27th International Photovoltaic Science and Engineering (PVSEC-27)

Agenda
* Overall Conference Summary (A. YAMADA)
* Award Ceremony (A. Yamada)
* Future PV Conference WCPEC-7, Alex Freundlich
EU-PVSEC, Arno Smets
PVSEC-29, Ying Zhao (A. Yamada)
GRE, K. Matsubara
27th International Photovoltaic Science and Engineering (PVSEC-27)

Overall Conference Summary

Program Chair: Akira Yamada
Conference Statistics
Number of papers presented by country

<table>
<thead>
<tr>
<th>Country</th>
<th>No. Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>412</td>
</tr>
<tr>
<td>South Korea</td>
<td>96</td>
</tr>
<tr>
<td>Taiwan</td>
<td>35</td>
</tr>
<tr>
<td>Singapore</td>
<td>29</td>
</tr>
<tr>
<td>Germany</td>
<td>26</td>
</tr>
<tr>
<td>China</td>
<td>25</td>
</tr>
<tr>
<td>USA</td>
<td>18</td>
</tr>
<tr>
<td>Thailand</td>
<td>15</td>
</tr>
<tr>
<td>Netherlands</td>
<td>13</td>
</tr>
<tr>
<td>India</td>
<td>13</td>
</tr>
<tr>
<td>Australia</td>
<td>12</td>
</tr>
<tr>
<td>Others</td>
<td>72</td>
</tr>
</tbody>
</table>

Total: 768 papers
<table>
<thead>
<tr>
<th>Area</th>
<th>Number of Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1: Crystalline and Thin Film Silicon PV</td>
<td>193</td>
</tr>
<tr>
<td>Area 2: Thin-Film Compound Semiconductor PV</td>
<td>135</td>
</tr>
<tr>
<td>Area 3: III-V Compound Semiconductor and Concentrator and Space PV Technologies</td>
<td>48</td>
</tr>
<tr>
<td>Area 4: Organic and Dye-Sensitized Solar Cells</td>
<td>52</td>
</tr>
<tr>
<td>Area 5: Perovskite Solar Cells</td>
<td>81</td>
</tr>
<tr>
<td>Area 6: Advanced Concepts and New Emerging Materials for Future PV</td>
<td>64</td>
</tr>
<tr>
<td>Area 7: Performance and Reliability of PV Modules</td>
<td>89</td>
</tr>
<tr>
<td>Area 8: PV Systems Including BOS Components</td>
<td>52</td>
</tr>
<tr>
<td>Area 9: PV System Integration Including Smart Grid</td>
<td>29</td>
</tr>
<tr>
<td>Area 10: PV Deployment; Industry, Market and Policy</td>
<td>18</td>
</tr>
</tbody>
</table>

**Number of papers presented by Area**

**Sum:** 133
## Number of participants

<table>
<thead>
<tr>
<th>Country</th>
<th>Number</th>
<th>Pre-registration</th>
<th>On-site registration</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>514</td>
<td>12</td>
<td>198</td>
<td>212</td>
</tr>
<tr>
<td>South Korea</td>
<td>104</td>
<td>13</td>
<td>337</td>
<td>369</td>
</tr>
<tr>
<td>Taiwan</td>
<td>29</td>
<td>14</td>
<td>150</td>
<td>158</td>
</tr>
<tr>
<td>China</td>
<td>29</td>
<td>15</td>
<td>55</td>
<td>61</td>
</tr>
<tr>
<td>Germany</td>
<td>26</td>
<td>16</td>
<td>43</td>
<td>49</td>
</tr>
<tr>
<td>Singapore</td>
<td>20</td>
<td>17</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Thailand</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States of America</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>others</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>852</td>
<td>784</td>
<td>68</td>
<td>852</td>
</tr>
</tbody>
</table>
Conference Highlights
Area 1

• World record efficiency for c-Si solar cell of 26.7% and module of 24.5% using back contact HJ solar cell was shown in Keynote speech. (KN-1)

• Dr. Yamamoto also stressed that development of low cost fabrication process for HJ-IBC is one of the most crucial issues for industry.

• IMEC introduces Ni/Ag co-plated contacts for high efficiency n-PERT solar cells. (Bifacial, 1MoO1.3)

• Jinko Solar showed the p-type mono-Si PERC cell with an efficiency of 22.78% (1TuPL.1)

Figure 1: Cross-section of the imec n-PERT bifacial cell with co-plated contacts.
• Aluminum paste suitable for PERC is developed and LCO (Laser Contact Opening) geometry optimization is investigated by Toyo Aluminum KK. (1MoO2.3)

• Yusuke Hayama (1TuO1.4) : New methodology for visualizing dislocation clusters in multi-crystalline Silicon ingots was introduced, and it could become a very important method used to further improve mc-Si material quality.
Area 2

- 23.3% (in-house, under certification) CIGS solar cell by novel Cesium surface treatment and improved absorber was reported by Solar Frontier. (2ThO4.3)

![Graph showing CIGS cell performance with Cs-treated surface.](image)

- AVANCIS demonstrated 18% CIGS 30x30 cm² submodule using Cd-free buffer layer. (2TuO4.2)

![Graph comparing absorber performance with different buffer conditions.](image)
• A new record efficiency for pure Se kesterite of 11.7% by Na addition + oxygen treatment was presented in 2WeO3.1.

Fig. 1, J-V curve of our best performing CZTSe cell

<table>
<thead>
<tr>
<th></th>
<th>$eff$ (%)</th>
<th>$V_{OC}$ (V)</th>
<th>$J_{SC}$ (mA/cm$^2$)</th>
<th>$FF$</th>
<th>$n$</th>
<th>$J_0$ (A/cm$^2$)</th>
<th>$R_s$ (Ω cm$^2$)</th>
<th>$R_{sh}$ (Ω cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM-CZTSe$^{[N]}$</td>
<td>11.6</td>
<td>0.423</td>
<td>40.6</td>
<td>0.673</td>
<td>1.57</td>
<td>$1.38 \times 10^6$</td>
<td>0.32</td>
<td>602</td>
</tr>
<tr>
<td>AIST-CZTSe</td>
<td>11.7</td>
<td>0.423</td>
<td>41.7</td>
<td>0.666</td>
<td>1.56</td>
<td>$1.15 \times 10^6$</td>
<td>0.38</td>
<td>1000</td>
</tr>
</tbody>
</table>
Area 3 (efficiency, III-V and Si tandem, EV)

- 33.3%: III-V + Si Wafer Bonding with topcom, and 2-terminal (3TuPl.2)
  III-V nano-wire with 20% coverage was proposed, which reduces 80% III-V material usage (3TuPl.2)
- 33.0%: 4-terminal (III-V 2J + Si) was presented by Sharp. (3TuO5.2)
- 30.9%: 5J full MOVPE, InGaAsN, 30.7%: XTJ-prime (3TuO5.1)
- 20.7%: GaAs HVPE (3TuO5.4)
- Unique concept – low CPV module on board vehicle was demonstrated. (3FrO6.5)
The steady development of new materials was discussed in 4WeO6.2. In the paper, quite good performance, and device stability depending on the structures and crystallinity of the materials were achieved.

The solid-state SSCs achieving 10% efficiencies by co-sensitization and excellent p-type CuI filling in TiO$_2$ electrode method was demonstrated. (4WeO6.1)
Area 5 (Large-area solar cells and tandem structure)

• Panasonic Group reported Module-scale perovskite cell with area of 203 x 203 mm². THG-YAG laser irradiation after mechanical scribe of cells gives low contact resistance due to Sn diffusion into residual-TiO₂ resulting in a Voc of 38.6V. (5MoO3.2)

• Nankai Univ. group reported two-terminal tandem perovskite-HIT (silicon solar cell over 20%) tandem cell with optimization of fabrication process of each layer and interface. (5MoO3.3)
Area 5 (New concepts and Basic Science)

- H. Segawa presented a perovskite doping method with cheap/scalable K which significantly reduced hysteresis and improved uniformity of the perovskite layer. (5MoO4.1)
- Using pump-probe techniques, Dr. Sum provided insights on hot carrier perovskite solar cells. (5TuO7.2)
- A new interesting findings were revealed for perovskite solar cells. The paper firstly confirmed the co-existence of crystal phase cubic and tetragonal in the same device at room temperature. (5WeO7.5)
Area 6

- Panasonic presented all plastic CPV module (PIC) with an efficiency of 31.5%. (6TuO9.1)

![Cross sectional image of a CPV module](image1)

- R. Tamaki: good experimental presentation and result was shown. (6ThO5.2)

![I-V measurement](image2)

Figure 1: 2D-ΔEQE maps on a GaSb/GaAs quantum ring solar cell at (a) 9 K, (b) 70 K, and (c) 120 K.
Area 7

• The economic impact the uncertainty on solar cell calibration and the benefits of differential spectral responsivity was highlighted in 7MoO5.1.

• Strong influence of atmospheric condition on outdoor measurements of PV modules was reported in 7MoO5.2.
• Strategies for better understanding durability of PV module materials was discussed in Area 7.

• Dr. Singh analyzed the loss in shingled bifacial PV modules, and found that smaller cell strips leads to higher module efficiency due to less resistive loss. (7WeO8.4)

• Mechanism of PID is extensively studied from various groups.  
  • direct bias application to pn junction (Jonai, AIST),  
  • detailed analyses of Na migration (Ohashi, Gifu Univ.),  
  • carrier dynamics by transient absorption spectroscopy (Islam, NAIST),  
  • light illumination (Hara, AIST),  
  • excellent work by Ohdaira (JAIST), the paper clarified that the origin of PID with decreased Jsc for silicon heterojunction PV modules is reduction of In-based TCO to metallic In.
Area 8

• Replacement of pyramids with column structure for all-black front surfaces was demonstrated. (8TuO3.5)

• World largest floating PV testbed was introduced. (8TuO3.4)

• New way to remove dust particles was proposed. (8TuO3.6)
• Automatic failure detection method was developed using only PV output. (8WeO1.5)

• Fujisawa SST concept considering not only energy but also human community was demonstrated. (8WeO1.1)
The value of RE Integration Studies

Dr. C. Brancucci of NREL presented integration studies of various scales such as a small island, interconnected power systems in US, and North America.

RE Integration study covers capacity expansion study, production cost study and Power Flow Study (Stability Study).

The RE Integration study is now spreading to the countries of emerging economy.
The PV penetration has been affecting operation and investment in a power system. PV can provide not only energy but also services to a bulk power system, distribution system, and buildings.

In the session the following researches are presented:

- PV generation forecast
- Regional PV generation fluctuation analysis
- Regional PV generation monitoring
- Energy management of PV and battery
- Energy management of PV and EV
C. Breyer, LUT showed sunny outlook!

PV supply share in 2050 at about 69% as least cost

Key insights:
- energy system transition model for 145 regions forming 92 countries
- LCOE decline on energy system level driven by PV plus battery
- beyond 2030 solar PV becomes more competitive than wind energy
- solar PV plus battery finally runs the system more and more
- solar PV supply share in 2050 at about 68% (!!) as least cost

source: Breyer Ch. et al., 2017, Solar Photovoltaics Demand for the Global Energy Transition in the Power Sector, Progress in Photovoltaics, DOI: 10.1002/pip.2950
K. Sugibuchi described perspectives of Japanese PV market until 2030 and discusses enablers that can achieve more than 150 GW of PV dissemination such as storage batteries, new application in the future. The report strongly encouraged Japanese PV community. (10FrO5.4)

Figure 1: Outlook of Japanese PV market (Revised figure will be presented at PVSEC-27)
Source: RTS Corporation
Women in PV@PVSEC-27

• Jointly hosted by WinPVJ Division, JSPS175 Committee, Gender Equal Committee, JSAP and PVSEC-27
• First workshop in PVSEC
• Female researchers in different fields and regions shared their experience, achievement and insight
IEA PVPS Workshop: PV for Transport

- PV can contribute CO$_2$ reduction in transport sector
- Potential for VIPV (Vehicle integrated PV)
- New PVPS task (working group) will be proposed
IEA PVPS Workshop: PV for Sustainability

- Focusing on Socio-Economic Sustainability and PV Recycling
- Interactive session to identify key indicators for economic and social indicators
- Session of reviewing technology trends on PV module recycling

Soon to be published
http://www.iea-pvps.org/
27th International Photovoltaic Science and Engineering (PVSEC-27)

Award Ceremony

Program Chair: Akira Yamada
Best Paper Award
Area 1

• 1ThO1.2
  • “IMPROVED UNDERSTANDING OF LIGHT-INDUCED DEGRADATION AND REGENERATION IN MULTICRYSTALLINE SILICON SOLAR CELLS”
  • Jan Schmidt, Dennis Bredemeier, Dominic C. Walter
  • ISFH, Germany

• 1ThO2.1
  • “TOWARDS INDUSTRIALIZATION OF HETEROJUNCTION WITH THIN AND ULTRA-THIN WAFERS”
  • Samuel HARRISON, Adrien Danel, Julien Gaume, Maryline Joanny, Charles Roux
  • CEA-LITEN, France
Area 2

• 2ThO4.3
  • “INVESTIGATION ON ALKALI-TREATMENT MECHANISMS FOR IMPROVING ENERGY CONVERSION EFFICIENCY OF Cu(In,Ga)(Se,S)2 MODULES”
  • Jyh-Lih Wu, Kong Fai Tai, Yasuaki Iwata, Takuya Kato, Hiroki Sugimoto, Veronica Bermudez
  • Solar Frontier, Japan
Area 3, and 6

• 3FrO6.5
  • “SOLAR POWERED CAR BY STATIC CONCENTRATOR PHOTOVOLTAICS”
  • Taizo Masuda, Kenji Araki, Kenichi Okumura, Shinichi Urabe, Yuki Kudo, Takashi Nakado, Akinori Sato, Masafumi Yamaguchi, Kazutaka Kimura
  • Toyota Motor, Japan
Area 4, and 5

• 5MoO3.2
  • “203mm × 203mm largest sized highly efficient MAPbI₃ solar module”
  • Hiroshi Higuchi, Takayuki Negami
  • Panasonic corp., Japan
Area 7

• 7FrO7.1

• “$J_{SC}$ AND $V_{OC}$ REDUCTIONS IN SILICON HETEROJUNCTION PHOTOVOLTAIC MODULES BY POTENTIAL-INDUCED DEGRADATION TESTS”

• Keisuke Ohdaira, Seira Yamaguchi, Chizuko Yamamoto, Atsushi Masuda

• JAIST, Japan
Area 8, 9, and 10

• 8TuO3.6
  • “ELECTROSTATIC CLEANING EQUIPMENT FOR REMOVAL OF DUST FROM SOLAR PANELS”
  • Hiroyuki Kawamoto
  • Waseda University, Japan
Young Researcher Paper Award
Area 1

• 1Mo2.3
  • “INVESTIGATION OF THE ALUMINUM PASTE COMPOSITION AND LASER CONTACT OPENING GEOMETRY FOR PERC SOLAR CELLS”
  • Masahiro Nakahara,
  • ToYo Aluminum, Japan

• 1TuPo.23
  • “THERMAL STABILITY OF IN-SITU ALUMINA/TITANIA STACKS FOR BORON EMITTER PASSIVATION ON N-TYPE SILICON SOLAR CELLS”
  • Dongchul Suh
  • Hoseo University, Korea
Area 2

• 2TuO6.3
  • “ANALYSIS OF RECOMBINATION RATES IN Cu(In,Ga)(S,Se)$_2$-BASED SOLAR CELLS WITH CdS, ZnS(O,OH), AND (Cd,Zn)S BUFFER LAYERS”
  • Jakapan Chantana
  • Ritsumeikan University, Japan
Area 3, and 6

• 6TuO5.2
  • “FULL SPECTRUM QUANTUM EFFICIENCY MAPPING ON TYPE-II QUANTUM NANOSTRUCTURE SOLAR CELLS”
  • Ryo Tamaki
  • University of Tokyo, Japan
Area 4, and 5

• 4WeO5.1
  • “μM-THICK VACUUM DEPOSITED PTHALOCYANINE: C$_{60}$ PHOTOVOLTAIC CELLS UTILIZING CO-EVAPORANT INDUCED CRYSTALLIZATION”
  • Toshihiko Kaji
  • Tokyo University of Agriculture and Technology, Japan
Area 7

• 7WeO8.4
  • “LOSS ANALYSIS AND DESIGN OPTIMIZATION OF SHINGLED BIFACIAL PHOTOVOLTAIC MODULES”
  • Jai Prakash Singh
  • SERIS, Singapore
Area 8, 9, and 10

• 8WeO1.4
  • “ADVANCED MODELLING OF ENVIRONMENT INTEGRATED PV SYSTEMS: FROM LOCATION TO LOAD”
  • Rudi Santberge
  • Delft University, The Netherland
Student Paper Award
Area 1

• 1TuO1.4
  • “TRACKING AND VISUALLIZATION OF DISLOCATION GENERATION IN MULTICRYSTALLINE SILICON BY PHOTOLUMINESCENCE IMAGE PROCESSING”
  • Yusuke Hayama
  • Nagoya University, Japan

• 1ThO1.3
  • “EFFECTS OF CARBON CONCENTRATION ON OXYGEN PRECIPITATION THROUGH ANNEALING PROCESS IN N-TYPE CZ-SILICON EVALUATED BY IR LIGHT SCATTERING TOMOGRAPHY”
  • Kosuke Kinoshita
  • Meiji University, Japan
Area 2

• 2WeO4.3
  • “FORMATION OF A NOVEL Mg-P-Zn TERNARY SEMICONDUCTOR: A KEY MATERIAL OF EFFICIENCY ENHANCEMENT IN Zn₃P₂-BASED SOLAR CELLS”
  • Ryoji Katsube
  • Kyoto University, Japan
Area 3, and 6

• 6ThPo.182
  • “AB INITIO CALCULATION OF TRANSPORT PROPERTIES BETWEEN PbSe QUANTUM DOTS FACETS WITH HALIDE LIGANDS (Cl, Br, I)”
  • Bo Wang
  • University of New South Wales, Australia
Area 4, and 5

• 5MoO3.1
  • “HIGH PERFORMANCE PEROVSKITE MODULES FOR BUILDING INTEGRATED PHOTOVOLTAICS”
  • Lucija Rakocevic
  • IMEC, Belgium
Area 7

• 7TuPo.207
  • “PRECISE SHORT CIRCUIT CURRENT CORRECTION OF THIN-FILM PHOTOVOLTAIC MODULES USING SPECTRAL INDEX”
  • Yuhei Horio
  • Ritsumeikan University, Japan
Area 8, 9, and 10

• 9TuO8.6
  • “DAY AHEAD PLANNING OF PV POWER GENERATION TO MINIMIZE IMBALANCE COST CONSIDERING SOLAR RADIATION FORECAST ERROR”
• Ayumu Iio
• Tokyo University of Science, Japan
27th International Photovoltaic Science and Engineering (PVSEC-27)

Agenda
*Overall Conference Summary (A. YAMADA)
*Award Ceremony (A. Yamada)
*Future PV Conference WCPEC-7, Alex Freundlich
EU-PVSEC, Arno Smets
PVSEC-29, Ying Zhao (A. Yamada)
GRE, K. Matsubara