

Introduction to the “**Graduate School of Integrated Energy(PV)-AI**” Supported from the Ministry of Trade, Industry and Energy & KETEP

O-Bong Yang

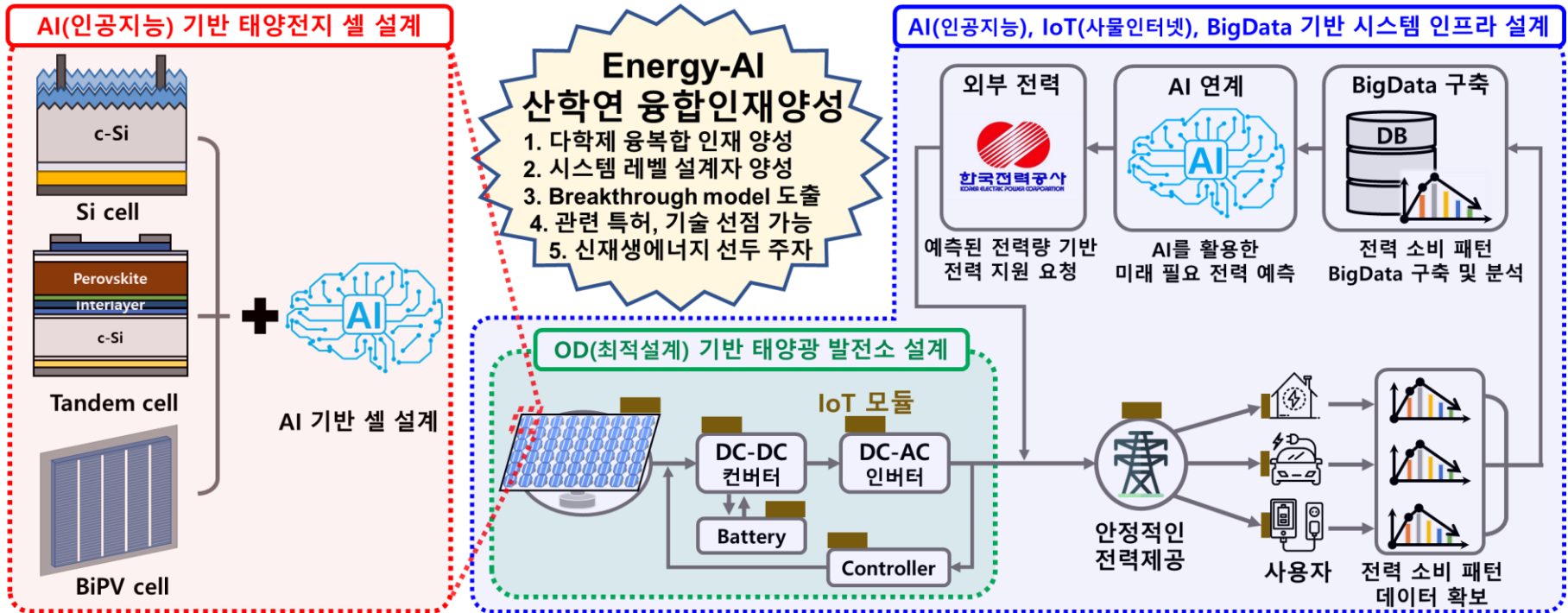
**Graduate School of Integrated Energy-AI &
School of Chemical Engineering
Jeonbuk National University, Korea**

- Education of Master and PhD by Integrated PV(Photovoltaic)-AI(Artificial intelligence)
 - Project title: Energy-AI integrated Graduate School (Photovoltaic-AI Integrated Manpower Training Project)
 - Supervising agency: MOTIE/KETEP
 - Participating Institutions: Korea Univ. (Director Prof. Dong-hwan Kim), Hanwha Solutions Co, Shinsung ENG Co, LG Electronics TM Solutions Co, J Solution Co et al
 - Project period: 2020.6.1~2024.12.31 for 5years
 - Budget : 1B\$/year (5B\$/5years)
 - Objectives of PV-AI Projects
 - Education of PV-AI convergence manpower: 20/year of Master/PhD
 - Solar cell material and device innovation and smart grid optimization by PVAI
 - PVAI researcher will lead Korean PV industry and Korea N&RE Vision 3020 (20% N&RE by 2030)

Project content: PV+AI+ α (IoT, big data) integrated Education and research

Education and R&D for PV material/Device and smart grid based on AI

- Adopting AI's Optimal Design Technique for high performance Si solar cell, Tandem cell, BIPV design/development
- Smart grid design in Solar Power Plant by AI-based PV Technology and Big Data provided by IoT.



전북대, 고려대, 산업체

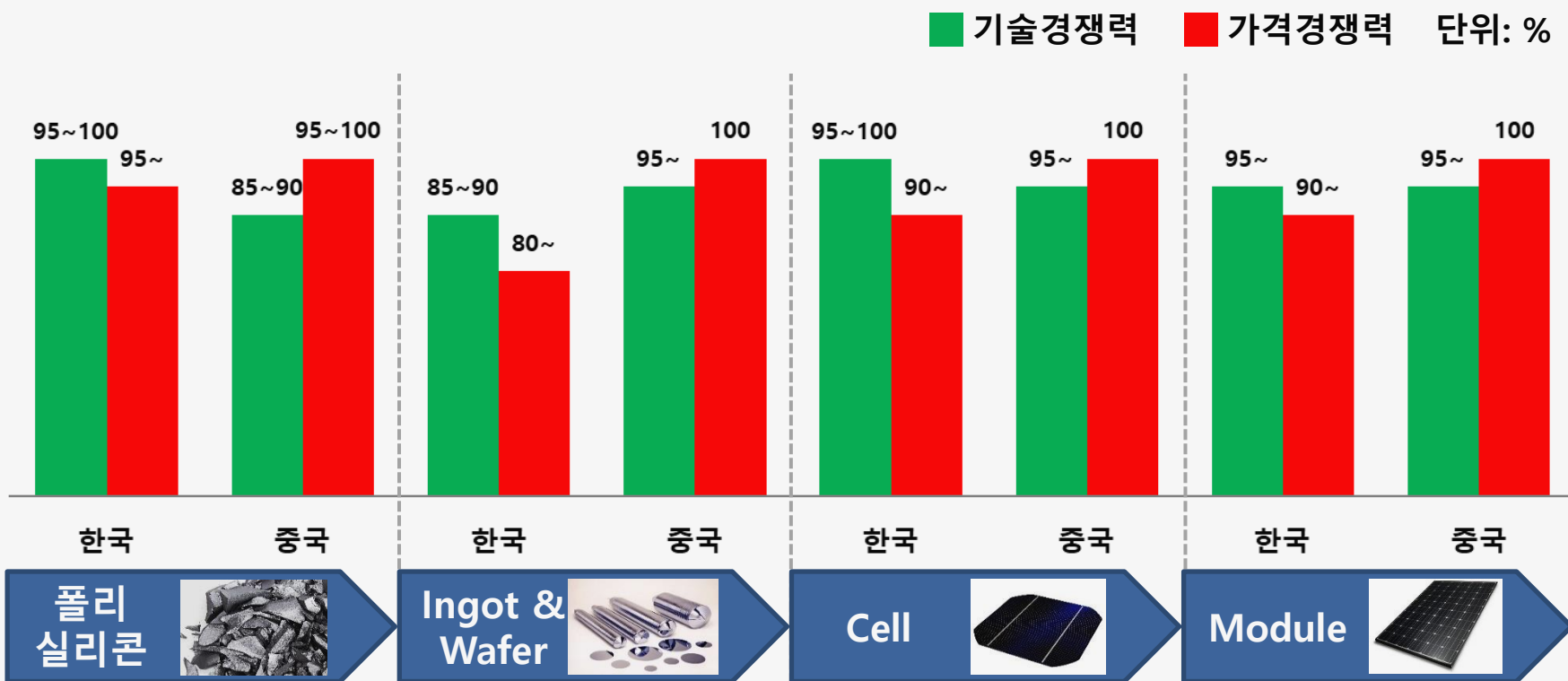
(한화솔루션, 신성E&G, 솔라시도코리아, SG에너지, 씨피에스, 제이솔루션, 중앙강재)

전북대, 산업체

(티엠솔루션스, 금강이엔지, 삼신기업)

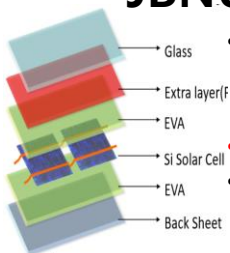
- Securing PV's Competitiveness vs China: **PV-AI integration is key for Technology innovation**
 - China has excellent price competitiveness: Korea needs to compete with China by securing technological competitiveness
 - Korea's strategy to secure technological competitiveness: **Technology innovation through the integration of AI and PV is key**

In 2018, **Korea VS China PV Co Competitiveness, G: Tech, R: Price**



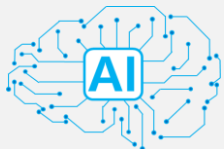
■ PVAI Convergence Training Strategy:

JBNU Research

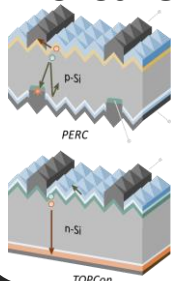


- Next Generation cell materials development by AI tech
- **BIPV** Solar cell design
- AI-based PV power plant design and smart grid

Joint technology



Korea University Research



- AI based PERC solar cell device design
- AI based Design of Tandem-type Solar Cells
- IoT Based Solar Cell Deterioration Study

Curriculum

	1학기	2학기	3학기	4학기
AI 응용 교육 과정	반도체 이론	PV 이론	모듈 및 시스템	PV-AI 융합
현장실습 인턴십	AI 기초 및 응용		현장실습 (셀, 모듈 제작 및 발전소 견학)	인턴십 AI 산업응용 (태양광 업체)
학생참여 R&D 프로젝트	한화솔루션, 신성이엔지, 티엠솔루션스, 제이솔루션 애로기술 해소			
융합교육	전북대-고려대 AI 온라인강의 상호제공, 인력교류, 협동세미나, 협동연구			

- 인턴십 현장 실습 제공
- 기업체 전문가 PV 특강

Industry

- Cooperative PVAI research and provide the internship
- Supply the big data for PVAI cooperation



융합인력양성

- AI 기반 최적화 모델 제공
- PV-AI 융합 인재 공급

Jeonbuk National University

- BIPV with PVAI
- Perovskite and organic PV with AI tech
- Sola cell new materials based on AI
- Smart grid study with PVAI

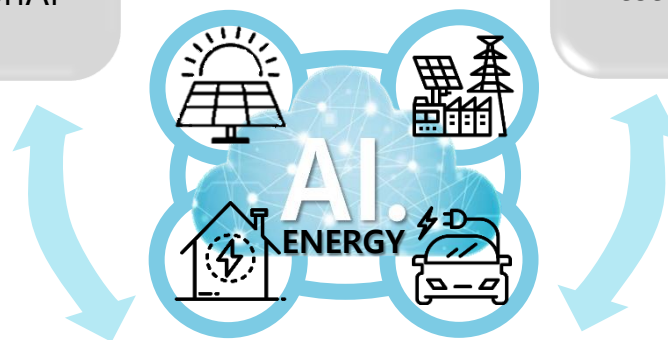


Korea University

- Ultra High Efficiency Solar Cell technical research (target over 26.5%)
- IoT+AI solar cell Deterioration Research
- Tandem device by AI optimization design research (target over 28%)



PV-AI Integrated Graduate School



Industry-linked education

- PVAI customized R&D and training
- Special lectures by business experts on PV
- Provide big data for PVAI researches
- Internship



	1학기	2학기	3학기	4학기
Curriculum	<ul style="list-style-type: none"> Organic and inorganic energy material Semiconductor device physics Special lecture on optoelectronic materials and devices Basic theory of semiconductor and solar cell Artificial intelligence theory 	<ul style="list-style-type: none"> BIPV solar cell and module design Hybrid convergence device special lecture Special lecture on energy storage technology High efficiency and thin film solar cell technology (Si, CIGS, Perov, Tandem) Artificial intelligence application 	<ul style="list-style-type: none"> Solar cell and module deterioration, analysis and simulation AI-based solar conversion technology and design Optimal Design (OD) Theory and Programming for Photovoltaic Power Plant Design Design Theory of IoT and AI-Based Solar Cells 	<ul style="list-style-type: none"> Fuzzy-based economic and environmental analysis IoT-based solar cell practice Paper Experiment Presentation-PVAI Industry-academia collaboration project and thesis guidance
Advanced Course	<ul style="list-style-type: none"> Artificial Intelligence: Special Lecture on Big Data Processing Statistics Solar cell: solar device manufacturing and measurement practice PVAI Integrated Seminar 			
Industry Internship	<p>Field practice</p> <ul style="list-style-type: none"> Solar Cells, Modules Design and Production Field Exercise Field Exercise in Design and Construction of Photovoltaic Power Plants 		<p>Internship</p> <ul style="list-style-type: none"> Internship of Solar Cells and Modules Companies Internship of Solar Power Plant Design and Construction Company 	
R&D project	<p>Student-led Corporate Customized R&D Project</p> <ul style="list-style-type: none"> Hanwha Solution: AI-based charge-selective solar cell and module technology development LG electronics: AI-based double-sided light-receiving solar cell development Shinsong E&G: AI-based TOPCON solar cell characteristics analysis and improvement technology TM solutions: OD(Otimal design) development for solar power plant Solar city Korea: Development of AI-based paste materials SG energy: AI-based BIPV development Geumgang Energy CPS J solutions Central Steel 			
Cooperative education	<p>Jeonbuk National University-Korea University Education exchange</p> <ul style="list-style-type: none"> Supply mutual online lecture R&D project of Jeonbuk National University-Korea University-industry-academia cooperation research progress Conducting Human Resources Exchange and organizing a cooperative seminar 			

PVAI Education Curriculum

curriculum		Subject	AI (Artificial Intelligence) based solar cell design	Solar power plant design based on OD (optimal design)	AI, IoT, BigData infrastructure design and system
Solar energy (Total 21 subjects)	Organic and inorganic energy material	O			
	Semiconductor device physics	O			
	Special lecture on optoelectronic materials and devices	O			
	Basic theory of semiconductor and solar cell	O			
	Special lecture on energy storage technology	O	O	O	
	BIPV solar cell and module design	O		O	
	Hybrid convergence device special lecture	O			
	Fundamental Theory of Semiconductor and Solar Cells	O		O	
	High efficiency solar cell technology	O			
	High efficiency and thin film solar cell technology (Si, CIGS, Perov, Tandem)	O			
	Solar cell and module deterioration, analysis and simulation	O	O	O	
AIBO* (AI, IoT, Bigdata)	Artificial intelligence theory	O	O	O	
	Artificial intelligence application	O	O	O	
	AI-based solar conversion technology and design		O	O	
	Optimal Design (OD) Theory and Programming for Photovoltaic Power Plant Design		O		
	Design Theory of IoT and AI-Based Solar Cells		O	O	
	Special lecture on Big Data Processing Statistics		O	O	
	Fuzzy-based economic and environmental analysis			O	
	Practice of IoT and AI-based solar cells			O	
	Electronics Interpretation Software Class			O	
Industry Subjects (5 Subject)	Industry Cooperation Seminar	O			
	Industry Internship	O			

*AIBO: AI, IoT(사물인터넷), BigData, Optimal Design(OD)

PVAI education and research plan

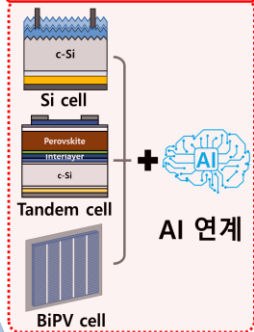


태양광발전-AI
융합인력양성사업

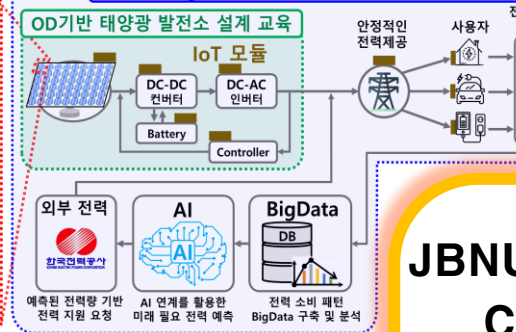


AI, IoT, 빅데이터, 최적설계 기반 BIPV, Perovskite, 생산기술, 발전소 설계

AI기반 태양전지 셀 설계 교육

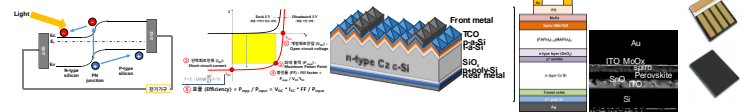


AI, IoT, BigData 기반 시스템 안정성 설계 교육

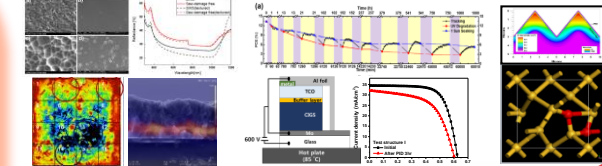


박막(CIGS)/고효율 실리콘 태양전지, 열화 및 안정성

- 태양광 기초 이론 교육
- 태양광 고효율화 기술 교육
- 신재생에너지 기초 이론 습득 및 연구 동향 파악
- 고효율 태양전지 설계
- 탠덤 태양전지



- 태양광 소자, 모듈의 분석 및 시뮬레이션 교육
- 태양광 분석 교육
- 열화 원인 분석
- 시뮬레이션



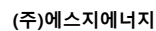
JBNU-Korea Univ. Cooperative Education

Industry-Academic Cooperation Seminar and tutorials

- Energy special seminar**
 - Energy sector policy, Market, Inviting domestic and foreign experts
- Energy start-up course**
 - start-ups in the energy sector, Technology transfer, Patent writing method, Specialist Invitation Seminar on Research Methodology, etc.
 - Introducing energy specialists for work/employment by explaining the current status of the industry
- Customized R&D projects and on-the-job training for companies**
 - Master/PhD Students participating in industrial interns for solving and improving the skills
 - Organizing a joint workshop based on industry-academia cooperative research
 - Participating Institutions-Participating Companies permission to utilize Research Facility Equipment and materials, manpower exchange, field training, and internship opportunities



(주)제이솔루션

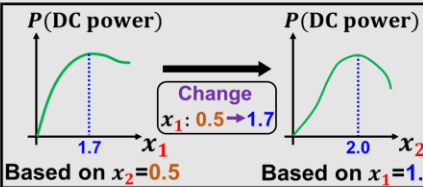


Student-led R&D Project1

- Development of High efficiency silicon and tandem solar cells by AI based design methods
 - Development of Charging Selective Technology for High Efficiency Silicon Solar Cells and Modules(Hanwha Solutions)
 - Development of Tunnel Oxide-Based Solar Cell Technology(Shin seong energy)
 - Development of High-Efficiency bi-facial Solar Cells (LG electronics)

Empirical design approaches

Design variables: (x_1, x_2)
Initial point: $(x_1=0.5, x_2=0.5)$



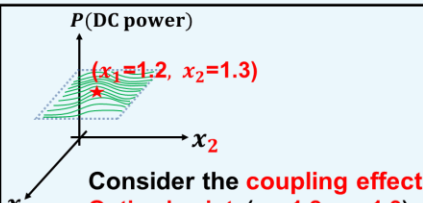
Change $x_1: 0.5 \rightarrow 1.7$

Based on $x_2=0.5$ Based on $x_1=1.7$

Better point: $(x_1=1.7, x_2=2.0)$
But, not optimal point

Limitation
Can not consider the **coupling effect**
(i.e. coupling effect between x_1 and x_2 in this example)

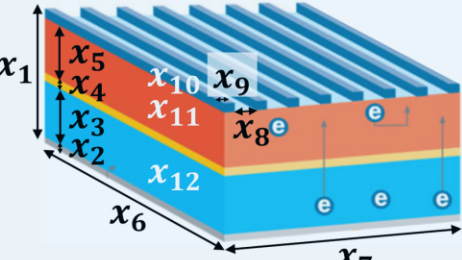
AI-based design approaches



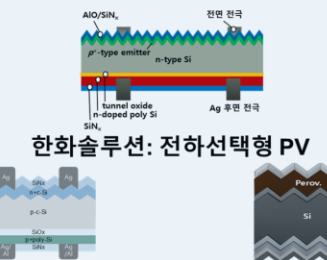
Consider the coupling effect
Optimal point: $(x_1=1.2, x_2=1.3)$

AI-based design approach for the solar cells

Structural design variables: $\{x_1, x_2, \dots, x_8, x_9\}$
Material quantity design variables: $\{x_{10}, x_{11}, x_{12}\}$



Solar cell (Si, Tandem)



신성이엔지: TOPCon PV 고려대학교: Tandem PV

Breakthrough (optimal) solar cell

Case	Design Variables						Performances		
	Structure (cm)			Material quantity (g)			Voltage (V)	Measured Current(A)	
	x_1	x_2	...	x_9	x_{10}	x_{11}	x_{12}		
1	2.0	0.2	...	0.1	20	180	200	-3.5057	1.364
2	2.5	0.1	...	0.1	15	170	150	-4.1291	1.760
3	3.8	0.3	...	0.2	18	230	180	-2.0588	0.760
⋮	⋮	⋮	...	⋮	⋮	⋮	⋮	⋮	⋮
n	1.5	0.1	...	0.1	22	250	220	-3.1291	1.259

Experiment & Data Acquisition

Build BigData

AI Algorithm

Data Learning

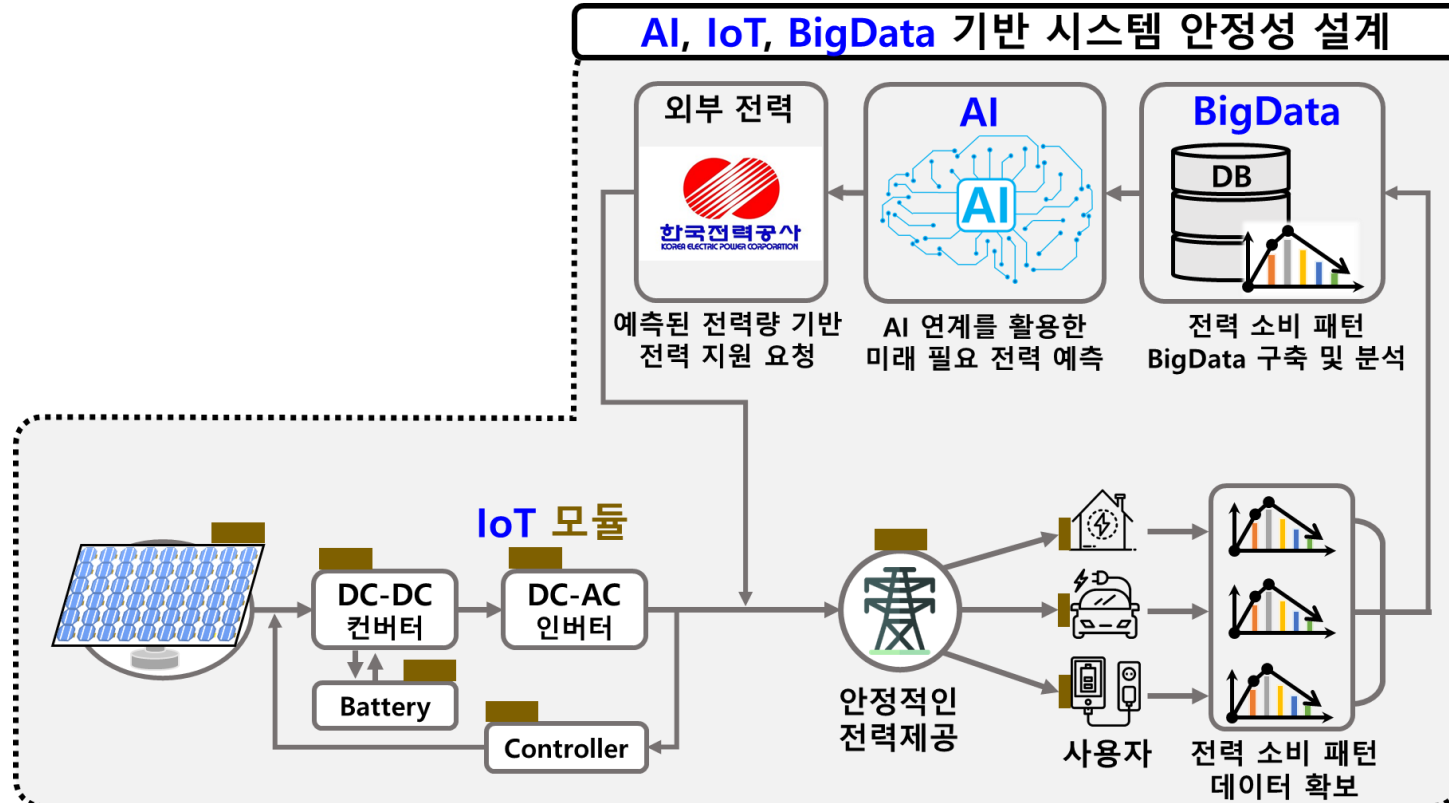
Optimization

Can consider the **coupling effect** among all the design variables (x_1, \dots, x_n)

Student-led R&D project 2

○ AI, IoT(사물인터넷), BigData based smart grid design

- To ensure the stability of solar power plant systems by IoT-based big data for smart grid design and O&M
- Development of Power Demand and Supply Prediction by AI Program Based on BigData with IoT



Director capability(Prof. O-Bong Yang)



양오봉
교수

AI 분야 전문가



정길도
교수



이말례
교수



이승범
교수



한지훈
교수

IoT 분야 전문가



조성익
교수



이종열
교수

PV 분야 전문가



이수형
교수



김민
교수



노원엽
교수



M. Shaheer
Akhtar 교수

Field of expertise: organic and inorganic material solar cells, next-generation solar cells, artificial intelligence, IoT

총괄 책임자 경력

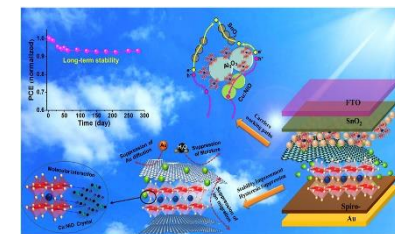
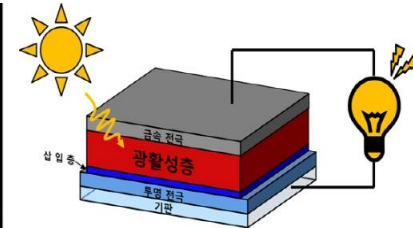
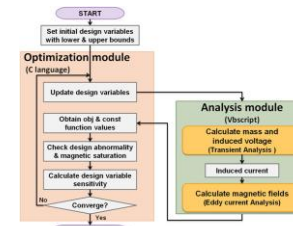
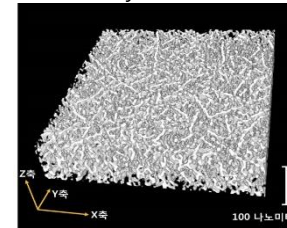
- 1) Member of the Saemangeum Committee (Chairperson)
- 2) Korea Photovoltaic Society, Chair
- 3) US National research energy laboratory(NREL) Visiting researcher
- 4) Saemangeum renewable energy projects, Members of the public council
- 5) A member of the Planning and Evaluation Committee of the Economic and Humanitarian Society Research Council
- 6) Nonghyup Economic Group, Solar Energy Advisor
- 7) Presidential Committee for Balanced National Development, Special Committee for Innovation City, Member
- 8) 1st Jeollabuk-do Regional Innovation Council, member
- 9) Global Photovoltaic Conference (GPVC) 2019, 2017 Chairman
- 10) Presidential Commission on Employment, Advisory Committee
- 11) Democratic Peace and Unification Advisory Council, Advisor

참여 교수들 최근 주요 연구 업적 : 600
편 이상

- 1) SCIENCE
- 2) NATURE PHOTONICS
- 3) ADVANCED FUNCTIONAL MATERIALS
- 4) ADVANCED ENERGY MATERIALS
- 5) IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS
- 6) IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY
- 7) ENERGY ENVIRONMENTAL SCIENCE
- 8) JOURNAL OF MATERIALS CHEMISTRY A
- 9) APPLIED SURFACE SCIENCE
- 10) NANO ENERGY
- 11) SOLAR ENERGY MATERIALS AND SOLAR CELLS
etc.

Representative research performance

- 1) Development of a foldable solar cell like paper
- 2) Development of high-efficiency organic solar cell using printing technology
- 3) Development of perovskite solar cell with improved stability



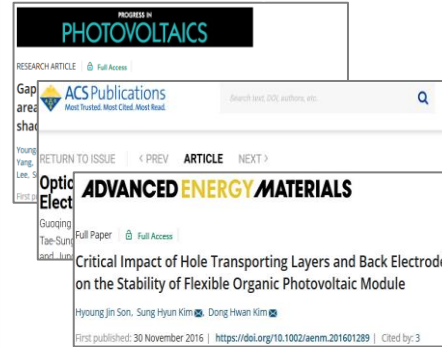
Competency of the research director of the participating institution (Korea University)



김동환 교수 이해석 교수 전용석 교수 강윤묵 교수 박현정 박사

- **Specialty:** Silicon solar cell / module / tandem solar cell
- **Technology transfer:**
- **Technology transfer of new concept solar cell silicon wafer manufacturing technology”**
- **(2009.12, fixed technology fee 200 million won + additional current technology fee)**
- **Technology transfer of “coaxial solar cell technology”**
- **(2010.01, flat-rate technology fee 280 million won + additional current technology fee)**
- Major research achievements in the last 3 years: Adv. Energy Mater, Adv. Funct. Mater, ACS Appl Mater Interfaces, Prog. Photovoltaics, etc. (Recent 46 papers, IF sum> 150.0)
- Representative Research Achievements: Development of next-generation high-efficiency silicon solar cell technology, high-efficiency PERC solar cell and module mass production technology, and perovskite high-efficiency and stability technology development
- Tasks: 1. (Industry-Academic Cooperation) Research on lead-free paste for front and rear electrodes for simultaneous firing of crystalline silicon solar cells, 2. (national project) Development of ultra-high efficiency crystalline silicon solar cell and module mass production technology
- **Awards:**
- 1. 2019 Science and Technology Medal of Innovation (Ministry of Education, Science and Technology)
- 2. 2018 International Conference PVSEC AWARD (Top Prize in Solar Power Field)
- 3. 2013 Nanotechnology Award, Minister Award (Ministry of Science, ICT and Future Planning)
- 4. 2010 New Renewable Energy Grand Prize, Minister's Award (Ministry of Knowledge Economy)

Representative thesis of Korea University

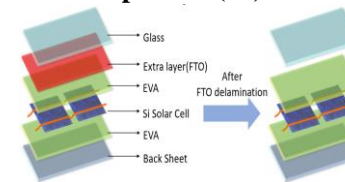


Published excellent papers in the field of silicon and tandem solar cells (more than 46 papers in the last 3 years)

Advanced Energy Materials, Advanced Functional Materials, Progress In Photovoltaics 등

Korea University patent

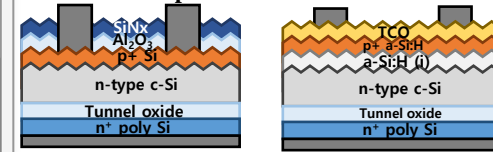
Silicon solar cell, module and perovskite solar cell field
Material-device-process related patents (89)



Representative patent: Silicon solar cell module recycling technology

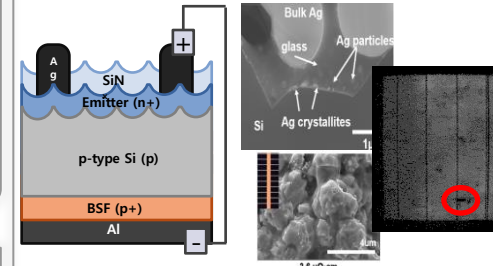
High efficiency of silicon solar cell and development of tandem solar cell technology

<Development of next-generation high-efficiency solar cell technology and new concept solar cell structure>

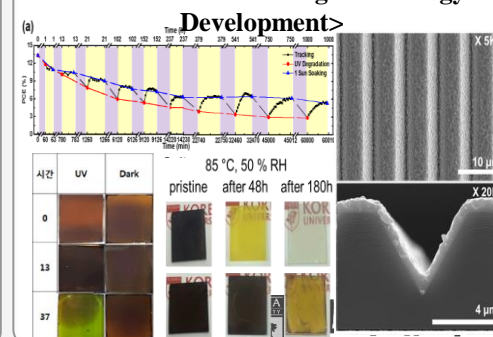


TOPCon 22.0% ASETOB 23.7%

<Silicon solar cell electrode formation mechanism analysis>



<Perovskite Solar Cell Safety Analysis and Conformal Coating Technology Development>



■ Leading and Supporting the Korean PV Industry and Vision 3020

- ❑ 4GW renewable energy power plant in Saemangeum, Jeollabuk-do (Declaration of renewable energy vision)
- ❑ 3GW solar power plant, 1GW offshore wind farm, 0.1GW hydrogen fuel cell power plant, bio production facility
- ❑ Establishment of national renewable energy demonstration research complex (Saemangeum, Jeonbuk)
- ❑ Renewable energy demonstration and smart grid test bed
- ❑ **Saemangeum renewable energy cluster, supply of high-quality human resources for the design and operation of the national empirical research complex**

Saemangeum renewable energy vision declaration ceremony (2018.10.30.)



Saemangeum National Renewable Energy Demonstration Research Complex (draft), KETEP



Our vision !

Our PV-AI Integrated Graduate School will be the platform of convergence of AI and PV, Wind energy, bio-energy, hydrogen-fuel cell for the sustainable world.

