PVSC 50 Daily Highlights Thursday June 15, 2023

Welcome to the penultimate day of the 50th IEEE Photovoltaic Specialists Conference!

Plenary Sessions:

Area 1 Plenary: Elisa Antolin from Universidad Politecnica de Madrid showed that transition metal dichalcogenides (TMDCs) are much more absorptive than standard PV materials, allowing creation of ultrathin solar cells. Current cells are proof-of-concept devices, but the platform has potential for low cost fabrication. Increased control of doping of MoS2 and development of Ohmic contacts have enabled improved efficiencies. While work progresses toward higher efficiency, liquid phase methods are being explored to allow moving to large-area devices. Interference cavities allow enhancing optical absorption in these ultrathin devices, with demonstration of above-gap AM1.5G averaged absorptance of 0.88 with just an 11 nm thick absorber. A target application for these materials is semitransparent PV for windows, allowing a pleasing spectrum of transmitted light for building occupants.

Area 3 Plenary: Daniel Derkacs from SolAero by Rocket Lab provided a great overview of space photovoltaics from cells to interconnect to vehicle configurations. Different orbits require different considerations from thermal cycling to the energies and types of the radiation environment, with notes on the huge increase in LEO launches recently. Solaero products include the ZTJ which is up to 6th gen, Z4J AlInGaP/AlInGaAs/InGaAs on Ge, and IMM AlInGaP/AlGaAs/GaAs/InGaAs/InGaAs second gen up to 34% efficiency; lower PRF but absorption is lower by 6% and runs ~10 C cooler than Ge based 3J. Radiation effects of cell coverglass was discussed, as well as requirements for high emissivity, and absorption of UV to prevent darkening of silicone adhesive. Higher energy electrons cause more damage by dislodging As, while the opposite is true for protons where low energy cause damage as they stop in the material. We got a crash course on the NRL displacement damage dose (DDD) method to calculate damage. Next, panels and craft considerations were discussed, including the need for DC currents to flow in opposite directions to cancel magnetic effects. Assembly is often unique and expensive, volume manufacturing is possible. Costs are 3k-25 $/kg to launch to LEO which represents 25-200 $/W for Z4J rigid or 75-600 $/W for silicon. Non-reoccurring engineering can be as high as 1000% of final panel cost. Rocket Lab is not against Si for space, but customers not yet interested due to lower radiation hardness and larger size, which also affects atmospheric drag.

Area 5 Plenary: Susanna Thon from Johns Hopkins University discussed research motivated by the opportunity to use PbS colloidal nanocrystal quantum dots to fabricate hybrid multi-junction solar cells. Single junction efficiencies of 15% for PbS QDs vs 18% for perovskite nanocrystals; bulk films have yet higher efficiencies in the mid 20%. Interested in understanding how PbS QDs can reach their potential for use in multi-junction solar cell architectures. Typical material development process involves a starting hypothesis for improving performance, material synthesis, extensive characterization and analysis, the process is then iterated. Desirable to speed up the characterization step using multi-modal optoelectronic

scanning that can include: PL, PC, PV, EL, EQE, steady-state IV, transient photovoltage and photocurrent, many of which are measured as a function of space and time [details published in Advanced Materials 32, 1906602, (2020)]. The data arising from multiple measurements can be correlated space and time using statistical partition methods to identify hidden performance limiting defects. Inhomogeneous films are usually considered undesirable but with multi-modal spectroscopy it becomes possible to treat a single device as a large number of much smaller devices. Machine learning requires tens of thousands of samples fabricated under different conditions, however using multi-modal spectroscopy the spatial variation within a sample can provide this variation and is suitable to training a machine learning model. Extremely good correlation between measured and predicted performance obtained and will be published in a forthcomming paper.

Technical Sessions (Morning):

Area 2 - Interface and Other Defect Passivation

Darius Kuciauskas (NREL), gave a very interesting and detailed talk on factors ultimately limiting open circuit voltage of CdSeTe/CdTe solar cells. He showed potential fluctuations present in devices doped with arsenic and attributed most of the voltage losses seen to losses due to radiative recombination. Luisa Kujovic (Loughborough University), showed 21.4 % efficient CdSeTe/CdTe solar cells using intrinsic ZnO front emitter. This device efficiency was achieved when the ZnO was deposited at room temperature showing there is potentially room for improvement with further process tuning. Else Kawna Roy (University of Utah) utilized selective etching to create nanoscale passivating Al2O3 contacts that can probe specific grains and grain boundaries. They showed it's possible to achieve contacts as small as 500 nm as well as illuminate and obtain JV characteristics of specific grain interiors and boundaries.

Area 3 - Space Devices, Materials, and Experience

Kaitlyn VanSant (NASA GRC) showed perovskite architectures and cell designs that were flown as part of the MISSE program. Samples were recovered for end of life photoluminescence analysis and the resulting data was used to inform future design. Romain Cariou (Univ. Grenoble Alpes) reported on terrestrial silicon adapted into thinned absorber devices for space operation. It was proposed that thinner absorber is beneficial to improve radiation hardness in silicon heterojunction cells. Michael D. Kelzenberg (Caltech) showed on-orbit telemetry was received from the Alba solar power module and IV measurements were selected when the array was correctly oriented towards the sun. Luigi Schirone (Saspienza University of Rome) discussed an end-of-life optimized 3J solar cell design demonstrated an enhanced current remaining factor on-orbit through the mission duration. Scott J Ireton (Angstrom Designs) gave an overview of large-area LED based solar simulators and balloon flight-based calibration services for multijunction solar cells based on the Aerospace AMU. Emily Kessler-Lewis (RIT, Best Student Presentation Award Finalist) demonstrated a stacked photovoltaic/electroabsorption modulator in a 0.5U cubesat form factor capable of operating at MHz data rates.

Area 5 - Advanced Characterization for Photovoltaic Materials and Devices

Yanqi Luo (Argonne) used X-ray measurements to evaluate the impact of MACl addition to CsFAPbI3 perovskite solar cells and found that there is a critical MACl loading above which Cs-rich dendrites are formed that lowers photocurrent. Goutam Paul (NREL) presented a study on KPFM of cross-sections of perovskite solar cells with various amounts of bias voltage applied to discover the electric field distribution in the perovskite bulk material. Mirella Al Katrib (IPVF, ILV) used couple X-ray photoelectron spectroscopy and glow discharge-optical emission spectroscopy to characterize triple cation double halide perovskite solar cell and study the surface composition, buried interfaces, and depth profiles in these devices. Zhanoning Song (Toledo) presented simulation results of capacitance evaluated as a function of temperature and frequency of the applied AC voltage to characterize defect states in perovskites. Harrison Wilterdink (Sinton Instruments) described a method for contactless testing via optically-induced electroluminescence, motivated by decreasing silver on commercial Si cells for electrical contacting. The contactless method achieved comparable performance to standard I-V tools and could be integrated into production lines with a test time of <0.6 seconds. Jin Young Kim (Seoul National University) elaborated on the challenges related to the EQE characterization of monolithic multi-junction solar cells and presented a measurement approach for 2- and 3-terminal contact structures.

Area 6 - Alternative Halide Perovskite Materials, Organic, and Dye-Sensitized Solar Cells

Vincent Whiteside (University of Oklahoma,) gave a really interesting talk dealing with temperature dependent characteristics of perovskite solar cells, in particular when the temperature increases you can recovery the FF. Lowering illumination also improves the performances. Carlo Andrea Riccardo Perini (Georgia Institute of Technology) talked about the instability of the interfaces with bulky cation commonly use to improve the devices performances; he intriguingly explained how the role of the solvent isopropanol is critical by comparing structural characterizations with thermal evaporated films. Finally he explains how the combination of the tunneling structure and n=1 or 2 crystal phases can affect the extraction efficiencies. Yuhuan Meng (University of Washington) showed in a great talk methods to quantify the rate of perovskite decomposition and the different degradation pathway depending on oxygen and water. Full chemical kinetic model for MAPI and SnPb perovskite degradation have been discussed, demonstrating how the Jsc losses are correlated indeed to the degradation. Rohit Prasanna (Swift Solar) showed great progress in performance and reproducibility in manufacturing perovskite tandem, including development of a contact layer that can retain up to 97% of the iVoc. Also discussed the potential to use perovskite tandems in EVs which have the potential to achieve 2400 miles per year. Yongxi Li (University of Michigan) showed that they did not see degradation in the absorber but they did see degradation at the interface. ZnOx diffused into the organic material and ways were shown to overcome that. Carbon was also used as a buffer layer to prevent Cl redistribution into the interface of the device. Dalia Martinez Escobar (UC Merced) presented two types of modules, one with PERC silicon and another with TOPCon silicon, both 4T configurations. Modules were tracked outside with influence in irradiance, ambient temperature, wind speed etc. Presenter showed 96 days of data which was good to see.

Area 8 - Field Experience and Data Analytics

We heard about of a range of approaches to connect complex real world data sets to field performance. Dirk Jordan (NREL) shared results showing that, on average, extreme weather events (e.g. wind speed of 90-115 Km/h, storms with hail > 25mm and snow >1 m with weight 2.0 lbs/ft2) cause only 1% annual power loss, but that there is a long tail in the risk distribution, with some systems losing much more. William C Oltjen (Case Western, Best Student Presentation Award Finalist): Proposed a model called FAIRification based on a study over 3 years of 140 inverters from 67 sites in Florida for more productive and automated data analysis. Metadata templates can be used to improve the re-usability of complex datasets. We also heard from Claudia Buerhop-Lutz (Forschungszentrum Juelich) that many different backsheets can be found in a single installation, and they can affect ground fault risk differently throughout the plant. Steven Koskey (Turbine Logic) showed that extracting PV power plant configuration from field data is nontrivial. Angele H.M.E. Reinders showed combining all information from PV fleet data, stressors, and degradation attributes will be a challenge. Mehmet G. Ogut (Stanford, Best Student Presentation Award Finalist) discussed contributions to simplify Gaussian Copula Modelling via a smooth periodic linear algebra function which is able to give more detailed forecast for a fleet of nearby PV systems that can be used to generate synthetic data, detect anomalies, and impute missing data.

Area 10 - Solar Forecasting and Uncertainty

Alex F. Kubiniec Clean Power Research) showed how training Random Forests on 6 to 12 months of satellite data to forecast solar irradiance over the next 24h. ML forecasts can improve NWP forecast quality for longer forecast horizons; with an example using a single NWP and dependence on amount of training data. William B. Hobbs (Southern Company) discussed the link between 24HA forecast error in NMAE terms and cost (relative to no error). Interestingly: some forecast errors yield negative costs. Mengmeng Cai Vahan (NREL) proposed a ML-based approach for real-time estimation of PV potential high limit (PHL, or available headroom). Used real-world data collected by PV plant operators and achieved relative prediction errors as low as +-1% at both the plant and regional levels. Priya Gupta (Indian Institute of Technology Roorkee, Best Student Presentation Award Finalist) explored a new noise-assisted multivariate decomposition (NA-MEMD) technique. The NA model makes faster and more accurate prediction compared with the standard MEMD technique and ML models of different complexities (20 to 60% reduction in RMSE error). Manajit Sengupta Jaemo (NREL) proposed a simple optimization method using satellite-derived gridded observations from the National Solar Radiation Data Base (NSRDB) to post-process the global horizontal irradiance (GHI) and direct normal irradiance (DNI) forecasts simulated from the Weather Research and Forecasting (WRF) model. For the case of Puerto Rico, this post-processing method improved overall GHI forecasts up to 37% (DNI: 15%) for mean absolute error and 97% (DNI: 76%) for mean bias error. Faisal Rashed (Leidos) presented a unique model to characterize and model overprediction/clipping (sub-hourly loss) "adjustment factors" using a regression model from coarser (hourly) dataset. The main interesting takeaway from the Q&A came from J. Stein (Sandia) where he recommended a workshop to explore developing an international standard (IEC) sub-hourly loss adjustment methodologies at the next PVPMC.

Special Session - WIPV Lunch:

Loraima Jaramillo Nieves (LUMA Energy) gave a great presentation discussing the state of gender equality in the photovoltaic community. She showed Solar is more gender diversified than other energy sectors/sources, with a breakdown of activity/region. Things are good compared to the older days, but we can do better. There are barriers to entry, which need to be overcome, but also need to work on retention considerations like parental leave and childcare, and barriers to advancement including lack of gender targets, and the glass ceiling. When a survey asked in Puerto Rico why fewer women join the PV workforce, largest response was "perception of gender roles", but worth noting 96% of respondents were male. Why should we care care? Obviously it's because it's the right thing to do, but beyond that: gender balanced teams deliver better performance, gender equity policies see greater women's job satisfaction and motivation and lower turnover…it makes sense from a corporate and business perspective. But also to reach our sustainability goals we need all the hands we can get. What can we do? Assess inequality, take advantage of growth momentum, develop a strategy and action plan, and put more women in the decision taking room. Help can come from things internally or take advantage of outside/NPO to help. Foster networking, encourage young participation in STEM, define DEI values for your company (lots of work but it pays off!), join the broader discussion. In Puerto Rico: there are programs for women training sessions to install solar in their community, Sola Mamas, assembly, design, maintenance, microgrids three driven by women owned businesses (5 total). At Luma, 30% of workers are women, better than industry at 20%. They hosted an EV go-kart race for 45 female students. Check out Semillas de Triunfo doing outreach projects about STEM, conservation, etc. and Girls + Environment environmental justice in their own communities. The session ended with a generous networking/discussion session which was well-utilized.

Technical Sessions (Afternoon):

Area 1 - Quantum Dots, Upconversion, and Hot Carriers

Muhammad Hanif (UNSW, Best Student Presentation Award Finalist) achieved phonon confinement using a parabolic AlAs/GaAs superlattice acoustic Bragg reflector resulting in phonon coherency times of 0.5 ns. Hambalee Mahamu (Kobe University) observed 2-step photon absorption at the interface between AlGaAs and InAs. Dhanvini Gudi (Johns Hopkins University) achieved a 3.4% power conversion efficiency increase from a PbS colloidal quantum dot solar cell using WSe2 hole transporting layers. Dana Kachman (Johns Hopkins University) demonstrated variation in process conditions improved both device efficiency and yield (94%) of ZnO nano-particles. Vladimir Svrcek (AIST) demonstrated a 1% absolute improvement in power conversion efficiency for a FAPbI3 solar cell, mainly through improved fill-factor, through the inclusion of silicon nanocrystals.

Area 2 - Advances in Materials and Devices

Koosha Nassiri Nazif (Stanford) showed 8% efficiency, 46 W/g specific weight TMD solar cells. Detailed balance limit modeling presented. Various - current - fill factor - voltage relationships discussed. Also, no lattice matching is needed for TMD which could get 20-25 % photo conversion efficiency. Taylor D Hill (First Solar) showed 750 mV Voc with 50% fill factor using CdSe 1.72 eV absorber with the intent for use with Si as top tandem partner. PTAA organic contact used with inorganic PV absorber. Gregory A Manoukian (Drexel, Best Student Presentation Award Finalist) discussed Bayers theorem simulations and associated decays graphically explained. Further improvement to modeling required to include more realistic trap states effects, especially on recombination behavior. Demonstrated transport model to quantify recombination mechanism in CdTe based devices using time-resolved terahertz spectroscopy. Patrick Pearson (Uppsala University) showed the presence of silver does not directly affect the doping but it does directly correspond to sensitivity of doping. Xiaojing Hao (UNSW) presented very promising results with single junction bifacial antimony sulfoselenide (Sb2(S,Se)3 with a bifaciality factor of 0.86, achieving 7.4 % and 6.36 % device efficiency from glass side and film side illumination respectively. >10% efficient ultra-compact 350 nm absorber film solar cells (certified efficiency).

Area 4 - Metallization, Interconnection, Module Integration, and Recycling/Sustainability and Novel PV Integrations – 2

This session discussed very interesting recycling methods, simplified using less chemicals and non-chemically involved processes. Also overcoming the bottleneck of SHJ solar cell by introducing transparent passivating SiC:H(n) contact. Leonie Jakob (Fraunhofer ISE) showed a simplified metallization process for replacement of Ag screen printing by oxidizing titanium seed layer via anodization. Found that non-aqueous solution led to better results than aqueous solution. Theresa K Chen (ASU, Best Student Presentation Award Finalist) used one step process with HF and H2O2 to recycle silver from silicon solar cells. Recovery can approach 100%, though purity drops the longer the recovery process progresses. Mahantesh Khetri (University of Virginia, Best Student Presentation Award Finalist) used laser ablation to remove silver from silicon solar cells submerged in water. Process creates silver nanoparticles, which can be reused for a variety of applications. Non-chemically involved recycling process with 95% purity. Alexander Eberst (Forschungszentrum Julich, RWTH Aachen University, Best Student Presentation Award Finalist) substituted amorphous Si with non-crystalline SiC:H(n) to reduce parasitic absorption. Found a tradeoff between thickness of passivation layer and conduction allows for improved FF and Voc. David A. van Nijen (TU Delft, Best Student Presentation Award Finalist) used lateral integration of MOSFET with PV to improve reliability by eliminating the need for separately soldered transistors. Found that MOSFETs processed similar to IBC PV processes enabled desired transistor behavior in the dark, but when exposed to light, were leaky.

Area 6 - Single Junction and Tandem Halide Perovskite Solar Cells – 2

Lei Chen (*University of Toledo)* introduced potassium citrate into PEDOT:PSS which lead to improvement of grain boundaries and thereby efficiency. Daniel Martinez (Swift Solar) reported on the development of a thin film bypass diode for implementation onto perovskite modules. David P. McMeekin (Oxford, Monash University) showed the addition of DMACl changes the crystallization of perovskite, FACS is more

stable using DMA route. Julia E Huddy (Dartmouth, Best Student Presentation Award Finalist) reported that flexography enables large area printing of perovskite cells achieving 20% PCE with 60 m/min deposition rate. Kristina Geistert (*Light Technology Institute, Institute of Microstructure Technology)* achieved only 5% upscaling loss with slot die coating and gas quenching.

Area 7 - Module Materials, Design, and Manufacturing

Yifeng Chen gave his speech for the 2023 Stuart Wenham award. He described the path at Trina towards high-efficiency i-TOPCon cells and modules from Lab to Fab, 3 optimized module dimensions which lead to the development of innovative of rectangle solar cells. He showed module power from 450 to 700 W with 25.6% i-TOPCon solar cells, and the champion i-TOPCon module with aperture efficiency of 24.2%. He finally illustrated 6 interesting empirical learnt lessons from the PV industry. In the remaining part of the session, topic covering PV module production processes were presented and discussed. Rico Meier (ASU) presented a non-destructive method using ultrasound to characterize crosslinking within the solar module. Jan Paschen (Fraunhofer-ISE) illustrated a novel Al-foil interconnection technique utilizing laser welding and Aluminum to substitute environmentally harmful materials and also significantly reducing the use of silver. Mauro Pravettoni (SERIS) compared the reflectance properties of various commercial size modules to investigate their impact in terms of glare, in view of urban PV deployment. In the last talk, David L. Young (NREL) illustrated the use of femto-second lasers to form glass-to-glass welds for hermetically sealed, polymer-free modules: he showed that the fs laser welds are strong enough for a suitably framed module to pass the standard static mechanical load test for module qualification.

Area 11 - Towards 100% Renewable Electricity

Christian Breyer (LUT University) showed 100% renewable has huge opportunities in the Caribbean. Puerto Rico could have an electricity system powered mostly by solar that produces electricity cheaper than we do today Ronald A. Sinton (Sinton Instruments) discussed charging EVs during the day. Use renewables, boycott oil and gas, it's better and cheaper for everyone. Arnulf Jaeger-Waldau (European Commission) Public perception of PV systems is important and differs for utility and rooftop systems. Engaging communities can help accelerate installations. Jacob T. Stid (Michigan State University, Best Student Presentation Award Finalist) How much is marginal land used for photovoltaics? The smaller the system the more marginal land is used. The potential to utilize marginal land is significant. Zabir Mahmud (US Merced, Best Student Presentation Award Finalist) asked what will the most commonly used configuration of PV systems be in 2045? Tracked and tilt has advantages in summer and winter but a south facing tilt may win out. Juzer Vasi (Indian Institute of Technology Bombay) reported that in 2023 India had installed 68GW of PV capacity. Yearly installations of 30 GW need to be installed. India is well set up to become its own supplier. Module manufacturing will reach 100GW per year by 2026

SOCIAL ACTIVITY: THURSDAY EVENING SOCIAL EVENT

After all of the technical content was complete for the day, the social event on the terrace was a great way to unwind with colleagues old and new. Those with keen eyes may have seen Conference Chair Mariana Bertoni breaking efficiency records on the dance floor!

POSTER SESSION AWARD NOMINEES AND **WINNERS**:

Posters:

AREA 1: FUNDAMENTALS AND NEW CONCEPTS - 2

Emily L. Warren – Winner (Understanding Practical Efficiency Limits for Tandem Solar Cells)

A simple to use a model to estimate tandem cell parameters from direct user inputs of material parameters. It helps with the difficult problem of choosing from the many different material combinations and configurations that can be used for a tandem device by using the spectral efficiency of materials systems. In addition, the model can help with understanding how advances in one material system will impact the performance of a tandem device. It can be used for 2T or 4T tandems and closely matches published efficiency data for actual tandem devices. Inputs are straightforward and a nice feature is data that tracks the recent improvement of performance of particular materials. The model will be available for widespread use on GitHub in the near future.

Mathieu de Lafontaine (GaAs Betavoltaic Cell Modeling for Light to Medium Element Radiation Conversion into Electrical Power)

Monte Carlo simulations are used to study GaAs betavoltaic cells. Calculations of drift diffusion and electron matter interactions are used to assess a GaAs heterojunction solar cell illuminated as a betavoltiac device by beta sources emitting electrons up to 100 keV. Results indicate that 99% electron-hole pairs are generated within 1 µm of the front surface of the heterojunction, 20% in the window layer. This indicates that optimal devices would be ultra-then, as 20% of the power density is lost in simply thin devices. Another indication is that base thicknesses must also be thinner than traditional GaAs photovoltaic cells. These results will be used in further optimization of betavoltaic device design.

O.M. Rigby (Correlated Mapping of Raman Spectroscopy and Cathodoluminescence of Emerging Absorber Bournonite (CuPbSbS3))

A Raman investigation of the degree of order/disorder in Bournonite ($CuPbSbS_3$), particularly on the Pb-Sb sub-lattice. Bournonite is an emerging material that shows high stability and has a E_g of about 1.25 eV. It potentially has ferroelectric properties that make it interesting for photovoltaic devices enhanced by the ferroelectric effect. Results indicate a disordering of Pb-Sb with a very low anti-site formation energy and also a ternary phase $Cu_{12}Sb_4S_{13}$ (tetrahedrite) that has not been previously been observed. In addition, the first very weak cathodoluminescence is observed at room temperature that reveals the grain structure in the material.

AREA 2: INTERFACES AND MODELING

Bishal Shrestha – Winner (Optical properties of (InxGa1-x)2O3 alloys and evaluation as emitter layer in CST PV)

Sho Aonuki (Device modedling of HTL/BaSi2 heterojunction solar cells)

Luis C. Infante-Ortega (SnO2 buffer layers for high efficiency CdSeTe/CdTe devices.)

AREA 3: III-V AND BEYOND: DEVICES AND PERFORMANCE

Aesha P. Patel – Winner (Radiation Tolerance Studies of CdSe/CdTe Bilayer Solar Cells on Space-Qualified Cover Glass)

Katelynn E Fleming (Epitaxial Growth and Testing of 1.1 eV Metamorphic InGaAs/GaAs Laser Power Converters)

Ryan M. France (10-junction Edge-Illuminated Passivated-Contact Silicon Minimodules for Laser Power Conversion)

AREA 6: ADVANCES IN PEROVSKITE, ORGANIC, AND DYE-SENSITIZED SOLAR CELLS

Jack R. Palmer – Winner (A New Route to Facilitate Scaling of Lead-Tin Halide Perovskites: Thin Films via Solvent Self-Volatilization)

Paul F. Ndione (Optimizing the Design of 4-Terminal Perovskite/c-Si Tandem Photovoltaics)

Yangwei Shi ((3-Aminopropyl)trimethoxysilane Surface Passivation Improves Perovskite Solar Cell Performance by Reducing Surface Recombination Velocity)

AREA 9: POWER ELECTRONICS AND GRID INTEGRATION – 2

Eli Shirazi – Winner (Optimal Allocation of Voltage Regulations to Maximize the Hosting Capacity of Distribution Systems)

Andrew R. R. Dow (Development of an Adaptive Droop Control Method for Interconnected Lunar DC Microgrids Using Power Hardware-in-the-Loop)

Rachid Darbali-Zamora (Microgrid Design Toolkit Cost Optimization for Remote Rural Community in the Island of Puerto Rico)

AREA 10: SOLAR RESOURCE ASSESSMENT – 2

Clifford W. Hansen – Winner (Clear-sky detection using time-averaged, tilted-plane data)

Spyros Theocharides (Evaluating the Weather Forecasting Models and the Impact to PV Generation Forecasting)

Shelbie L. Wickett (Trends in Solar PV Growth in Snowy Climates and Impact on Resource Adequacy)