle three points as marked show temperature difference for case without and with PCM placed in ESS chamber. The air temperature inside ESS is decided by inside heating load of battery by charging/discharging and the outside load by weather, and outside load has a high correlation. We will show for the various thermal characteristics in ESS chamber placing PCM module in detail.

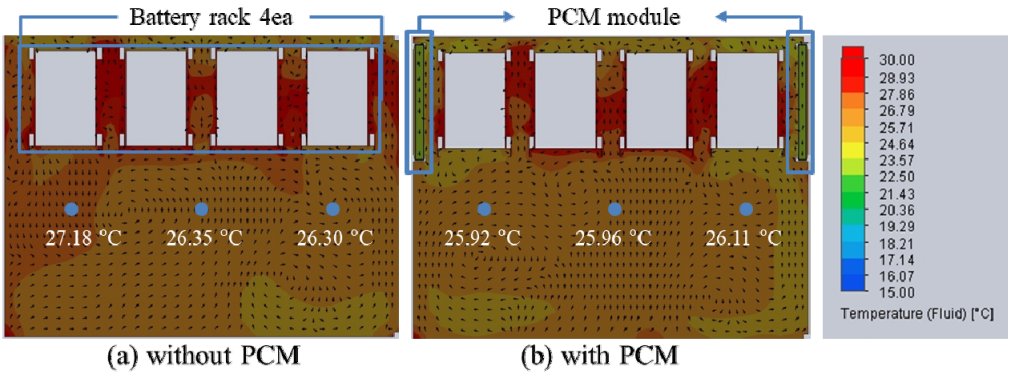


Fig. 1 Air temperature distribution for ESS chamber according to without/with PCM module

Key words : Battery thermal manegement system(배터리 열관리 시스템), Phase change material(상변화물질)

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N 타입 태양전지의 고전압 열화 (PID) 현상

배수현[1)*]

Potential induced degradation (PID) of n-type crystalline silicon solar cells

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Abstract : 실리콘 태양전지 모듈의 Potential induced degradation (PID)는 태양광 모듈 출력 감소 이슈 중에서 가장 화제되는 현상 중 하나이다. PID는 모듈을 직렬로 연결할 때, 모듈 내부의 태양전지와 접지된 모듈 프레임 사이에 높은 전위차이에 의해 발생된다. 많은 문헌들에서 p-type 웨이퍼를 기반으로 한 태양전지 모듈의 PID에 대해 연구되어 왔다. 고 효율 실리콘 태양전지 제작을 위해 n-type 웨이퍼를 사용하는 실리콘 태양전지 연구가 활발히 진행되는 추세이고, n-type 웨이퍼 기반 태양전지 모듈에 대한 PID 현상에 관한 연구 중요성이 증가하고 있다. 본 연구에서는 n-type 웨이퍼를 사용하며, p-type 상용 태양전지 구조와 동일하게 전면 에미터 및 후면 전계를 형성한 구조의 태양전지 모듈의 PID 현상을 확인하였다. n-type 및 p-type을 기반으로 하는 태양전지 및 모듈의 PID 시험을 진행하고, 출력 및 효율 변화, 양자 효율 (QE), electroluminescence 평가 등을 통해 두 태양전지 기반 재료에 따른 PID 현상의 차이점을 설명하였다.

Key words : Potential induced degradation(고전압 열화), Silicon solar cell(실리콘 태양전지), Module (모듈), Leakage current (누설 전류)

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비닐하우스 사이 공간을 활용한 수직형 영농형 태양광 발전설비 개발

조건영[1], 도기일[2], 남재우[3] 임철현[1]*

Development of vertical agrophotovoltaic system utilizing the space single span greenhouse

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Abstract : 2017년 12월부터 정부에서 시행되어 온 '재생에너지 3020' 및 그 간의 재생에너지 정책에 대한 평가를 바탕으로, 향후 국내 재생에너지 정책의 전반적 방향을 재설정하는 내용으로 2022년 11월 '에너지 환경 변화에 따른 재생에너지 정책 개선방안'을 발표하였다. 주요 정책 과제 중의 하나로 주민 수용성에 기반한 재생에너지 보급을 목표로 하고 있으며, 유휴부지 활용을 적극 확대하여 주민 반발을 최소화하는 것은 중요하다. 따라서 본 연구에서는 영농형 태양광 보급 모델 중의 하나인 단동 비닐하우스 사이의 유휴 공간을 활용함으로써 설치비용 절감과 동시에 공간 활용도를 높일 수 있는 영농형 태양광 시스템을 개발하였다. 충청북도 청주에 10.502m^2 규모의 실증단지를 확보하여 2가지 type의 기존 영농형 모델(30° 설치)과 펜스형 모델(90° 설치)로 구성하였다. 단동 비닐하우스 사이의 좁은 공간에 설치를 해야 함에 따라 사전 제작된 구조물을 회전직립식 시공법을 적용하여 시공 기간 및 비용을 최대한 절감하고자 하였다. 본 구조물은 MIDAS GEN 프로그램을 사용하여, 설계 기본 풍속 30m/s와 지상적설하중 0.5kN/m^2으로 구조적 안정성을 확보하였다. 15kW급(480W 양면형모듈, 각 13매)으로 각각 구성하여 높이 3m, 모듈사이의 거리를 4m로 설치하여 실증연구를 수행중에 있다.

Key words : Agrophotovoltaic(영농형태양광), Single span greenhouse(단동 비닐하우스), Vertical(수직형)

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2) 모든솔라(주)
3) 솔라팜(주)

원통형 배터리 모듈에서 셀과 셀 사이 냉각관 삽입 구조에 대한 냉각 성능 해석적 연구

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Numerical analysis study on the cooling performance of the cooling pipe insertion structure between cells in a cylindrical battery module the thermal characteristics of the pouch battery cell with C-rate

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Abstract : 리튬이온 배터리는 긴 수명, 높은 에너지 밀도, 낮은 자가방전율의 장점으로 인해 전기자동차에 널리 사용되고 있다. 리튬이온 배터리의 최적의 작동 온도는 20~40℃이며, 온도 범위에서 벗어난 열발생은 배터리의 수명을 단축시키고 극단적으로는 열 폭주를 유발해 화재 및 폭발의 위험성을 초래할 수 있다. 따라서 배터리에서 발생하는 열을 제어하기 위한 배터리 열 관리 시스템이 필수적이다. 기존의 원통형 배터리 냉각시스템은 하부에 냉각시스템을 두었으며, 이는 고율 충·방전 조건에서는 큰 영향을 미치지 않는다. 현재 테슬라는 원통형 배터리 셀 옆면에 냉각 채널을 부착하고 있으며, 이는 배터리 팩 시스템의 무게를 증가시키는 단점이 있다. 이에 본 연구에서는 원통형 배터리 모듈을 효과적으로 냉각시키기 위하여 셀과 셀 사이에 냉각 유로를 구축하는 시스템을 제안하였으며, 이에 대한 해석을 수행하였다. 또한, 기존의 냉각시스템과 제안된 시스템의 해석 결과를 비교분석 하였다. 그 결과, 3 C-rate, 냉각유량 2 l/min의 조건에서 기존의 냉각시스템의 배터리 모듈 평균온도 46.3℃로 나타났으며, 제안된 냉각시스템의 배터리 모듈 평균온도는 38.1℃로 나타나 약 8℃정도 감소됨을 확인하였다.

Key words : C-rate(충·방전율), Cooling pipe(냉각관), Cylindrical battery cell(원통형 배터리 셀), Temperature (온도)

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2) 조선대학교 기계공학과

고출력 N-Type HJT 모듈 제작을 위한 저온 Soldering 연구

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Low-temperature soldering process study for High Power Photovoltaic of N-type HJT Shingled-modules

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Abstract : The solar industry is actively researching the development of high-power photovoltaics modules that allow many cells's integration in the area of the modules, as known as shingled-modules. To manufacture the shingled-module, M6 HJT cells were scribed with conditions (140 kHz, 17.4W, 550mm/s. 2 times) using an IR laser (1064 nm) and the cross-sections of the cut cells were analyzed through SEM images. Subsequently, to produce the shingled-string, ECA (Electrically conductive adhesives) were dispensed on the bus-bars of the cut cells and then connected to the rear of another for series connection characteristics. Manufacturing process for PERC module is commonly performed using soldering method with End-ribbon around at 350 ℃. Contrastively, the transparent conductive oxide (TCO) layer and hydrated amorphous silicon (a-Si:H) layer inside the cell structure can be damaged, resulting in a decrease in cell characteristics and bowing phenomenon, that's because N-type HJT cells are exposed to the temperature about 350℃. To improve this problem, low-temperature soldering connection experiments using the equipment for End-ribbons connect were conducted, resulting in improvements of the bowing phenomenon.

Key words : low temperature Soldering(저온접합), Hetero-junction technology(이종접합 기술), Silicon solar cell, (실리콘 태양전지), Electrically conductive adhesives(전도성 접착제)

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2) 저자의 소속 : 전남대학교 신소재공학
3) 저자의 소속 : 한국생산기술연구원 그린에너지나노연구그룹
4) 저자의 소속 : 연세대학교 화공생명공학과

그린허브스테이션 활용을 위한 AI 기반 태양광 발전량 예측 알고리즘 개발

이민호[1)*], 장미금[1)], 정승환[1)], 최지은[1)] 이석호[1)**]

Development of AI-based PV Power Generation Forecasting Algorithm for use in Green Hub Station

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Abstract : 최근 세계적으로 유례없는 에너지난으로 인해 태양광을 비롯한 재생에너지원의 활성화에 대한 여론이 형성되고 있다. 그러나 신재생에너지원은 간헐적인 발전 특성으로 인해 발전량 예측이 어려워 계통의 신뢰성 저하와 계통관리가 어렵다는 문제가 지속적으로 제기되었다. 이에 신재생에너지의 발전 효율 향상과 그리드의 신뢰성 제고를 목적으로 태양광 발전량 예측기법에 대한 다양한 연구가 진행되고 있다. 본 연구는 AI 딥러닝을 적용한 소규모 분산전원으로의 활용 및 그린허브스테이션 발전량 예측기술 적용을 목적으로 태양광 발전량 예측 시스템을 개발하였다. 개발된 시스템은 일조량, 지면온도, 습도, 시정 등의 데이터를 기반으로 발전량을 예측하기 위해 LSTM(Long-Short Term Memory Network)모델을 적용하여 학습하였다. 또한, 모델의 과소적합 문제 방지를 위해 앙상블 모델을 적용하였으며, 최종적으로 두가지 모델의 1차, 2차 예측값을 비교 분석하여 최종 오차율을 산출하였다. 마지막으로 연속형 변수에 적용 가능한 NRMSE(Normalized Root Mean Squared Error)통계 방법을 적용하여 시스템의 정확도 성능 평가를 수행 및 도출하였다.

Key words : 태양광 발전량 예측, LSTM(Long-Short Term Memory Network), NRMSE(평균제곱근편차), Machine Learning(기계학습), DeepLearning(딥 러닝)

후기: "이 연구는 2022년도 정부(산업통상자원부)의 재원으로 한국에너지기술평가원의 지원을 받아 수행된 연구임(No. 20210501010010),“재생에너지 연계 MMC타입 ESS기반 모바일 허브스테이션 개발 및 운영 실증”

1) (재)녹색에너지연구원

태양광연계를 위한 재사용 배터리 표준·인증 동향

김주희[1)]*, 김지현[1),2)], 김창헌[1)]**

Standard and Certification Trends for Reused Batteries for Photovoltaics

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Abstract : 탄소중립 기본법의 법제화 및 제 10차 전력수급기본계획에 따라 재생에너지 활용은 10% 하향되었으나 재생에너지의 비중은 지속적으로 증가 예정이다. 또한, 기존에는 없던 4차 산업혁명인 전기차로 인한 전력 수요 증가 및 AI나 빅데이터와 같은 데이터 센터의 수요 증가로 인하여 2036년 최대전력수요는 117.3GW로 전망하고 있다. 태양광의 경우, 고출력·대면적 태양광 모듈 개발에 따라 태양광발전소의 전력생산량은 증가할 것으로 예상되고 이에 따라 에너지저장장치와의 연계를 고려해야 한다. 최근 급격히 증가한 전기차 보급에 따라 20년 275개에서 32년 기준 사용 후 배터리(폐배터리) 발생량이 10만개로 급증할 것으로 전망되고, 사용 후 배터리의 경제성이 긍정적으로 평가되어 사용 후 배터리 시장이 주목받고 있다.
본 연구에서는 전기차 사용 후 배터리의 분류 체계 및 재사용 배터리의 국·내외 표준 및 인증 동향에 대해 분석하였다.

Key words : Photovoltaic(태양광), Reused Battery(사용 후 배터리), Energy Storage System(ESS, 에너지저장장치), Standard(표준), Certification(인증)

후기: 본 연구는 산업통상자원부(MOTIE)와 한국에너지기술평가원(KETEP)의 지원을 받아 수행한 연구 과제입니다. (No. 20215810100310)

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부분음영, 컬러모듈 적용에 따른 시제품 마이크로컨버터 필드실증

김지현[1,2], 김주희[2], 김창헌[2]*

Field Demonstration of Prototype Micro-converter by application of Partial shade and color module

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Abstract : 국내 태양광발전설비는 2021년 기준 21GW를 넘어섰으며, 최근에는 REC 가격 하락으로 인해 수익률을 매년 해가 갈수록 떨어지고 있다. 이러한 가운데 수익률 향상을 위한 태양광발전설비의 유지보수의 중요성이 대두되고 있다. 일반적인 태양광발전 시스템에서는 중앙 집중형 인버터를 주로 사용하기 때문에 모듈 간 또는 어레이 간 출력 미스매치가 발생했을 때, 전체 태양광 발전량이 감소하는 문제가 발생한다. 이때, 마이크로컨버터는 발전 능력이 작은 모듈을 기준으로 하향평준화 되는 것을 막아주고, 개별모듈 최대전력점추적(MPPT) 제어를 통하여 최대효율 전력을 생산할 수 있게 한다.
본 연구에서는 태양광 모듈에 생성 된 음영 및 눈, 오염물질 등에 대한 전력보상능력을 보이는 마이크로컨버터 시제품을 출력저하(부분음영) 및 컬러모듈 적용에 따른 전류, 전압, 발전량을 비교 분석하였다.

Key words : Photovoltaic Power Plant(태양광발전소), Micro-converter(마이크로컨버터), Operation & maintenance(운영·유지보수), Partial shading(부분음영), Color solar module(컬러모듈)

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Plasmonic Effect of Au Nanoparticles in InGaN/GaN Multiquantum Wells for Unbiased Solar-Driven Water Splitting

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In this study, we looked at how modifying the number of InGaN/GaN quantum well pairs, optical bandgap tuning, and plasmonic coupling of Au nanoparticles with multiquantum wells (MQWs) affected photoelectrochemical (PEC) water splitting. When compared to reference GaN at zero bias, MQWs showed a 2-fold improvement in photocurrent density and applied bias photon-to-current conversion efficiency (ABPE%). It has also been demonstrated that optimizing the optical band gap by changing the MQWs' growth temperature will improve PEC water splitting efficiency. The green emission sample demonstrated a 15% improvement in photocurrent density and ABPE% when compared to the blue emission. Photocurrent density and stability were dramatically increased by decorating MQWs with Au NPs. This is the first time that MQWs in PEC water splitting have seen such a huge improvement in stability. After 14 hours, Au NP/MQWs displayed 80% photocurrent retention [1].

Keywords: Solar, Water splitting, InGaN, Multiquantum well, Plasmonic.

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Two-zone Furnace로 합성한 GeSe와 광전기화학적 물분해의 적용

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GeSe Synthesized Via Two-zone Furnace Technique and Application in Photoelectrochemical Water Splitting

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Abstract:
Energy, its consumption, and the solutions to the challenges related to it are crucial necessities. Sustainable, cleaner and renewable technology have been increasingly desirable in recent years as a means of mitigating the environmental issues associated with conventional fossil fuels and their byproduct. Hydrogen is a renewable and ecologically benign energy source when it is created organically. Photoelectrochemical (PEC) systems are an effective instrument for converting electromagnetic radiation into chemical fuels and energy. Several materials have been investigated for natural sunlight harvesting and photoelectrochemical water-splitting uses. Germanium Selenide (GeSe) is a potential photocathode material in recent years due to its favorable properties such as a sufficient bandgap, activity in the visible light range, chemical stability, non-toxicity, earth abundance, and cost-effective fabrication procedures. This work explains the making of GeSe using the two-zone furnaces method. A structural and morphological analysis was also conducted utilizing XRD, SEM, and. Furthermore, the PEC performance has been investigated.

Keywords: Photoelectrochemical Water Splitting, Germanium Mon selenide, Photocathode, Two-Zone Furnace

정공 수송층 최적화를 통한 저조도 실내용 페로브스카이트 광전변환 효율 향상

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Enhancing Photovoltaic Efficiency of Low Intensity Indoor Perovskite via optimization of Hole Transport Layer

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Abstract : Organic-inorganic halide perovskite materials have excellent defect tolerance, suitable bandgap, and high absorption coefficient at indoor light source(400~800 nm), making them a promising candidate for indoor photovoltaic studies that require only 0.3% of the solar light intensity. However, due to their low light characteristics, indoor photovoltaic devices are more sensitive to defects within the devices. In fact, photovoltaic materials such as silicon and $CuInGaSe_2$ show device performance in the range of 20 to 30% due to the low shunt resistance caused by defects in the device at low light intensity. On the other hand, in the case of perovskite solar cells, there are few defects in device, and the performance is 35 to 40% even at low light intensity. Despite various studies to reduce the effects of defects, the open circuit voltage (V_{OC}) and fill factor of perovskite solar cells are still at 76% (1 V) and 88.9% (80 %) compared to the theoretical limits of 1.27 V and 90.16 %

In this study, we achieved indoor efficiency of 40.7 % by controlling the interfacial defects within perovskite solar cells to enhance the V_{OC} and FF. to control the defects, we tested a self-assembled monolayer(SAM) called [2-(9H-Carbazol-9-yl)ethyl]phosphonic acid (2PACz). the anchoring group within the 2PACz molecule formed a dense, uniform, and thin hole transport layer through covalent bonding with the underlying transparent electrode. The carbazole group passivated the perovskite interface, thereby reducing interfacial defects. Additionally, the excellent band alignment between the perovskite and 2PACz layer reduced nonradiative recombination. As a result, we achieved 84% of V_{OC} (1.05 V) and 92.7 % of FF (83.4 %) compared to the theoretical limit, with a power output of 0.12 mW cm^{-2} and indoor efficiency of 40.7 %

Key words : Perovskite(페로브스카이트), Indoor photovoltaic(실내광전변환), Self-Assembled Monolyer (자가조립 단분자막)

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레이저 조사 그래핀 상단에 코팅된 온도 감응성 다차원 혼합 필러 기반 무선, 신뢰성, 유연성을 갖춘 온도 센서 시스템

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Wireless, Reliable, Flexible Temperature Sensor System Enabled by Coating Temperature-Sensitive Multi-Dimensional Hybrid Fillers on Laser-Engraved Graphene

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Accurate, reliable, and temporal measurement of temperature is crucial for helping identify chronic medical conditions and even mental health. Although temperature sensors that can differentiate 0.01°C in the range of 35-38°C is of interest in medical context, such high sensitivity could be only achieved with a table-top, bulky and rigid hardware, limiting their use in user-friendly, long-term and continuous monitoring in real world. While recent studies on temperature changes during sleep, in mood disorder, and under environmental effects require spatial and temporal mapping of body temperature *in vivo*, fetching data from the surface of our body in an accurate and continuous manner is challenging. In this study, we present a high-sensitive, reliable, and wearable temperature sensor array that provides on-body, time-dependent transients from small, multiple, and flexible electrodes. The sensor consists of electrical lines of laser-engraved graphene (bottom), coated with a composite of graphene mixed with zero-dimensional polymer ethylene-vinyl acetate (EVA) (top), leading to high-performance positive temperature coefficient (PTC) in the body temperature range. Both the top and bottom layers containing carbon retains superior adhesion properties, which minimizes hysteresis in contact resistance at rest over repeated temperature changes as well as under bending. the key characteristics of the sensor including intensity, reproducibility, and sensitivity increase through controlling fabrication variables for a combination of 0-D and 2-D carbon fillers (e.g., filler mobility and thermal expansion). We also optimize laser irradiation conditions to enhance electrical conductivity of the laser-induced graphene. Collectively, our sensor could be applied to various applications including cold chains, wearable devices, and Internet of Things (IoT).

Key words : Positive temperature coefficient(정 온도 계수), Multi-dimensional hybrid fillers(다차원 혼합 필러), Laser-engraved graphene(레이저 조사 그래핀)

실리콘 웨이퍼 상단에 형성된 나노구조 알루미나 친수성/소수성 특성

박동재[1)]*, 홍채연[2)], 임효령[3)]**

Hydrophilic/hydrophobic Properties of Shape-controlled Nanostructured Alumina on Silicon Wafer

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Abstract : Substrate texture is commonly employed in silicon microstructures for photovoltaic systems to optimize their ability to absorb and utilize solar radiation. This same micro/nano hierarchical structure can also be expoliated to regulate wettability of both liquid and vapor-phase water in various applications including microelectromechanical system (MEMS), vapor getter, and anti-biofouling surfaces. Here, we optimize the surface morphology and functional group of aluminum-deposited silicon wafer by using various chemical treatments such as texturing and anodizing. These treatments can impart either hydrophilic or hydrophobic properties to the surface, and under optimal conditions can even produce a super-hydrophilic surface. This simple and cost-effective approach enables rapid modification of large, specific areas and is compatible with conventional microfabrication techniques. Collectively, this engineered aluminum/silicon structure can be utilized in bioMEMS applications to adjust water contact angles, due to its controlled, hierarchical surface.

Key words : Hydrophilic surface (친수성표면), Anodization (양극산화), Texturing (텍스쳐링)

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A Wide Bandgap Halide Perovskite Based Self-Powered Blue Photodetector with 84.9% of External Quantum Efficiency

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Abstract : Herein, we report a self-powered, color-filter-free blue photodetector (PD) based on wide-bandgap (~2.5 eV) halide perovskites. A high external quantum efficiency (EQE) of 84.9%, which is the highest reported EQE in blue PDs, is achieved by engineering the A-site monovalent cations of wide-bandgap perovskites. The optimized composition of formamidinium (FA)/methylammonium (MA) increases the heat of formation, yielding a uniform and smooth film. Moreover, the incorporation of Cs^+ ions into the FA/MA composition is proved to suppress the trap density and increase charge-carrier mobility, yielding the highest average EQE of 77.4%, responsivity of 0.280 A W^{-1} under blue light. The proposed device exhibits peak responsivity of 0.307 A W^{-1}, which is higher than that of the commercial InGaN-based blue PD (0.289 A W^{-1}). This study will promote the development of next-generation image sensors with vertically stacked perovskite PDs.

Key words : Blue photodetector(청색 광센서), compositional engineering(조성 엔지니어링), halide perovskite (페로브스카이트 할로겐화물)

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Establishing a firm electrolyte/metal electrode interface for high-performance composite polymer electrolyte-based all-solid-sate Li-metal batteries

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All-solid-state Li batteries offer numerous advantages such as high performance, safety, and wide operating temperature range, making them promising for commercial energy storage applications. Li-metal is an ideal anode for polymer-based all solid-state batteries due to its high theoretical capacity. However, achieving large-scale energy storage requires mechanically robust electrolytes, stable solid-electrolyte-interface (SEI), and reliable charge storage, which have not yet been accomplished with PEO-based solid polymer electrolytes (SPE) due to their low ionic conductivity and unfavourable SEI formation. To address these issues, it is crucial to investigate the SEI and identify suitable fillers to achieve a stable composite polymer electrolyte (CPE). In this study, researchers used surface-functionalized silica mesoballs (MBs) as fillers to fabricate MB-CPE. The MBs offer a large surface area, Lewis acid sites, and a uniform distribution within the PEO matrix, which reduces the energy barrier of Li-ion diffusion and enhances Li-ion transport at the PEO/MB interface. As a result, MB-CPE demonstrated a high conductivity (1.53×10^{-3} @30 ℃ & 1.16×10^{-2}@60 ℃) and Li-ion transference number of 0.80. Symmetric cell testing showed that MB-CPE is highly compatible with Li anodes and stable for more than 2200 h at a high current density (200 μA cm^{-2} @60 ℃). In addition, full cell testing with [Li/MB-CPE/$LiFePO_4$] structure exhibited a retention capacity of ~90% after 400 cycles. A SEI compositional study was conducted to examine the electrolyte/Li interface.

Key words : Inorganic filler, Solid electrolyte interface, composite polymer electrolyte, Li-metal batteries, High ionic conductivity

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Nonflammable Deep Eutectic Electrolytes Containing Fluorinated Acetamide Solvent for Lithium-Oxygen or Lithium-ion Batteries

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Abstract :

Various strategy in secondary ion batteries such as solid-state electrolyte, non-flammable liquid electrolyte, or ionic liquids have been developed to overcome the safety issues. A deep eutectic electrolyte (DEE), which could be prepared by mixing two or more different solid hydrogen bond acceptors and donors at a certain molar ratio, has similar properties to ionic liquids and molten salts such as good ionic conductivity and non-flammability. For example, it could form liquid-state DEE at room-temperature by the interactions of the polar groups in organic acetamide with the cations and anions in Li salt. Among the many organic materials, fluorinated organic materials have been attracted in energy storage applications as non-flammable electrolyte materials or fire-retardant.

Herein, we have developed a new type of N,N-methyltrifluoroacetamide(NMFA)-based DEE and NMFA/fluoroethylene carbonate(FEC) based DEE by just mixing NMFA, FEC and lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) for LOBs and LIBs, respectively. This NMFA/FEC-based DEE with good compatibility to Li metal anode and high thermal, chemical, and electrochemical stability well inherits the advantages of amide-based electrolytes and DEEs, overcoming the shortcomings of commonly used organic electrolytes.

As a result, the NMFA based DEE and NMFA/FEC-based DEE provide high-safety and non-flammability. More importantly, The NMFA/FEC-based DEE enables the stable cycling and improved lifetime of LIBs in LFP//Li full-cells. But, in case of LOBs, the NMFA-based DEE shows unstable cycling performance than NMA-based DEE indicating high reactivity with lithium anode.

In summary, we introduced the fluorinated acetamide based DEE as non-flammable electrolytes for LIBs and LOBs.

Acknowledgement : This work was supported by the DGIST R&D Program of the Ministry of Science and ICT (23-ET-08).

Key words : Deep Eutectic Electrolyte, Nonflammable Electrolyte, Lithium-oxygen batteries, Lithium-ion batteries

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단결정 TiO_2로 보호된 할로겐화물 페로브스카이트 태양전지 기반 광전기화학적 물분해 소자

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Photoelectrochemical Water-splitting device based on a halide perovskite solar cell protected by a single crystal TiO_2

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Abstract : The photoelectrochemical (PEC) splitting of water is a renewable method of producing hydrogen. By incorporating a solid-liquid junction on photovoltaics, PEC can simplify the solar hydrogen production system by removing peripheral components (such as an Ag metal grid or power electronics), which may result in a significant reduction in system cost and efficiency loss. Yet, one of the major obstacles in PEC is that light-absorbing materials can be readily damaged by acidic or alkaline electrolytes at the solid-liquid interface. For halide perovskite light absorbers, the severity of this problem increases. The halide perovskite solar cell is an emerging photovoltaic material with significant potentials, however, due of its instability when in contact with water or oxyhgen, PEC devices producing a solid-liquid junction between halide perovskites and electrolytes has been exhibiting poor stabilities. In this study, we protect a perovskite PEC device with a single-crystal TiO_2 wafer to increase its stability. To inject and conduct electrons through the TiO_2 wafer, the wafer was thermally annealed in the presence of hydrogen and then placed onto a perovskite solar cell using a transparent conductive oxide. On top of the TiO_2 wafer, Pt catalysts are deposited to catalyze the hydrogen evolution reaction. The PEC device exhibited an open-circuit voltage of 1.1 V and a short-circuit current density of 14 mA/cm^2.

Key words : Photoelectrochemistry(광전기화학), Halide perovskite(할로겐화물 페로브스카이트), Hydrogen production(수소 생산), Water-splitting(수전해)

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휘발성 알킬암모늄 염화물을 이용한 페로브스카이트 층의 성장 제어

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Controlled growth of perovskite layers with volatile alkylammonium chlorides

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Abstract : Controlling the crystallinity and surface morphology of the perovskite layers by methods such as solvent engineering and methylammonium chloride addition is an effective strategy for achieving high-efficiency perovskite solar cells (PSCs). In particular, it is essential to deposit an α−formamidinium lead iodide ($FAPbI_3$) perovskite thin films with fewer defects due to their excellent crystallinity and large grain size. Herein, we report the controlled crystallisation of perovskite thin films with the combination of alkylammonium chlorides (RACl) added to $FAPbI_3$. The δ− to α−phase transition of $FAPbI_3$ and the crystallisation process and surface morphology of the perovskite thin films coated with RACl under various conditions were investigated through in situ grazing incident wide-angle X-ray diffraction and scanning electron microscopy. RACl added to the precursor solution was believed to be easily volatilised during coating and annealing owing to dissociation into RA^0 and HCl with deprotonation of RA^+ induced by $RA\cdots H^+$–Cl^- binding to PbI_2 in $FAPbI_3$. Thus, the type and amount of RACl determined the δ− to α−phase transition rate, crystallinity, preferred orientation, and surface morphology of the final α–$FAPbI_3$. The resulting perovskite thin layers facilitated the fabrication of PSCs with a power conversion efficiency of 26.08% (certified 25.73%) under standard illumination.

Key words : Perovskite solar cell (페로브스카이트 태양전지), Alkylammonium chloride (알킬암모늄 염화물), phase transition (상 전이)

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High Performance Solar Water Splitting of CdS loaded Hierarchical ZnO-GaN Nanowires on Si for efficient H_2 evolution

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Gallium nitride nanowires (GaN NWs) are one of the most promising photoelectrode materials because of their direct band gap, which allows for high-efficiency photon absorption, and their conduction and valence band straddle with water redox level, making it an ideal candidate for solar water splitting without external biasing [1]. Unfortunately, because of their poor stability and low solar-to-hydrogen conversion efficiency, their practical application is limited. Loading the passivation layer and cocatalyst onto the surface of GaN NWs are two notable ways for resolving concerns about poor stability and low efficiency [2]. In this paper, a CdS/ZnO/GaN NWs photoanode for photoelectrochemical water splitting (PEC-WS) application was fabricated by utilizing VLS GaN NWs as a core material on a Si substrate passivated with ZnO conformal layer through ALD and CdS as a cocatalyst. CdS/ZnO/GaN NWs (3.6 mA cm^{-2}) photoanodes have a 10-fold greater photocurrent density than ZnO/GaN NWs (0.37 cm^{-2}) at 0 V under single Sun illumination. According to our findings, photo-corrosion of bare GaN NWs may be reduced by utilizing ZnO as a passivation layer and CdS as a cocatalyst, which suppresses surface defects and lowers the photogenerated charge recombination rate. As a result, enhancing the stability of GaN NWs in high pH electrolytes leads to efficient H_2 evolution (27.8 mol h^{-1}).

Keywords: Hierarchical, Nanowire, Solar, Water, Splitting.

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후면전극형 구조 기반의 변형 가능한 결정질 실리콘 소형 태양광 모듈

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Transformable Crystalline Silicon Solar Mini Module based on All-back-contact Structure

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Abstract : Transformable solar cell has attracted numerous interests because they can be employed with continuous power on the uneven surfaces of wearable devices. Crystalline silicon (c-Si) solar cells currently take more than 95% of the total solar cell market share due to the abundance, stability, and high efficiency of this material, but c-Si solar cells are difficult to bend and stretch because they tend to become brittle when external forces are applied. Therefore, c-Si solar cells inevitably need to be installed on flat surfaces due to the rigid nature of c-Si. In this work, we demonstrated a new class of transformable c-Si solar mini modules through the novel design of all-back-contact configuration and the introduction of PDMS-based elastic interconnecting electrodes. The transformable c-Si solar module showed a module efficiency of 14.7% and a high voltage output of 4.87 V with a size of 12 cm^2. Also, the transformable solar module showed stable photovoltaic properties by maintaining less than 4% variation of the initial efficiency under both the folding and stretching (up to strain 40%) conditions. We expect that the module is possible to overcome the solar module installation limitation and integrate compactly with flexible or wearable electronics for the continuous power source.

Key words : Crystalline silicon(결정질 실리콘), Elastic interconnection electrode (신축 연결 전극), All-back-contact structure (후면 구조), Transformable solar mini module (변형 가능한 태양광 미니 모듈)

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게이트 전압으로 제어 가능한 광 검출기 및 양극성 트랜지스터

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Gate-tunable photodetector and high mobility ambipolar transistor

*Gwangtaek Oh[1], **Bae Ho Park[1]

Key words : Gate-tunable(게이트제어), photodetector(광검출기), ambipolar transistor(양극성 트랜지스터), high mobility(높은전자수송), graphene(그래핀), barristor(배리스터)

Abstract : Next-generation electronic and optoelectronic devices require a high-quality channel layer. Graphene is a good candidate owing to its high carrier mobility and unique ambipolar transport characteristics. However, the on/off ratio and photoresponsivity of graphene are typically low. Transition metal dichalcogenides (e.g. $MoSe_2$) are semiconductors with high photoresponsivity but lower mobility than graphene. Here we propose a graphene/MoSe2 barristor with a high-k ion-gel gate dielectric. It shows the highest carrier mobility (~247 $cm^2/V•s$) among reported $MoSe_2$ devices, high on/off ratio (3.3x104), and ambipolar behavior that is controlled by an external bias. The barristor exhibits very high external quantum efficiency (EQE, 66.3%) and photoresponsivity (285.0 mA/W). We demonstrate that an electric field applied to the gate electrode can significantly modulate the photocurrent of the barristor resulting in high gate tuning ratio (1.50 μA/V). Therefore, this barristor shows potential for use as an ambipolar transistor with high mobility and on/off ratio and a gate-tunable photodetector with high EQE and responsivity.

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Porous Au@g-C_3N_4 전극을 이용한 효과적인 전기화학적 이산화탄소 환원

성채원[1),*], 배효정[2)], 허지원[1)], Vishal Burungale[1)], 하준석[1),2),**]

Efficient Electrochemical Reduction of CO_2 to CO by Porous Au@g-C_3N_4 Electrode

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Abstract :

The huge consumption of fossil energy and the dramatic rise in atmospheric CO_2 concentration has led to various environmental issues such as an energy crisis and global warming. Converting CO_2 to value-added chemicals and fuels has been considered an effective approach to mitigate the above dilemma. Among various products that can be generated in the CO_2 reduction reaction (CO_2RR), CO is especially attractive due to its compatibility with well-established industrial processes (e.g. Fischer–Tropschreactions) to achieve cascade catalysis toward value-added chemicals and fuels. It is widely accepted that on Au surfaces, CO_2 molecules are initially adsorbed and activated to *COOH. Then *COOH is further reduced to *CO, followed by its desorption to form CO gas. Recently, porous Au (pAu) has been reported to have a Faradaic efficiency (FE) of 95.9% at an applied potential of −0.6 V vs RHE for 10 h. However, on Au surfaces, the activation of CO_2 to *COOH intermediate suffers from a huge energy barrier.
Here, pAu@g-C_3N_4 was used as an electrode to convert CO_2 into formic CO. The existence of pyridinic nitrogen atoms and high oxophilicity of C atoms of graphitic carbon nitride (g-$C_3N_{4)}$ will boost the interaction between the catalysts and reactants/intermediates such as *COOH and *CO in electrochemical reduction. The relevant electrical properties of the EC cells with electrodes made of pAu@g-C_3N_4 will be discussed at the conference.

Key words : Electrochemical Reduction(전기환원), CO_2 Reduction(이산화탄소 환원), porous Au(다공성 금), g-C_3N_4(흑연질화탄소)

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Low temperature growth of SiO_2 thin film deposited by atomic layer deposition

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Abstract : 원자층 증착 (atomic layer deposition, ALD) 방법은 각각의 반응 기체들을 순차적으로 주입하여 기판 표면에서 흡착과정 (self-limited adsorption)을 통해 박막에서 일어나는 반응을 이용하여 박막을 형성하는 방법이다. ALD 특징으로는 매우 얇은 박막을 형성할 수 있을 뿐만 아니라, 두께 및 조성비 제어가 가능하며, uniformity, 다른 증착 방법에 비해 높은 step coverage를 갖기 때문에 아주 미세한 패턴 형성과, 균일한 박막 특성 덕분에 현재 유행하는 초미세 반도체 공정에 대해 매우 적합하다. Gate insulator로 사용되는 SiO_2 박막의 증착 방법으로 low pressure chemical vapor deposition (LPCVD) 방식은 800 ~850 ℃의 고온에서 증착해야 되는 반면 ALD의 경우 일반적으로 250 ℃정도로 비교적 저온에서 공정 가능하다. 본 연구에서 온도에 따라 ALD 방법으로 증착 된 SiO_2 박막의 특성을 비교하였다. 일반적인 공정 온도인 250 ℃보다 낮은 온도로 공정을 진행하여 증착 된 SiO_2 박막의 저온 증착 가능성을 확인하였다. Cycle 수에 따른 증착률인 growth/cycle (GPC) 특성과, x-ray photoemission spectroscopy (XPS)를 이용한 박막 내 조성비와 불순물비, ellipsometer를 이용한 두께 측정 및 uniformity를 관찰하였고, SiO_2 박막의 전기적인 특성은 current-voltage, capacitance-voltage curve를 이용해 equivalent oxide thickness (EOT), 절연 파괴 강도 등을 측정하였다.

Key words : Gate insulator, atomic layer deposition, SiO_2 thin film, low temperature growth, thin film transistor

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Colloidal Ni_2P Nanocrystals Encapsulated in Heteroatom-Doped Graphene Nanosheets: A Synergy of 0D@2D Heterostructure Towards Overall Water Splitting

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ABSTRACT

Transition metal phosphides (TMPs) nanostructures have been extensively studied for hydrogen evolution reaction (HER) and oxygen evolution reaction (OER). However, a phase-controlled synthesis of colloidal Ni_2P nanocrystals (NCs) or related heterostructures remains challenging and their use as a bifunctional electrocatalysts in overall water splitting (OWS) is not systematically studied. Herein, zero-dimensional (0D) colloidal Ni_2P NCs are synthesized using a robust solution-phase method and encapsulated in two-dimensional (2D) N- and S-doped graphene (NSG) nanosheets via a facile ex-situ sonication to form 0D@2D Ni_2P@NSG heterostructure. The interaction between the surface functionalities of Ni_2P NCs and defective NSG via the strong van der Waals force provides a robust sheath to Ni_2P NCs when encapsulated in NSG nanosheets, further enhancing the specific surface area and active sites exposure. Density functional theory calculations indicate that the dual interaction of N, and S dopants with the Ni_2P benefits the coordinative effect of the optimized water and hydrogen free energy adsorption. As a result, Ni_2P@NSG electrocatalysts manifest high catalytic activity towards HER and OER, and a two-electrode alkaline electrolyzer assembled by Ni_2P@NSG as both anode and cathode requires only 1.57 V to reach current density at 10 mA/cm^2.

광전기화학적 이산화탄소 환원 효율 향상을 위한 $CuO/g-C_3N_4$ 전극의 설계 및 제작

허지원[1)*], 배효정[2)], 하준석[1,2)**]

Enhancing the Photoelectrochemical Reduction of CO_2 using $CuO/g-C_3N_4$ Heterojunction Electrodes

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Abstract: Carbon dioxide(CO_2) emissions from indiscriminate fossil fuel use have caused problems such as abnormal climate in the atmosphere and oceans. To address this issue, alternative fuel and energy development, CO_2 capture and storage, and high energy use reduction in building are being improved. Photoelectrochemical CO_2 reduction is attracting attention as a promising technology that reduces CO_2 and produces alternative fuels. This technology can synthesize various hydrocarbon compounds, such as carbon monoxide, methanol, and formic acid, from CO_2, a greenhouse gas. Among numerous electrode materials used for this reaction, copper(Cu) is the only substance known to produce C2 compounds. However, Cu based materials have some disadvantages, such as low activity, poor selectivity, instability, and limited conductivity. To address these issues, an alloy with g-C_3N_4 was formed, improving the low conductivity and selection of copper oxide(CuO). This study fabricated a photoelectrode based on the alloy with g-C_3N_4.

Key words: g-C_3N_4, Copper Oxide(산화 구리), CO_2 reduction(이산화탄소 환원)

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고효율 주석 기반 페로브스카이트 태양전지를 위한 박막의 두께 증가 전략

류준[1)]*, 이서준[2)], 조성원[1)] 강동원[1,2)]**

A Strategy on Increasing Film Thickness of Sn-Perovskites for High Efficiency Solar Cells

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Abstract : 페로브스카이트 태양전지는 높은 광변환 효율과 낮은 제조 비용으로 차세대 태양전지 소재로써 주목받고 있다. 그러나 이러한 페로브스카이트 태양전지는 납이 포함되어 있어 환경적으로 유해하다는 문제가 있다. 이를 해결하기 위해 최근 비납 계열의 페로브스카이트 중에서 주석 기반 페로브스카이트가 주목받고 있다. 그러나 이전까지의 연구에서는 주석 기반 페로브스카이트의 단점 중 하나로 두께를 증가시키는 것이 어려워 현재까지 연구에서 주석 기반 페로브스카이트의 두께는 약 300 nm 수준으로 보고되었다. 장파장 대역의 빛을 충분히 흡수하지 못하여 단락전류밀도가 감소하는 문제점이 있다.

본 연구에서는 주석기반 페로브스카이트 박막의 두께를 증가시키는 방법에 대해 제시하였다. 두꺼운 조건의 주석기반 페로브스카이트 박막을 제작할 때 반용매에 $PC_{61}BM$을 녹여 코팅함으로써, 페로브스카이트 박막을 열처리할 때 전구체의 용매가 증발하는 속도를 감소시켰다. 또한 $PC_{61}BM$의 농도에 따라 전구체 용매가 증발하는 속도를 조절할 수 있다. 이에 따라 주석 기반 페로브스카이트의 결정성장속도 및 핵생성속도의 균형을 제어하여 약 500 nm의 두께를 가진 고품질의 박막이 제작되었다. 이를 토대로 페로브스카이트 태양전지를 제작하여 측정한 결과 장파장 대역의 외부양자효율(EQE)이 증가된 것이 확인되었으며, 이에 따라 단락전류밀도가 약 3.6 mA/cm^2증가하였다. 또한 결과적으로 광전변환 효율이 절대효율로 약 1% 증가하였다.

본 연구결과는 주석 기반 페로브스카이트 태양전지의 두께를 증가시키는데 공헌할 수 있으며, 광변환효율의 증가를 위한 디딤돌이 될 것으로 기대된다.

Key words : Sn-based perovskite(주석기반 페로브스카이트), Thickness(두께), Anti-solvents procee(반용매공정)

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에탄올 산화제를 이용한 ALD 기반 페로브스카이트 패시베이션용 금속 산화물층 연구

기호재[1)]*, 허재영[1)]**

A Study on ALD-based Metal Oxide Layer for Perovskite Passivation by using Ethanol Oxidant

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Abstract : In recent years, solar cells based on organic-inorganic mixed perovskite have emerged as a next-generation prospect, and several studies have been conducted to commercialize them. Perovskite solar cells (PSCs) show high photoelectric conversion efficiency of over 24% along with excellent electrical and optical properties, but they are generally vulnerable to heat and moisture; therefore, researchers are trying to improve their stability by using various protecting strategies. A thin passivation layer has been succesfully applied to passivate the perovskite material and improve its stability. Atomic layer deposition (ALD) is a widely used method to deposit passivation layers in the field of microelectronics due to its fine control over the thickness and the ability to passivate various structures and complex surfaces uniformly. In the ALD process, the deposition of metal oxide thin films is usually carried out using deionized water, ozone, or O_2 plasma as oxidants, and the process is generally carried out in the temperature range of 150 to 300 °C. However, new process conditions must be proposed since such process conditions can cause unintentional oxidation or damage in the PSCs.

Al_2O_3 is one of the widely used materials as a passivation layer for electronic devices. Several studies have been reported on the low-temperature Al_2O_3 process using ALD. However, since water was used as oxidant in most studies, the effect of moisture on perovskite materials cannot be ignored; therefore, the passivation layer should be deposited using another oxidizing agent that can displace water for better stability. In this study, we propose a low-temperature ALD-Al_2O_3 process with ethanol as an oxidant, and a metal oxide film is additionally combined to improve passivation properties. The growth behavior of the metal oxide thin film using ethanol at a low temperature of 100 °C or less was studied, and the passivation characteristics were confirmed.

Key words : Perovskite solar cell (페로브스카이트 태양전지), Passivation layer (패시베이션 층), Atomic layer deposition (ALD), Oxidant (산화제)

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In-situ induced oxygen vacancies during rapid synthesis of Ni:FeOOH boosts the water oxidation activity and stability of $BiVO_4$ photoanode

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Abstract: Put The coupling of oxygen evolution reaction (OER) catalysts with photoanodes is a promising strategy for improving the photoelectrochemical (PEC) performance by passivating the photoanode′s surface defect states and facilitating charge transfer at the photoanode/electrolyte interface. However, a serious interface recombination issue caused by poor interface and OER catalysts coating quality often limits the further performance improvement of photoanodes. Here, we demonstrated a rapid synthesis of ultrathin Ni:FeOOH catalysts with in-situ induced oxygen vacancies (Vo) using a facile Fenton-like reaction to enhance the water oxidation activity and stability of $BiVO_4$ photoanode. The combined physical characterizations and PEC studies revealed that the reductive environment in a Fenton-like reaction in-situ produces abundant Vo in Ni:FeOOH catalysts, which significantly improves charge separation and charge transfer efficiency while also providing high active sites and a low energy barrier for OER. As a result, Ni:FeOOH-Vo catalysts yielded a more than 2-fold increased photocurrent density in $BiVO_4$ photoanode (from 1.54 mA cm^{-2} to 4.15 mA cm^{-2} at 1.23 V_{RHE}), accompanied by high stability for 5 h. This work not only highlights the significance of abundant Vo in catalysts but also provides new insights into the rational design and fabrication of efficient and stable solar water-splitting systems.

Key words: Photoelectrochemical Water Splitting, Bismuth Vanadate, Oxygen vacancy Fenton-like reaction, Ultrathin Ni:FeOOH.

참가 및 등록안내

▶ 등록비 안내

구분	종신회원	정회원	학생회원	비회원
사전등록	180,000원	230,000원	110,000원	-
현장등록	210,000원	260,000원	140,000원	300,000원

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1. 온라인 사전등록
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     사전등록 : 2023년 3월 3일(금) 24시까지
     납부기간 : 2023년 3월 17일(금) 24시까지

2. 현장등록
   - 장소 : 웨스틴조선부산 그랜드볼룸(1F) 앞 로비

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주요 행사일정 및 장소

▶ 학회 제2차 정기이사회

- 일시 : 2023년 3월 30일(목) 11:00~12:30
- 장소 : 웨스틴조선부산 오킴스(1F)
- 대상 : 한국태양광발전학회 2023년 이사진

▶ 학회등록자 오찬

- 일시 : 2023년 3월 30일(목) 11:00~12:50
- 장소 : 웨스틴조선부산 그랜드볼룸 B(1F)
- 대상 : 초청연사, 2023 춘계학술대회 등록자

▶ 개회식

- 일시 : 2023년 3월 30일(목) 13:00~13:30
- 장소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 참석자 : 초청연사, 2023 춘계학술대회 등록자

▶ 정기총회

- 일시 : 2023년 3월 30일(목) 18:00~18:30
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- 대상 : 한국태양광발전학회 임원, 종신회원 및 정회원

▶ 만찬

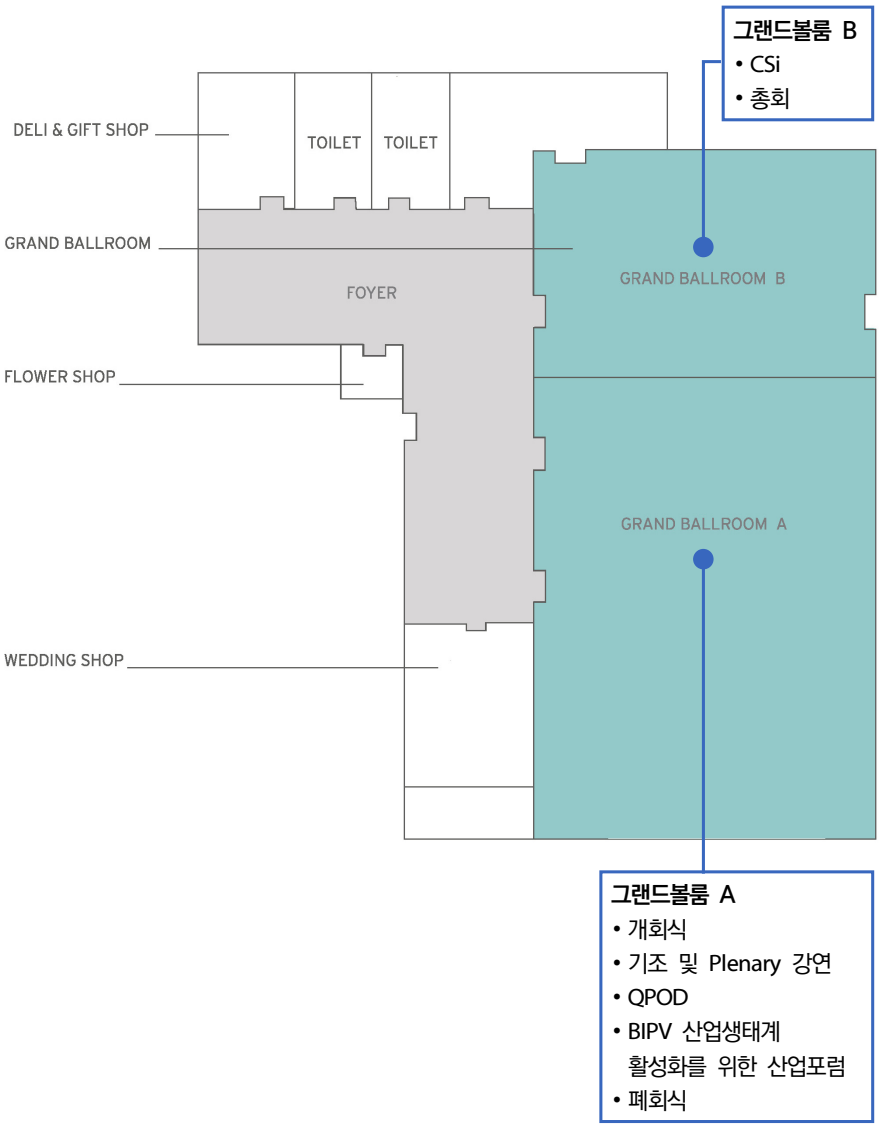
- 일시 : 2023년 3월 30일(목) 18:30~20:00
- 장소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 대상 : 초청연사, 2023 춘계학술대회 등록자(종신회원 및 정회원)

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- 장소 : 웨스틴조선부산 그랜드볼룸 A(1F)
- 대상 : 초청연사, 2023 춘계학술대회 등록자

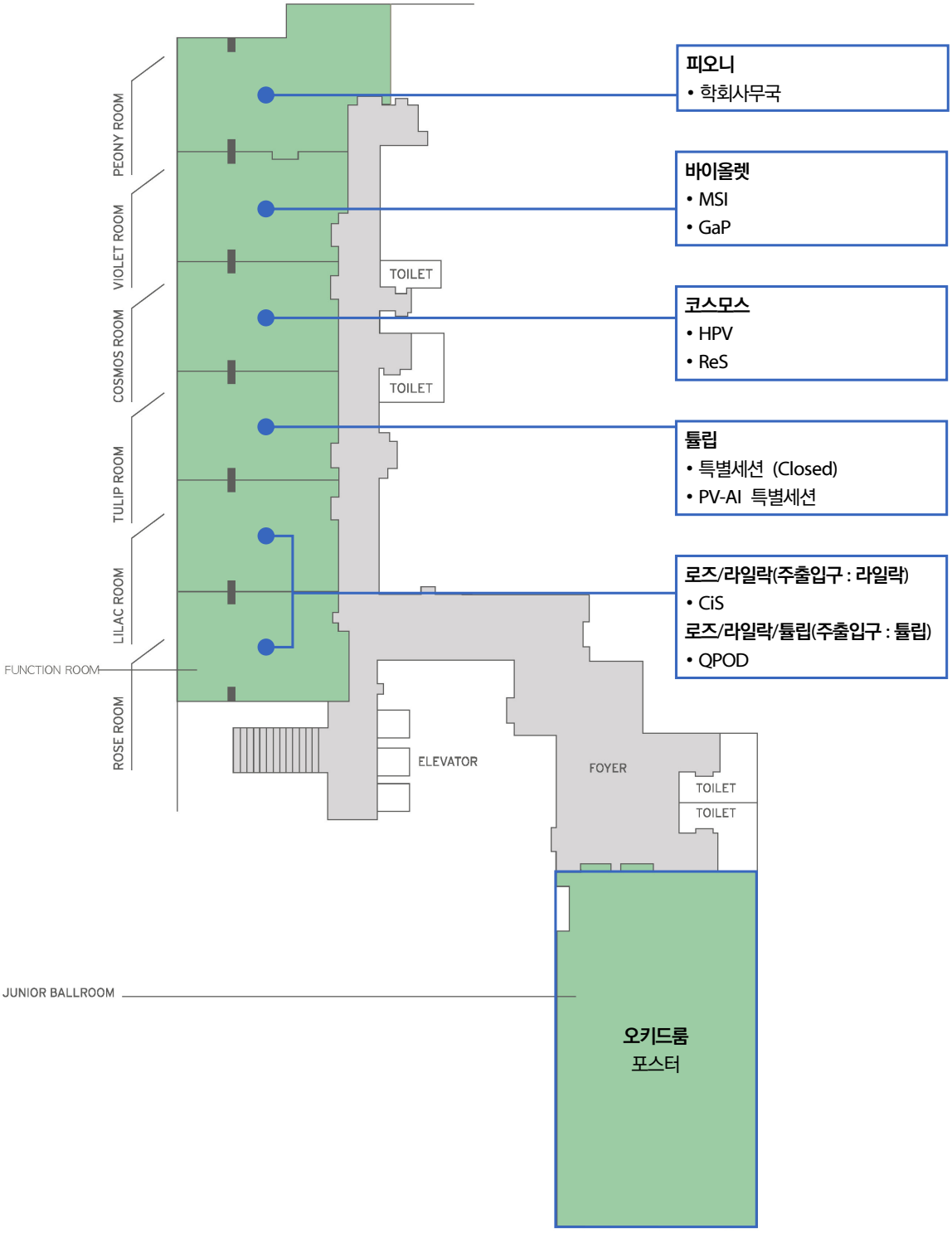
행사장 안내

GRAND BALLROOM /1F



행사장 안내

JUNIOR BALLROOM & SMALL FUNCTION ROOM /2F



구두 및 포스터 발표 안내

KEYNOTE & PLENARY

- 발표 시간 : 40분(발표 35분, 질의·응답 5분)

INVITED SESSION

- 발표시간 : 15~25분(발표 12~22분, 질의·응답 3분)
- 시청각 기자재 : 빔 프로젝트
- 요청 사항 : 발표자는 발표파일을 USB메모리로 지참하여 해당 발표세션 전 휴식시간에 발표장 컴퓨터에 파일을 복사한 후, 정상적으로 화면에 보이는지 확인 요망

ORAL SESSION

- 발표시간 : 10~15분(발표 7~12분, 질의·응답 3분)
- 시청각 기자재 : 빔 프로젝트
- 요청 사항 : 발표자는 발표파일을 USB메모리로 지참하여 해당 발표세션 전 휴식시간에 발표장 컴퓨터에 파일을 복사한 후, 정상적으로 화면에 보이는지 확인 요망

POSTER SESSION

- 발표 장소 : 오키드룸(2F)
- 포스터 규격 : 가로 90cm, 세로 120cm(포스터 판넬 규격 : 가로 1m, 세로 2m)
- 우수포스터 심사 : 초록 제출시 학회지(CPR) 투고에 동의하여 우수포스터 심사를 신청한 논문으로서 학생발표자가 배석한 경우에만 심사함
- 우수포스터 심사시간 : 3월 30일(목) 17:30~18:30 / 3월 31일(금) 12:50~13:40
- 포스터 세션시간 : 3월 30일(목) 15:00~18:30 / 3월 31일(금) 09:00~13:40
  * 접수번호가 아닌 프로그램북에 배정된 세션별 논문번호(예시 : CSi-P-1)를 확인 후 부착함
  * 모든 포스터는 세션 종료시간까지 부착되어 있어야 함
  * 세션 종료 후 부착된 모든 포스터를 제거하여야 하며, 기한내에 제거하지 않은 포스터는 임의로 폐기함

좌장 및 발표자 숙지사항

좌 장

① 담당분야의 시간과 발표장을 확인해 주십시오.
② 발표시작 10분전까지는 발표장에 입실해 주십시오.
③ 발표자들이 모두 참석했는지 발표시간 전에 확인해 주십시오.
④ 발표시간은 질의응답 3분 포함 초청강연 총 15~25분, 일반구두 총 10~15분입니다.
⑤ 시간을 알리는 종은 발표시작 8분 경과 시 한번, 10분 경과 시 두번 종을 울리십시오.
⑥ 두번째 종소리 후에는 발표를 종료시켜 주십시오.

초청강연자

① 발표분야, 발표장 및 시간을 확인해 주십시오.
② 발표 시작 10분전까지는 발표장에 입실해 주십시오.
③ 발표파일을 USB메모리로 지참하여 해당 발표세션 전 휴식시간에 발표장 컴퓨터에 파일을 복사한 후, 정상적으로 화면에 보이는지 확인하시기 바랍니다. 개인 노트북도 사용가능하나 휴식시간 중에 미리 연결하여 확인하시기 바랍니다.

Oral 발표자

① 발표분야, 발표장 및 시간을 확인해 주십시오.
② 발표 시작 5분전까지는 발표장에 입실해 주십시오.
③ 종료시간을 알리는 종은 발표시작 8분 경과 시 한번, 10분 경과 시 두번 종이 울립니다.
④ 두번째 종소리 후에는 곧 발표를 종료하여 주십시오.
⑤ 발표파일을 USB메모리로 지참하여 해당 발표세션 전 휴식시간에 발표장 컴퓨터에 파일을 복사한 후, 정상적으로 화면에 보이는지 확인하시기 바랍니다. 개인 노트북도 사용가능하나 휴식시간 중에 미리 연결하여 확인하시기 바랍니다.

좌장 및 발표자 숙지사항

Poster 발표자

① 발표분야, 발표장 및 시간을 확인해 주십시오.

② 발표장소는 오키드룸(2F)이며, CSi, QPOD 일부, MSI, HPV 부문은 3월 30일(목) 16시 이전에 포스터를 부착하시고, CiS, QPOD 일부, GaP, ReS 부문은 3월 31일(금) 10시 이전에 포스터 부착을 완료하여 주시기 바랍니다.

③ 포스터 규격(가로 90cm, 세로 120cm)을 준수해주시고, 프로그램북에 배정된 세션별 논문번호(예시 : CSi-P-1)를 확인 후, 해당되는 판넬에 부착해 주십시오.

④ 우수포스터 심사는 학회지(CPR) 투고에 동의하여 초록 제출시 우수포스터 심사를 신청한 학생회원의 논문에 대해서만 심사를 하게 됩니다. 단, 발표시간에 학생발표자가 참석하지 않은 포스터는 심사에서 배제됩니다. 우수포스터상 수상자 시상은 폐회식(3월 31일(금) 15시, 그랜드볼룸 A)에서 진행될 예정입니다.

웨스틴조선부산 오시는 길



부산광역시 해운대구 동백로 67 웨스틴조선부산(Tel : 051-749-7000)

KTX 부산역	택시	요금	약 23,000원
		소요시간	약 30분
	버스	방법	1003번 버스 탑승 → 동백섬 입구 정류장 하차
		소요시간	약 60분
부산 종합버스터미널	택시	요금	약 25,000원
		소요시간	약 40분
	버스	방법	1호선 노포역 탑승 → 동래역 하차 후 31번 버스로 환승 → 운촌역 하차
		소요시간	약 65분

한국태양광발전학회

2023 춘계학술대회

발행처 : (사)한국태양광발전학회
주소 : (우)06192, 서울특별시 강남구 선릉로90길 10, 샹제리제센터 B동 303호
전화 : 02-538-8505 팩스 : 02-538-8506
E-mail : koreapv@kpvs.or.kr
홈페이지 : http://www.kpvs.or.kr
발행일 : 2023년 3월 30일
발행인 : 김진혁
인 쇄 : ㈜에이퍼브
전화: 02-2274-3666, E-mail: apub.edit@apub.kr

Korea Photovoltaic Society

한국태양광발전학회
2023 춘계학술대회

후원·협찬 및 전시 기관

GOLD

세미랩코리아㈜, 한화솔루션 큐셀부문

SILVER

㈜엘케이켐, ㈜코에스, ㈜나인테크

BRONZE

㈜에스케이솔라에너지, 와이아이테크㈜

전시업체

㈜맥사이언스, 오엠에이, ㈜한양솔라에너지, 한빅솔라㈜

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Compact AC Hall system for a wide variety of PV materials

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Provides:

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- Carrier concentration
- Sheet resistance

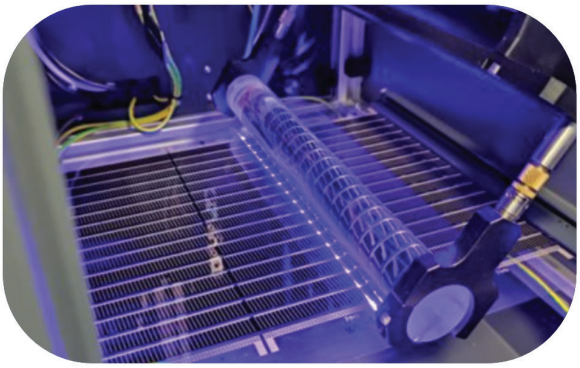
Unique Photo-Hall option measures properties of minority carriers, proven for:

- Silicon
- Perovskites
- Kesterites



SEMILAB

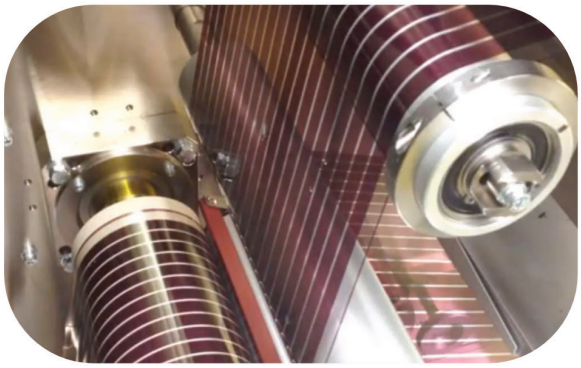
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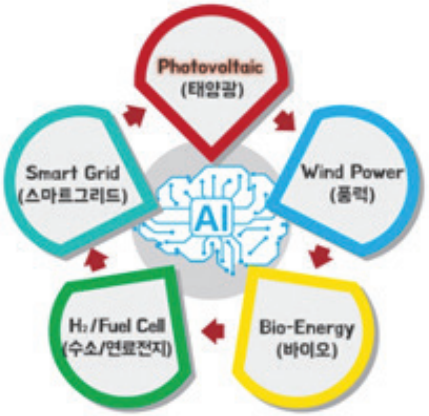


정부 지원 산업통상자원부 한국에너지기술평가원

e-AI Graduate School of Integrated Energy AI
JEONBUK NATIONAL UNIVERSITY, KOREA

대학원 신입생 모집 – 전북대학교

에너지-AI융합공학과 신입생모집



특별전형 모집일정

1학기 : 10월, 11월, 1월 중
2학기 : 5월, 7월 중

학위과정

- 석사과정
- 박사과정
- 석박사통합과정

교육내용

- AI(인공지능) 이론 및 응용
- 딥러닝
- 머신러닝
- 태양전지
- 차세대 태양전지 소재 및 소자
- AI 기반 태양광 발전소 설계
- AI 기반 스마트 그리드

장학제도 및 지원 혜택

- 산업통상자원부, 한국에너지기술평가원 국비지원사업
- 전액 국비장학금 지원
- 학업장려금 지원
  : 매월 석사과정 120만원, 박사과정 180만원
  (연구과제 참여 시 과제인건비 추가 지원)
- 개인용 최신식 노트북 제공 (수학 기간 중 교육 연구용)

방학특강

여름방학 : 7월 ~ 8월 중
겨울방학 : 1월 ~ 2월 중

지원방법 및 기타문의

H http://eai.jbnu.ac.kr/
T (+82)-63-270-3939
A 전북대학교 공과대학 3호관 220호
E E-mail: eai@jbnu.ac.kr

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신재생 에너지 소재 전문 생산 기업으로



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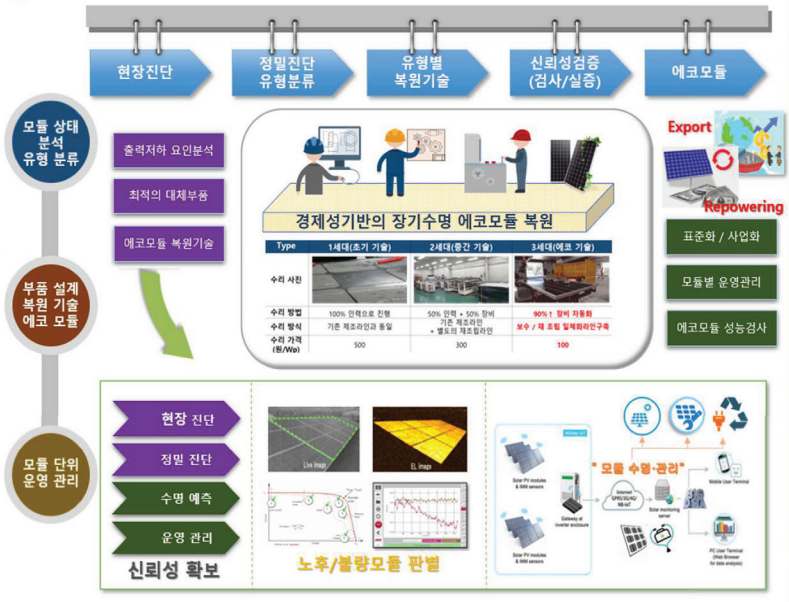
사용 후 모듈의 복원 기술 적용 에코모듈

사업개요

- 연구기간 : 2020년 5월 1일 ~ 2023년 4월 30일
- 개발내용
  - 불량모듈 분석 및 유형 분류
  - 고장유형 별 최적의 출력 복원
  - 고장관리 프로세스적용 수명모델
  - 에코 모듈 성능검증 표준 개발
- 기대효과
  - 자원의 순환경제 활성화 및 전력 인프라 확대 유도



노후 및 불량인 태양광모듈 운영기술 개념도



후원
산업통상자원부 KETEP 한국에너지기술평가원

연구개발기관
E2Z SKSE 충북테크노파크 한국에너지기술연구원 KILT 한국조명ICT연구원 녹색에너지연구원 성균관대학교 산학협력단

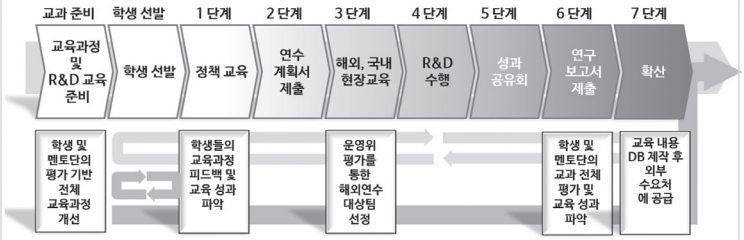
과학기술정보통신부 기후기술인재양성 시범사업
(2022.05-2025.01)

에너지·환경 기후기술인재양성 센터

(Education Center for Energy, Environment, and Climate Technologies, ECEECT)

Vision

7단계 교육과정을 통한 에너지·환경 산업 난제를 해결할 전략가형 과학인재 배출



에너지·환경 정책을 내재화한 융합·특화 기후기술인재양성 센터 구축

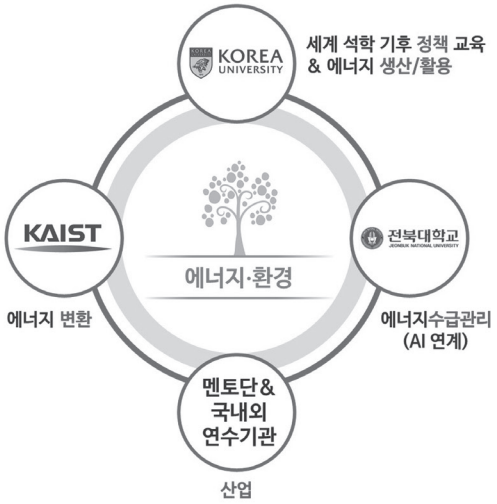
교육 : 기후기술 정책, R&D 기획
- 비학위 교육과정, 수료증 발행
- 글로벌 석학 온라인 강의

연구 : 기수별 5개 프로젝트 운영
- 산업난제 해결을 위한 연구주제 발굴 및 수행
- 에너지·환경 연구의 최적화된 컨소시엄 구성

국제협력: 해외 현장교육 프로그램 운영
- 본 센터와 교육, 연구 협력을 맺고 있는 글로벌 선진 대학 및 연구기관과 2주간 현장교육

멘토단 운영
- 연구주제 평가 및 자문, 산학협력 구축 및 연계, 국제협력 연계 및 자문

Total solution 제공 유일 센터 컨소시엄 구성
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정부지원 과학기술정보통신부 NRF 한국연구재단

고려대학교 에너지·환경 기후기술인재양성 센터

(02841) 서울특별시 성북구 안암로 145
고려대학교 KU R&D 센터 543호
Tel) 02-3290-4788

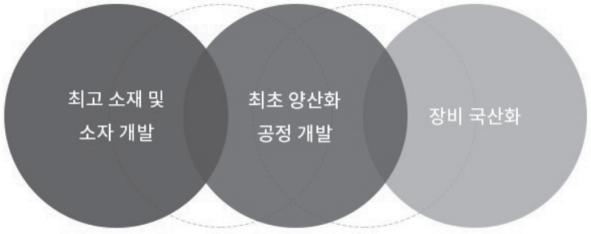
고려대학교 KOREA UNIVERSITY

Energy Innovation Research Center
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유무기복합형 태양전지 에너지혁신센터

차세대 페로브스카이트 태양전지 분야 세계 최정상급 연구 인력 양성

에너지혁신연구센터의 연구 3대 목표



유무기복합형 태양전지 에너지혁신연구센터
유무기 복합형 태양전지 최정상급 연구 인력 양성 거점 구축

❖ 본 센터는 고려대학교 태양전지 전문가로 구성된 교수진을 중심으로 소재, 소자, 공정의 전반적인 이해 및 연구력을 갖춘 **페로브스카이트 태양전지 최정상급 석박사 연구 인력 양성을 목표로** 합니다.

❖ **대표 기업과 참여/수요기업과의 연구개발 인프라와 협력 프로그램을 구축**하여 산업계 전반에서 필요로 하는 **실무적 인재**를 양성하고, 세계 유수의 연구 그룹들과 글로벌 네트워크를 구성하여 기술 및 인적교류를 통한 **글로벌 인재**를 양성하고자 합니다.

❖ **산업계와의 상호 교류를 활성화**할 수 있는 주체적 센터로 페로브스카이트 태양전지의 원천기술에서 양산기술까지 전주기적인 연구의 기술혁신을 주도하는 최정상급 인력양성으로 국내 태양광 산업 발전에 이바지하고자 합니다.

➢ **석박사 과정 지원을 적극 환영합니다.**

미래 태양광 분야 최고 전문가로 함께 할 석박사 과정생을 모집합니다.

➢ **관련 기업의 수요기업협의체 참여를 적극 환영합니다.**

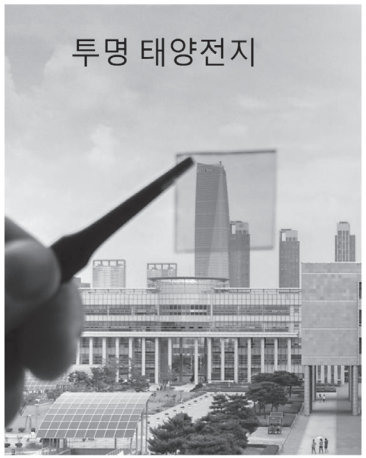
본 센터는 수요 기업협의체를 구성하여 관련 기술 교육 및 연구원 간 상호 교류, 산학협력 연구를 적극 추진하고있습니다

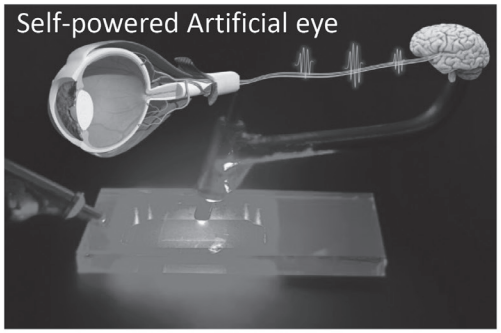
대표기업 (주)한화 참여기업 UniTest LKCHEM AINSFAC JC 정광산업기계 수요기업협의체

인천대학교 차세대 에너지 융합 연구소

MCIFE

Multidisciplinary Core Institute for Future Energies





연구 협력 목록:

1. 투명 태양전지 물질 및 디자인
2. 고기능성 투명 전극 및 구조체
3. Self-powered Bionics 기술

해외 언론 보도


TECH TIMES

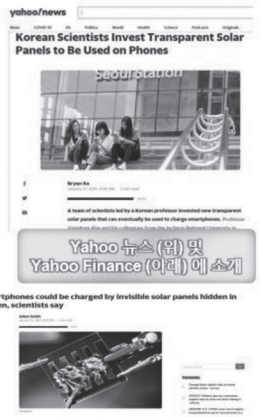
Korean Scientists Create First 'Invisible Solar Panels' You Can Integrate into Mobile Phones!

Tech Times (미국 뉴욕) 는 기술, 과학 및 의료 산업에서 발생하는 최신 혁신 및 개발에 대한 정보를 제공하는 매체


Electronics Weekly.com

Transparent solar cell from simple metal oxides

영국 최대 과학 및 비즈니스 저널인 Electronics Weekly에 소개


yahoo/news

Korean Scientists Invest Transparent Solar Panels to Be Used on Phones

Yahoo 뉴스 (원) 및 Yahoo Finance (아래) 에 소개

Smartphones could be charged by invisible solar panels hidden in screens, scientists say

dongguk UNIVERSITY 광에너지 융합기술 연구소 phet

Research Center for Photoenergy Harvesting and Conversion Technology

연구소 소개 및 비전

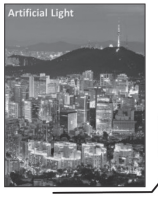
동국대학교 광에너지 융합기술 연구소는 융합에너지신소재 공학과를 비롯하여 화공생물 공학과 및 화학과 등 다양한 전공의 연구실로 구성되어 있으며 나노 소재 및 전기 화학을 기반으로 차세대 태양광 및 인공광전지, 광촉매, 물 분해, 이산화탄소 변환, 커패시터, 전기화학 바이오센서, 광전기화학 촉매 및 응용 등 폭넓은 연구를 수행하고 있습니다.

특히 본 연구소는 급변하는 기후 변화에 대응하고 스마트 빌딩 및 마이크로 그리드 시스템의 구축을 위하여 차세대 태양전지 기반의 인공광전지 소자에 대하여 광 에너지의 활용도와 심미성을 동시에 확보하여 보다 폭 넓은 실생활 접목을 목표로 소재 및 소자에 대한 원천 기술 연구를 집중적으로 수행하고 있습니다.

차세대 투명 태양전지 및 인공광전지

소자의 투과도와 광전 효율을 개선하기 위한 소재 및 소자에 대한 광범위한 연구 진행



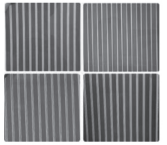


인공광전지



차세대 투명 태양전지

- 염료감응형 태양전지
- 페로브스카이트 태양전지
- 양자점 태양전지
- 고투과 R/G/B 모듈

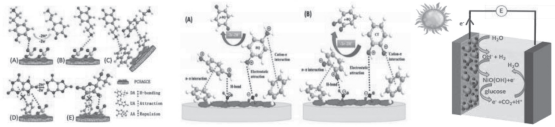


- 자가충전
- Wireless IoT
- 탄소 중립
- 예비 전원
- 조명 예술
- 소형 기기 상시 충전

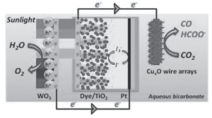
전기화학 기반 바이오센서

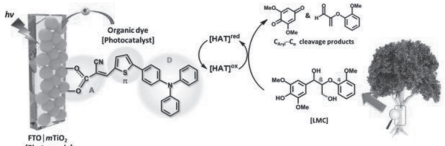
전기화학 기반의 wearable/flexible and Self-powered 바이오센서 개발





광전기화학 측매 응용





- CO_2 Reduction
- Supercapacitor
- Oxygen/Hydrogen Evolution Reaction(OER/HER)
- Dye-Sensitized Photo Electrochemical Cell(DSPEC)

Post-Doc /연구원/대학원생 모집

- **모집분야 :** 차세대 태양전지, 광전기화학, 전기화학 기반 에너지 변환·저장, 바이오센서, 재료 화학, 유·무기 반도체 소재/소자 등
- **전형 절차 및 일정 :** 홈페이지 http://nanochemdgu.wixsite.com/ncpec
  서류 접수 jjlee@dongguk.edu
- **문의 :** 02-2290-1474

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기술이전 및 사업화 지원

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연구장비 공동활용

교육지원/ 창업보육

BIPV No.1
SKSE
|주| 에스케이솔라에너지

가장 선호하는 BIPV 전문기업
BIPV 제조부터 시공까지 Total Solution 기업
주식회사 에스케이솔라에너지



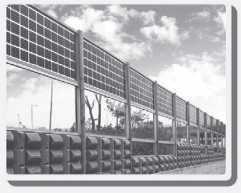
BIPV / BAPV

인버터 / PV모듈

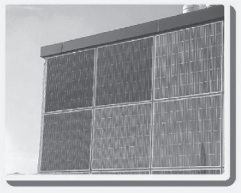
설치 시공

KS 인증 업체 | 이노비즈 | 지역스타기업 | 기술평가우수기업(T3) | 중기부장관표창

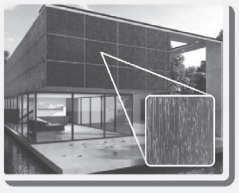
PRODUCT



양면, Half BIPV



Color BIPV



Pattern BIPV



태양광 루버

(주) 에스케이솔라에너지

본사 : 대전광역시 서구 월평북로 85, 3층 372호 (월평동,학산빌딩) 공장 : 세종특별자치시 연동면 장욱진로 112
사업자등록번호 : 709-86-01056 대표번호 : 042-381-0909 Fax : 044-903-0960 대표메일 : skse1@skse1.com

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주식회사 에스케이솔라에너지

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Chlorides
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Cyanates
Tetrafluoroborates
Hexafluoroborates
Acetates
Spiros

Cobalt Complexes (14)

DSC MATERIALS

Dyes & Sensitizers (6)

Electrolytes & Components

PASTES & INKS

Titania & Platinum Pastes (9)

Silver Inks (1)

GLASS & SEALANTS

Glass Substrates (15)

Sealants (8)

LIGANDS & ADDITIVES

Ligands & Intermediates (15)

Additives & Modifiers (7)

구입문의
이레상사

주 소 : 경기도 성남시 분당구 황새울로 319번길 6, 603호
전 화 : 010-9159-8069
E-Mail : hgkim@greatcellsolarkorea.com



clean energy clean energy clean energy clean energy

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