

The last day of PVSC saw the early morning sessions well attended. After generating their own highlights packages the evening before at and after the banquet, attendees backed up to make the session lively. Here are some highlights from the early sessions across Areas 2, 4, 5, 8 and a joint session:

Area 2 - Advances in CZTSSe

Sylvester Sahayaraj reported high-bandgap kesterite top cells for Si tandem by ion exchange (Ge alloying). Bandgaps near 1.4 eV were achieved by complete replacement of Sn with Ge. Devices were limited by interface recombination, low collection efficiency and bandgap fluctuations. PL spectrums shows single transition and no potential fluctuations. Sergio Giraldo outlined the implementation of absorber grading in CZTSe by transition metal oxides to improve passivation and avoided decomposition of the absorber at back interface. Nils Ross showed that S/(S Se) in annealed absorber depends only weakly on the initial composition if S is present during anneal, reorganization during annealing. Stener Lie spoke on reducing Cu-Zn antisites by substitution of Zn with Mn. A spray pyrolysis Se anneal allows one to control Mn incorporation as desired. Efficiency improvement from 6% to 7.5% with 5% Mn content were demonstrated. Ratheesh Thankalekshmi showed an increase of grain size in a non-vacuum spray deposition process by Na flux (Na₂S treatment) ten-fold after annealing, improving crystallinity. Mirjana Dimitrievska showed multiwavelength resonant Raman spectroscopy as an easy tool to determine defects in kesterite absorbers.

Area 4 - Silicon Material and Wafer Technology II

Mallory Jensen gave new insightful additional puzzle pieces to solve the riddle of LeTID-degradation with multiple diagnostic techniques down to element specific level. David Sperber identified clear surface degradation effects in SiO_x/SiN_x dielectric layers which frequently affect bulk degradation experiments. This is very valuable information for a large range of lifetime measurements. Daniel Chung of UNSW outlined how PL Imaging of bricks is reaching maturity as a diagnostic and predictive measurement tool.

Area 8 - Simulation and Optimization of Systems

Two presentations detailed partial shading modules - Jozef Szlufcik from IMEC compared different cell stringing within modules, and Bennet Meyers of Stanford compared different shading regimes and the dynamic mismatch they impose. Also of note was the uncertainty presentation by Giorgio Balluardo which increased visibility into possible methods of calculations of energy uncertainty at a system level, which the industry throws around without good understanding.

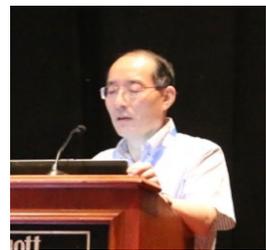
Joint Area Session - Si-Based Tandems: III-Vs and II-Vis

A well-attended session saw high quality presentations on approaches using II-VI and III-V top cells on silicon. Calli Campbell of ASU presented interesting preliminary results for MgCdTe to increase the band gap from CdTe. Encouraging results for 13% Mg layer were presented. Arthur Onno from UCL reported on an approach using strained layer superlattices as dislocation filters for AlGaAs cells on Si. Initial problems with AlGaAs material quality are being overcome. Manuel Schabel of NREL reported on the use of an IBC silicon cell that indicated 30% efficiency can be achieved using a 3 terminal setup. Shizhao Fan reported results for GaAsP on Si tandems where improvements to the silicon bottom cell should open up a pathway to 30% efficiency. Adele Tamboli of NREL gave a stimulating talk about looking at CdTe on Si to achieve cost effective tandems including looking for efficiency value beyond \$/W. Finally, Emily Warren of NREL spoke of some exciting development for thin III-V growth on Si using GoVS (growth on grooved silicon), using low cost templating such as sol gel and PDMS masking approaches.

It was then one last coffee break to charge up for the final technical sessions.

Area 2 - Advances in CdTe II

Yong-Hang Zhang reported on a (Cu,Zn)S window layer that was demonstrated for epitaxial CdTe devices with Voc over 950 mV. Imran Khan discussed how CdSeTe devices exhibited a 3X increase in lifetime over CdTe up to 30 ns. Tursun Ablekim showed how a detailed mapping of point defects in CdTe shows the importance of stoichiometry and compensation from vacancy complexes. Morgann Berg then demonstrated a new PEEM technique (photoemission electron microscopy) for nanoscale band measurements. Max Junda reported on the development of the first library of optical properties for CdSeS and CdSeTe alloys. John Walls Demonstrated the cause of blistering in sputter-deposited CdTe (argon bubbles) and offered ways to overcome this issue for high-speed deposition.



Area 4 - Metallization, Contact Formation and Module Integration

Interesting methods for electrochemical etching process for a simplified metallization of IBC solar cells by structuring the rear contact metallisation were demonstrated. Innovative back foils for a simplified cell and module manufacturing processes were also presented. Using a copper front metallization screen-printed front contact, a cell efficiency of 19% was achieved.

Area 5 - Non-Destructive Characterization Methods

Kristopher Davis reported on the development of an EL excitation spectroscopy setup with different LEDs for non-contact measurement of full spectrum QE curves, because this method is non-contact it can be used for PV modules as a cell-by-cell measurement. Timothy Silverman spoke about EL imaging of PV modules outside, that can be done with easy tools, constant-current PL (CCPL) measurements can be used for imaging modules and identify cracked cells and broken parts of a module. Justin Fada reported on machine learning techniques to analyze EL images and to identify different degradation types. Elias Goma presented bifacial modules characterization for characterizing the rear and back properties of the module. Prakash Uprety showed in-situ Raman micro spectroscopy of CZTS formation.

Area 9 - Field Reliability

There were excellent presentations on analysing field data by Rajiv Dubey (IIT-Bombay) and Dirk Jordan (NREL). Failures in systems were treated statistically by Giogio Belluardo (EURAC) and Geoff Klise (Sandia). Detailed loss modelling was done by Birk Jones (Sandia). The propagation of cracks during fielded operation was demonstrated by Claudia Buerhop (ZAE Bayern).

Joint Area Session - Mobile PV

Tatsuya Takamoto from Sharp presented MJ solar cells development for terrestrial and space applications. High efficiency 1.0cm² cells 37.9% have been achieved. Takamoto presented paths for decreasing the overall thickness of 3J IMM cells to less than 4µm to enable high specific power applications. Additional papers in this session from Microlink Device and Naval Research Labs show the value of lightweight III-V technology in multiple application areas.

After these sessions it was time for the closing ceremony, with the Conference Chair Angele Reinders bringing the curtain down on the 44th PVSC. Geoff Bradshaw the Awards Chair had the nice duty to announce the award winners, the student paper award winners are listed below:

Best Student Paper

Area 1: Natasha Hjerrild, "Experimental Results for Tailored Spectrum Splitting Metallic Nanofluids for c-Si, GaAs, and Ge Solar Cells"

Area 2: Amit Munshi, "Polycrystalline CdSeTe/CdTe Absorber Cells with 28 mA/cm² Short-Circuit Current"

Area 3: Boju Gai, “Multilayer-Grown Ultrathin Nanostructured GaAs Solar Cells”

Area 4: Mallory Jensen, “Assessing the defect responsible for LeTID: temperature- and injection-dependent lifetime spectroscopy”

Area 5: Bradley West, “Machine Learning and Correlative Microscopy: How ‘Big Data’ Techniques Can Benefit Thin Film Solar Cell Characterization”

Area 6: Jeremie Werner, “Perovskite/Silicon Tandem Solar Cells: Challenges Towards High-Efficiency in 4-Terminal and Monolithic Devices”

Area 7: Seonyung Park, “Proton Irradiation of 3J Solar Cells at Low Temperature”

Area 8: Klemens Ilse, “Comparing Indoor and Outdoor Soiling Experiments for Different Glass Coatings and Microstructural Analysis of Particle Caking Processes”

Area 9: Alan Lyons, “Anti-reflective and anti-soiling properties of KleanBoost(TM) a superhydrophobic nano-textured coating for solar glass”

Area 10: Xiaochen Zhang, “A Fast Quasi-Static Time Series (QSTS) Simulation Method for PV Impact Studies Using Voltage Sensitivities of Controllable Elements”

Area 11: Sven Killinger, “Evaluating different upscaling approaches to derive the actual power of distributed PV systems”

Area 12: Ilke Celik, “Energy Pay-Back Time of Perovskite Tandem Photovoltaic Solar Cells”

Well done to all of the student paper winners.



PVSC Napkin Award winner Seth Hubbard provided a neat summary of some of the technical highlights of this conference. The outstanding technical achievement award was this year awarded to two teams. First Zhengshan Yu and his co-authors for their work on 23.6% efficiency perovskite/silicon tandem cells, Stephanie Essig and her co-authors for 32% efficient III-V/Si dual junction solar cells.



It was then time to say goodbye to PVSC44 and to look forward to the next incarnation in Hawaii. There was even some exit music to get us ready for Hawaii well ahead of time. To top it off there was even a sing along session with PV lyrics provided!



Thank you to all of the session chairs who provided highlights that were used in these packages. A great big thank you to Jeremiah McNatt, who provided great editing and chasing up of missing information throughout. Also to Seth Hubbard and Angele Reinders for their feedback and suggestions, it was very much appreciated, particularly given how busy both were. But most off, thank you to all of our presenters for coming to PVSC44 and telling us all about your latest results!