

THE 29TH INTERNATIONAL CONFERENCE ON
PHOTOVOLTAIC SCIENCE AND ENGINEERING
THE 18TH CHINA PHOTOVOLTAIC CONFERENCE

PVSEC

Friday, November 8
International Reporting Hall
Closing Ceremony

PVSEC-29 Summary

Registration: 1448

Actual Participants: 1034

Keynotes & Plenary: 15

Invited Speech: 75

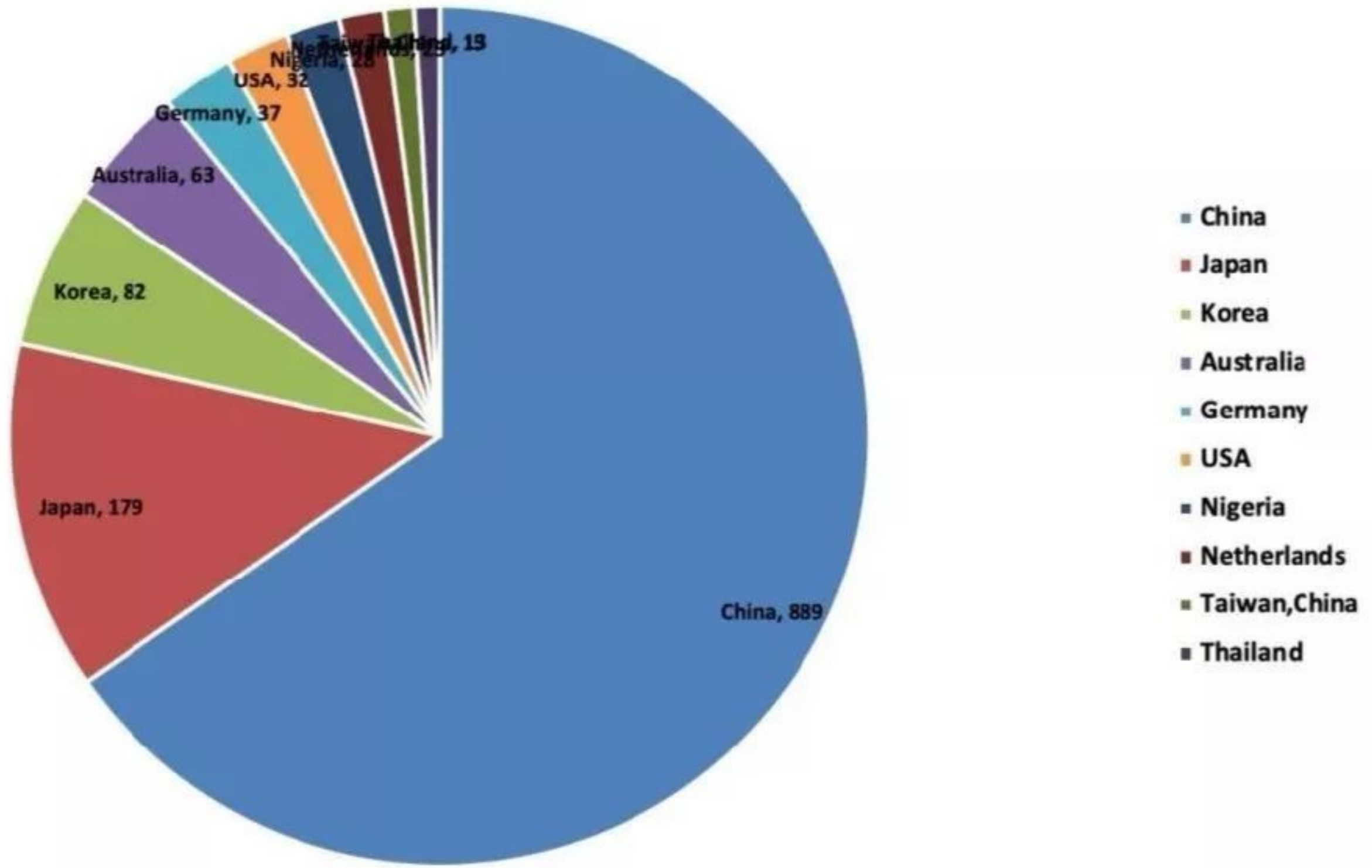
Abstract Submitted: 722

Oral Presentation: 284

Poster Presentation: 437



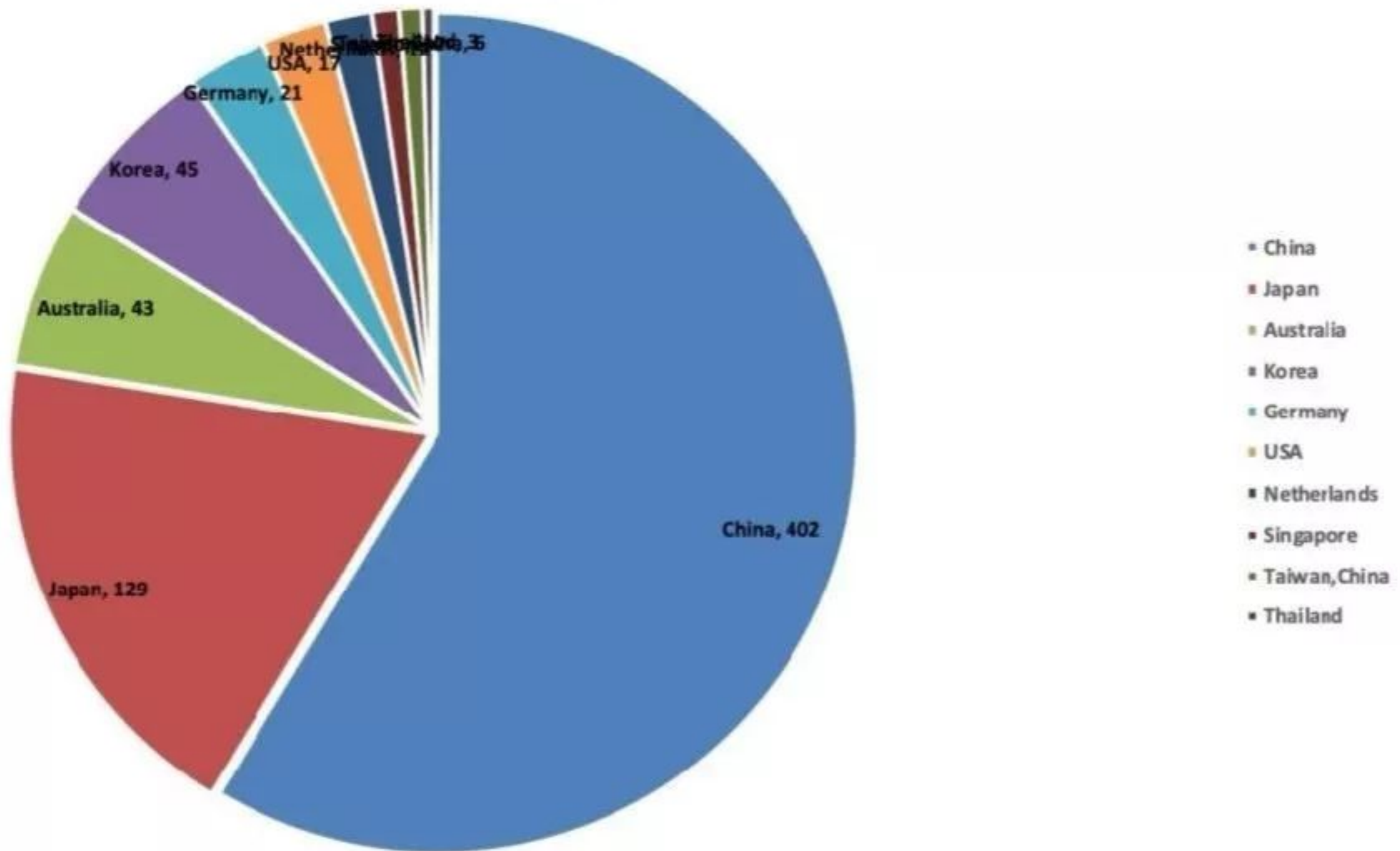
Registered Participants



PVSEC-29

29th International Photovoltaic Science and Engineering Conference
 Qujiang International Conference Center, Xi'an, Shaanxi, China
 4-8 Nov. 2019

Papers devided by country



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Hot Debate



Is HIT for immediate future?



Can Perovskite prevail from instability and toxicity?



C-Si: Cast mono or CZ?



From Ancient History to Future Perspective

- **Tandems, Topcon, HIT, perovskite (hybrid, all-inorganic, 2D).....**
- **Longi: Solar to Solar**
- **Cast mono c-Si**
- **Hydro-wind-PV combination**
- **PV – storage solution**



2019 solar cell best-efficiency table of China

Classification	Efficiency (%)	Area (cm ²)	Voc (mV)	Jsc (mA/cm ²)	Fill Factor (%)	Test Centre (date)	Description	单位中文备注
Silicon								
Si (crystalline cell)	24.85 ± 0.35	244.54 (t)	746.0	39.39	84.58	ISFH (8/19)	Hanergy, HIT	汉能
Si (crystalline cell)	24.58 ± 0.34	244.62 (t)	716.8	40.57	84.52	ISFH (5/19)	Trina Solar, n-bifacial/i-TOPCon	天合光能
Si (crystalline cell)	24.03 ± 0.34	244.59 (t)	694.0	41.58	83.26	ISFH (10/19)	LONGI, PERC	隆基股份
Si (multicrystalline cell)	22.8 ± 0.32	246.66 (t)	687.1	40.9	81.16	ISFH (9/19)	Canadian Solar, PERC	阿特斯
III-V Cells								
GaAs (single junction)	29.1 ± 0.58	0.9980 (da)	1127.2	29.78	86.67	FhG-ISE (10/18)	Hanergy, Alta Devices	汉能
Thin film chalcogenide								
CIGS (on glass)	22.92 ± 0.33	0.9856 (da)	779.0	36.97	79.57	FhG-ISE (2/19)	Hanergy, Solibro	汉能
CIGS (flexible)	20.56 ± 0.13	0.8657 (ap)	767.5	33.46	80.07	NREL (6/19)	Hanergy, MiaSole	汉能
Perovskite								
Perovskite (cell)	23.7 ± 0.76	0.0739 (ap)	1169.7	25.4	79.80	Newport (9/18)	CAS	中科院半导体研究所
Perovskite (cell)	22.2 ± 0.1	1.146 (da)	2.0	14.52	75.10	JET (8/19)	NIJ, tandem	南京大学
Perovskite (minimodule)	17.25 ± 0.55	19.277 (da)	1069.7	20.66	78.10	Newport (5/18)	Microquanta, 7 serial cells	杭州纤纳
Perovskite (submodule)	14.30 ± 0.35	300.74 (da)	2895.0	19.79	70.00	ESTI (10/19)	Microquanta, 28 serial cells	杭州纤纳
Organic Solar Cell								
Organic	16.48	0.04137	844.7	25.484	76.58	NREL (5/19)	SCUT	华南理工大学

*The efficiencies with red color is also the highest efficiency in the world.

Best-Efficiency-Summary Highlights

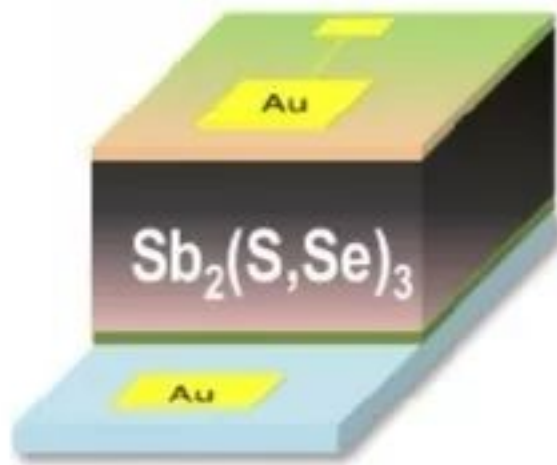
- Mono-crystalline cells (IBC 25%, HIT 24.85%, PERT/TOPCon 24.58%, PERC 24.03%) and multi-crystalline cell (PERC 22.8%, from casting ingot) with the best efficiencies have an industrial large area (~244.6 cm²), which are very easy to transfer into the mass production line.
- The best-efficiencies of thin film cells (GaAs one-junction (29.1%) & two-junctions (31.6%), organic solar cell (16.8%), perovskite mini-module (17.25%, 14.30%) are also the highest efficiencies in the world listed on NREL's Chart of Best Research-Cell Efficiencies or Martin Green's Solar cell efficiency tables.
- Perovskite module with a large area (300 cm²) and efficiency of 14.30% shows a good commercializing potential.

Area 1 – Advanced Concepts and New Emerging Materials for Future PV

Highlights:

1. Prof. T. Chen at USTC increased cell efficiency of $\text{Sb}_2(\text{S,Se})_3$ to over 10%.
2. Dr. K. Kamide at AIST proposes a concept to convert heat to electricity using narrow bandpass filtering, which does not require fast carrier extraction and can be realized with a Si absorber.
3. Dr. Z. Hameitri at UNSW reports a machine learning approach to better predict solar cell efficiency.

10% Efficient $\text{Sb}_2(\text{S,Se})_3$ Solar Cell



The calibration has been conducted by the PV Metrology Lab of NIM (National Institute of Metrology, China). Measurement of irradiance intensity and all other measurements are traceable to the International System of Units (SI). The performance parameters reported in this certificate apply only at the time of the test for the sample.

I_{sc} [mA]	2.140	V_{oc} [V]	0.655	P_{max} [mW]	0.890
I_{ms} [mA]	1.817	V_{ms} [V]	0.490	Efficiency [%]	10.0
FF [%]	63.5	Area [mm ²]	8.889		

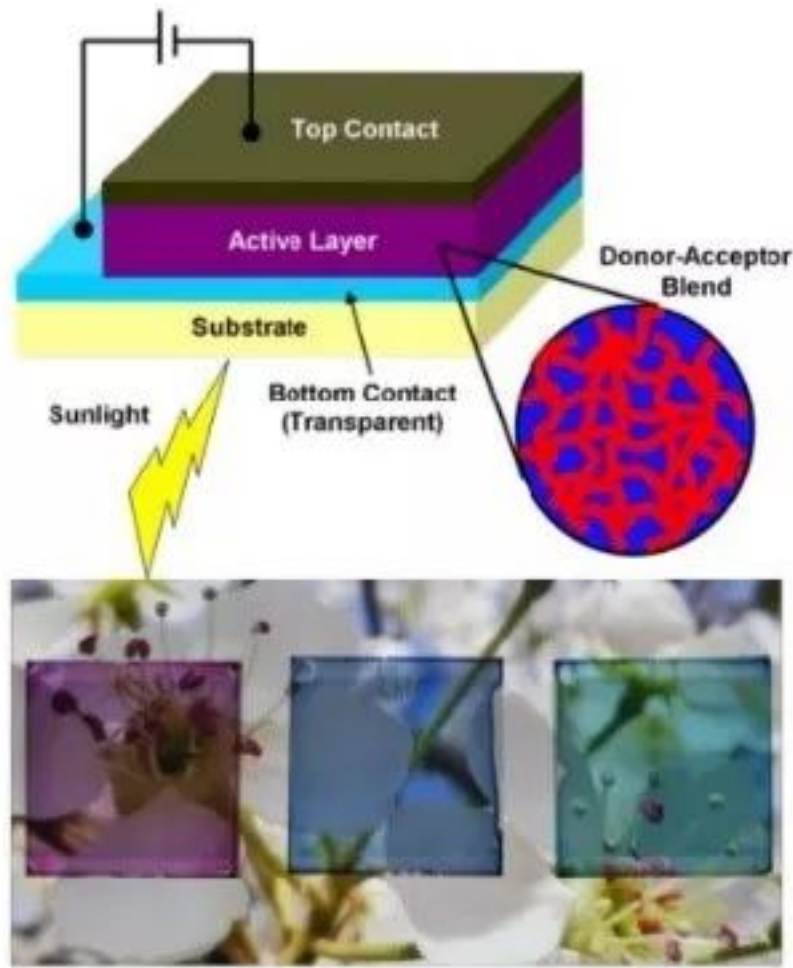
Area 2 Perovskite solar cells

Highlights:

1. Highly efficient perovskite solar cells : PCE 20.5% (2.76cm²); MA-Free Perovskite solar cells: PCE 21%; University of Tokyo, Japan, Takeru Bessho.
2. Highly efficient perovskite solar cells based on Evaporation + solution method suitable for textured wafer substrate to realize tandem solar cells: PCE 20.7%; Biao Shi, Nankai University, China.
3. Highly efficient inorganic CsPbI_2Br perovskite solar cells with a record efficiency of 16.79%, Zhike Liu, Shaanxi Normal University. China.
4. Highly efficient all perovskite tandem solar cells: PCE 22.2% (1cm²), Hairen Tan, Nanjing University, China.
5. Perovskite solar module: 702cm², PCE 13.2%; Shigehiko Mori, Toshiba Corporation, Japan.
6. Controlling Ions lateral diffusion of perovskite solar

Area 3 – Organic Solar Cells

Highlights:

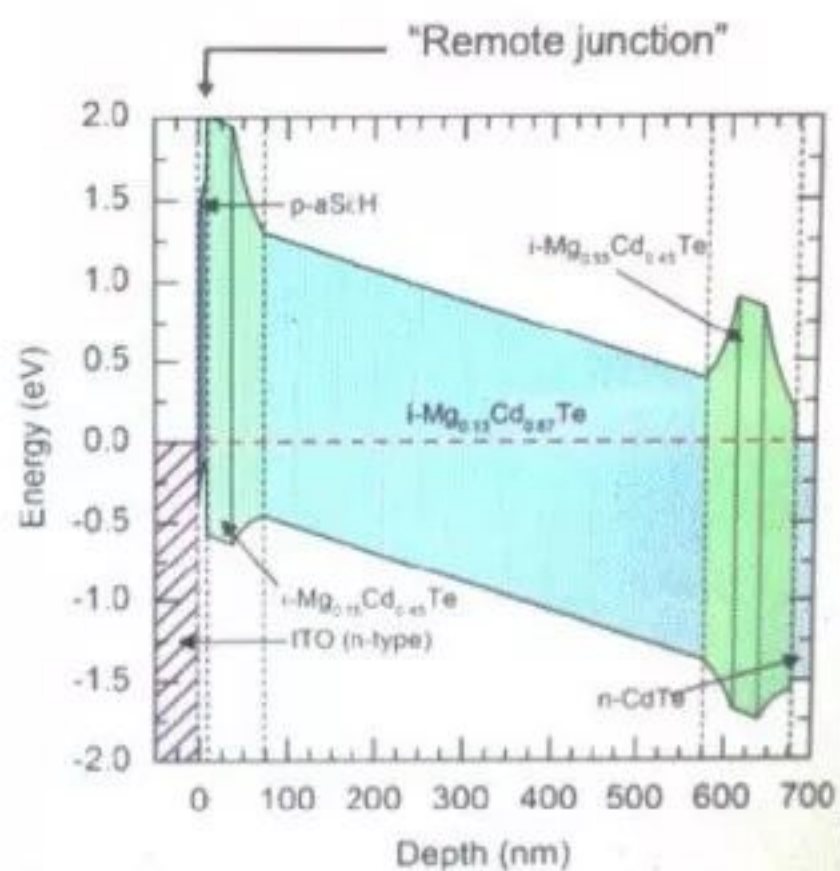


1. **PCE > 17% achieved in rigid small-size OSCs.**
2. **Flexible OSC modules demonstrated over 10% PCE.**
3. **For OSCs, the ITO-free substrates showed comparable properties to ITO-glass.**

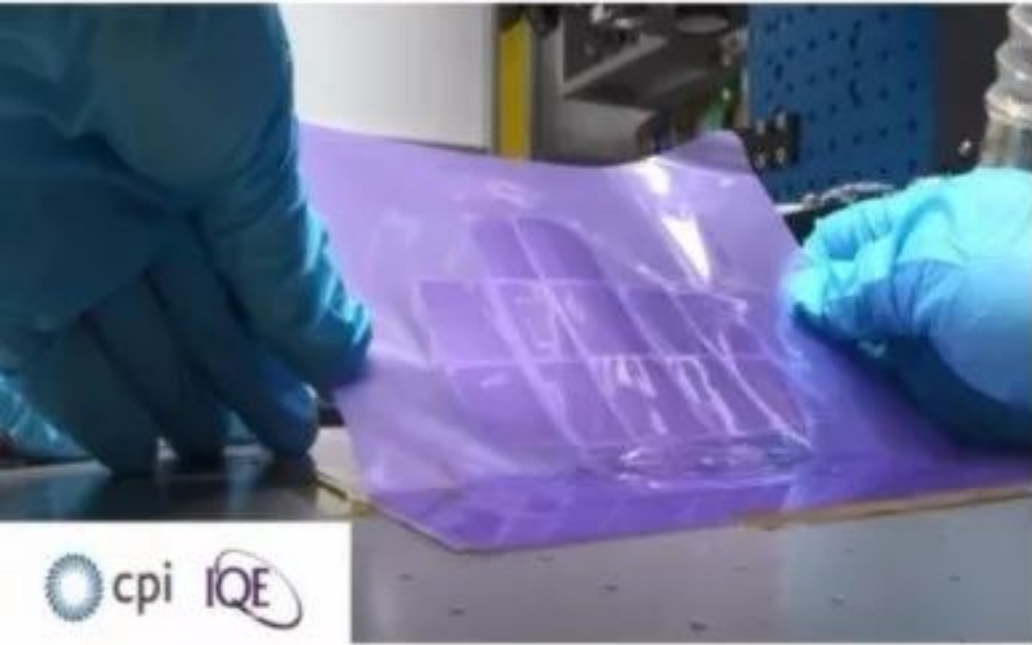
Area 4 –Thin Film Compound Semiconductor PV

Highlights:

1. **First Solar reported accumulative shipment of 25GW and 19% module efficiency (aperture).**
2. **Dr. I. Kosan presented a sputtered ZnMgO buffer for CIGS cells, showing 22% efficiency with reduced cost.**
3. **Longyan Energy, China shows 19.25% CdTe solar cell, 17.4% mini module (31.5 cm²).**
4. **Reel Solar, USA: 17.2% CdTe mini module efficiency (98 cm²).**



Area 5 - III-V Compound Semiconductor, Concentrator and Space PV Technologies

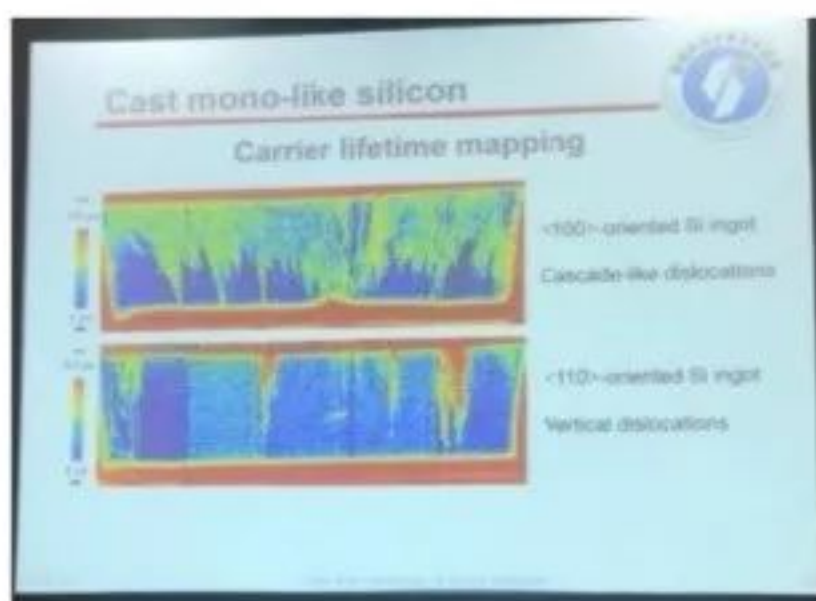


Highlights:

1. **Dr. A. Johnson from IQE PLC. Reported III-V on Silicon ELO.**
2. **Dr. H. Zhang from TIPS presented the AlInGaP sub-cell developed for MJ solar cells.**
3. **Dr. M. Takase from Panasonic showed 32.48% module efficiency.**

Area 6 – Silicon Feedstock & Wafers

Highlights:

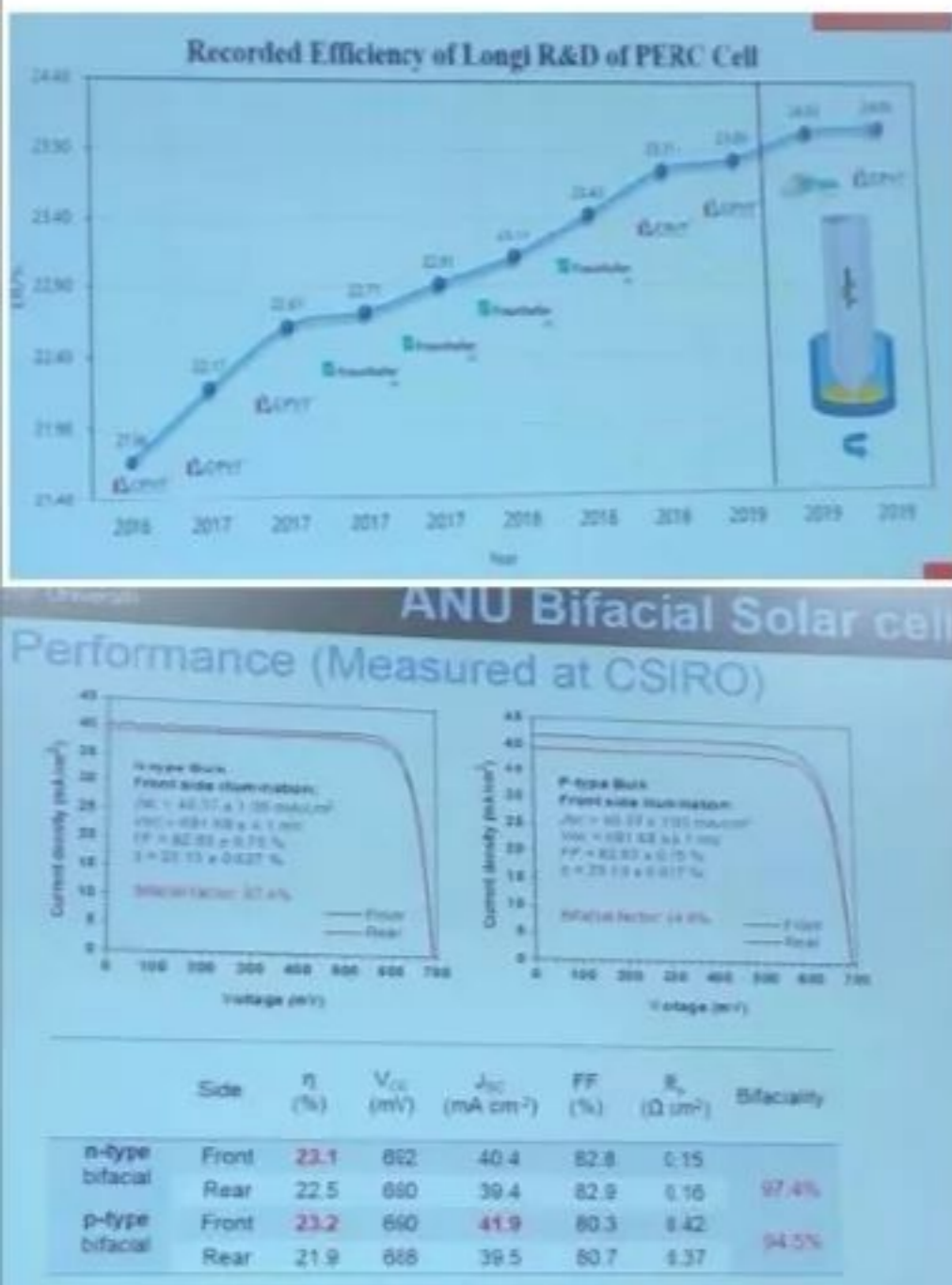


1. **The cast-mono silicon is the hottest topic in Area 6.**
2. **Professor Xuegong Yu presented grain boundary engineering to improve quality of the mono-like crystals.**
3. **Professor John Murphy taught advanced measurement methods for ultra-high bulk carrier lifetime in c-Si.**

Area 7 – Crystalline Si & Tandem Solar Cells

Highlights:

- LONGi, China reported 24.06% PERC cell efficiency, a new record for the type.**
- National University, Australia reported 97.4 % bifacial factor of N-Si bifacial solar cell, with the Front efficiency 23.1% and rear one 22.5%.**
- Hebei University, China reported minority carrier lifetimes 28.6 ms on a high resistivity Si wafer using SO3H organic polymer passivation.**
- Jinko Solar, China reported 24.58% champion N-Si solar cell efficiency.**

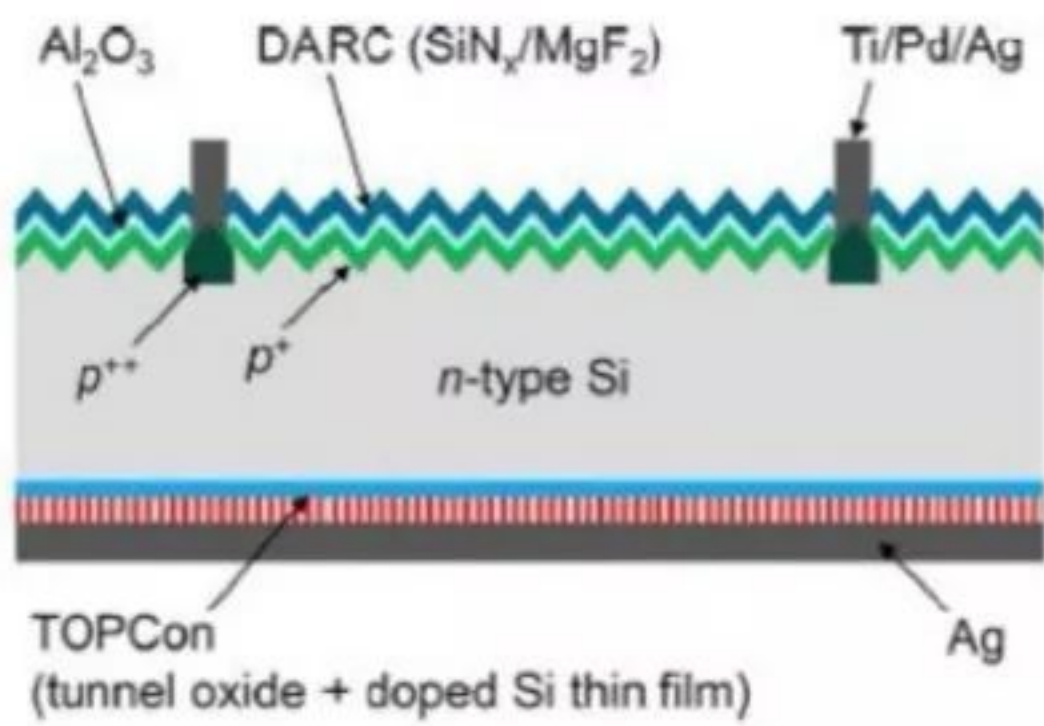


Area 8 – Thin Film, IBC and HJT Solar Cells

Highlights:

- Prof. C. Ballif (EPFL, CSEM) presented excellent results in the development of HJT for both front and back contact solar cells.**
- Dr. Ribeyron from INES compared the passivated contacts and HJT, presenting a roadmap toward a Tandem structure.**
- Prof. F. Meng (SIMIT-ZW) presented development of high-efficiency (23.7%) HJT cells and transferred to high-volume production with >50% local tools in China.**

Area 9 – Topcon Solar Cells



TOPCon shows potential to become the most competitive c-Si technology beyond PERC.

Highlights:

1. Trina reported large area cell efficiency 24.58%.
2. Joywood Solar reviewed mass production of nTOPCon at 2.4 GW capacity with average cell efficiency 22.8%.
3. Meyer Burger and SERIS introduced a production technology with high rate PECVD at efficiency 23.4%.
4. Dr. D. Yan from Australia National University presented a new fabrication process using sputtering to make p-TOPCon with cell efficiency 23%, a new approach to reduce cost even further.

Area 10 – Performance and Reliability of PV Module



Highlights:

1. Delf University of Technology presented a passive thermal management for PV modules to decrease operating temperature by 10 °C.
2. Highly reliable modules are presented for longer lifetime for PV modules.

PVSEC-29 Best Paper Award

NAME	ORGANIZATION	TITLE
Takeru Bessho	University of Tokyo, Japan	Photovoltaic properties of Less-hysteresis of potassium doped perovskite solar cells: Highly efficient perovskite solar cells : PCE 20.5% (2.76cm ²); MA-Free Perovskite solar cells: PCE 21%
Biao Shi	Nankai University, China	Unraveling the passivation process of PbI ₂ to enhance the efficiency of planar perovskite solar cells
Zhike Liu	Shaanxi Normal University, China	Precursor Engineering for High Performance CaPbI ₂ Br perovskite solar cells
Negar Naghavi	CNRS, France	Optimization of Ag-based Reflective back mirrors for ultrathin Cu(In,Ga)Se ₂ -based solar cells
Jia Ding	Arizona State University, USA	Comparison study of monocrystalline 1.7-eV MgCdTe solar cells with 15.2% efficiency
Michihiko Takase	Connected Solutions Company, Panasonic Corporation, Japan	Towards Scaling-Up of Plastic Integrated CPV (PIC) Panels: Status, Challenges and Prospects
Fan Jianbin	Longi Green Energy Technology Co. Ltd., China	The Roadmap to >24% of PERC
Guantao Yang	Delft university of technology, the Netherland	ultra-thin poly-Si passivating contacts for c-Si solar cells
Marco Ernst	Australian National University, Australia	Impact of (Multi-) Busbar Design in Full and Halved Cell Modules on the Cell-to-Module Yield under Realistic Conditions
Huan Wang	IEE, Chinese Academy of Science, China	Series-connected PV MVDC Converter with Wide Range Input and Output Voltage for Large Scale PV System

PVSEC-29 Best Paper Award

Name	ORGANIZATION	Paper Title
Yoshihiro	University of Tokyo, Japan	Photovoltaic properties of Less-hysteresis of potassium doped perovskite solar cells
Yan	Nankai University, China	Unraveling the passivation process of PbI ₂ to enhance the efficiency of planar perovskite solar cells
Yan	Shaanxi Normal University	Precursor Engineering for High Performance CaPbI ₂ Br perovskite solar cells
Yoshihiro	CNRS, France	Optimization of Ag-based reflective back mirrors for ultrathin (In,Ga)Se ₂ -based solar cells
Yoshihiro	Arizona State University	Compositional Engineering of Cu ₂ Te ₂ S ₇ Nanowires for 15.2% Efficient Perovskite Solar Cells
Yoshihiro	Chongqing University	Strategic Design of Perovskite Solar Cells
Yoshihiro	University of Saskatchewan, Canada	Impact of (multi-) layer design in the improved Cell Efficiency on the Cell Efficiency Yield
Yoshihiro	Australian National University, Australia	Real-time Monitoring of Perovskite Solar Cells
Yoshihiro	IEEE, China Academy of Electronic and Information Technology, China	Series Connected PMPV Converter with Wide Range Output Voltage for Large Scale PV System



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