

CALL FOR PAPERS

Technical Program



THE 44th IEEE PHOTOVOLTAIC SPECIALISTS CONFERENCE

June 25-30, 2017

**Washington Marriott Wardman Park
Washington D.C., USA**

Abstract deadline: January 27, 2017

Call for Papers

On behalf of the Technical Program Committee, I am honored to invite you to submit an abstract on your latest achievements in photovoltaic (PV) research, development, and applications to the 44th IEEE Photovoltaic Specialists Conference (PVSC-44). The PVSC-44 endeavors to cover all aspects of PV science and technology, and caters to the full spectrum of knowledge and innovation from basic science to electricity delivered to the customer. PVSC-44 aims to be a highly interactive venue for both seasoned PV experts as well as entry-level professionals and students. The conference provides a unique opportunity to meet, share and discuss PV-related developments in a timely and influential forum. Please contribute to the PVSC's tradition as a premier international conference on the science and technology that can contribute toward a world powered largely by PV systems.

To have your paper considered for presentation at the PVSC-44, please submit:

1. An evaluation abstract (3 pages maximum, for review, not for posting) and
2. A short abstract of 300 words or less for display on the PVSC-44 website.

Abstract submission is via the PVSC-44 website at <http://www.ieee-pvsc.org>. Evaluation abstracts are expected to be detailed enough to allow a thorough technical review. Please follow the suggested format, a template has been provided at the conference website for your convenience. This year's call also includes several cross cutting themes that span across the traditional PVSC 12 technical Areas and are referenced as Sub-Areas that are joint to several Areas. When submitting an abstract in response to these topics please select the Area that best fits the nature of the investigation proposed in your abstract. Additionally, this year we are offering an exciting opportunity to some of our high quality poster presenters, namely the ability to present your poster electronically on a large area flat panel display. More details on this opportunity can be found on the PVSC-44 website.

We are also continuing the option of offering authors who submit particularly high quality PVSC review abstracts, as evaluated by the program committee, an opportunity to directly submit a manuscript to the IEEE Journal of Photovoltaics (see below). This path allows authors to bring their peer reviewed journal quality research to the PVSC-44 and enjoy both the conference experience as well as publishing their work in a high impact journal.

The deadline for electronic submission of the abstracts is January 27th, 2017 at midnight Pacific Standard Time (UTC - 8 hours). Contributing authors will be notified of the acceptance status of their papers after March 22, 2017. For visa applications, an invitation letter can be issued any time after you register for the conference. We will also ask authors to confirm that they will be able to present their work at the conference and upload their manuscript by the due date of June 9th, 2017 for publication in the conference proceedings.

On behalf of the Technical Program Committee I look forward to welcoming and meeting with you at the PVSC-44 in the capital of the United States, Washington D.C.

Seth Hubbard
Technical Program Chair
2017 IEEE PVSC-44

Guidance from IEEE Journal of PV for peer-reviewed publication

The process to propose a presentation at the PVSC along with a paper in the IEEE Journal of Photovoltaics (J-PV) is simple. First, an extended abstract is submitted to the PVSC that describes the research (by January 27, 2017). This abstract is then reviewed by the PVSC program committee. If it is accepted as a high quality abstract, you will be asked to submit the required final paper to the IEEE J-PV by June 9, 2017.

The majority of PVSC-44 manuscripts will be published in the *Proceedings of the 2017 PVSC-44* with only final review for adherence to style requirements. A small number of papers will be invited to directly submit to *the IEEE Journal of Photovoltaics* for possible publication in this archival, peer-reviewed journal (Impact Factor = 3.74). Each submitted paper will be processed through the normal *J-PV* review process as if it were an unsolicited manuscript. If accepted, the paper will appear in the next available issue of the journal. Note: both the review process and the final published paper will not have any stated affiliation with the conference. If the paper is not accepted, then it will be published in the *Proceedings of the 2017 IEEE PVSC-44*, hopefully improved by the review process. It is believed that providing the opportunity to publish either a proceedings paper or a full journal manuscript will encourage the community to present their very best work at the PVSC. It is also believed that this policy will ensure the continued technical excellence of the PVSC.

At the time of submitting your extended abstract you will have the opportunity to indicate if you wish your paper to be considered for publishing in *IEEE Journal of Photovoltaics*. If you indicate as such, the program committee will evaluate your abstract on its suitability for *J-PV* and recommendation for submission. The list of recommended papers will also undergo a review by the editorial board, which could include suggestion of submission to a related IEEE journal, for those papers that might be better suited in that way. *J-PV* is a peer-reviewed, archival publication reporting original and significant research results that advance the field of photovoltaics (see the [J-PV website](#) for further details on the scope). In past years approximately 10 % of the submitted papers have had sufficiently significant research results to warrant publication in the journal, although the % varied considerably by area. If you are invited to submit a *J-PV* paper and choose to do so, you will submit the same paper BOTH directly to the *J-PV* website and to the PVSC website.

Timothy Anderson, Editor-in-Chief, IEEE Journal of Photovoltaics

Program Committee and Technical Areas



Program Chair

Seth Hubbard (Rochester Institute of Technology)



Deputy Program Chair

Sylvain Marsillac (Old Dominion University)



Area 1. Fundamentals and New Concepts for Future Technologies

Peichen Yu (National Chiao Tung University)



Area 7. Space and Specialty Technologies

Claus Zimmerman (Airbus, Inc.)



Area 2. Chalcogenide Thin Film Solar Cells

Mike Scarpulla (University of Utah)



Area 8. PV Modules, Manufacturing, Systems and Applications

Anton Driesse (PV Performance Labs)



Area 3. III-V and Concentrator Technology

Tyler Grassman (Ohio State University)



Area 9. PV and System Reliability

Tony Sample (EU Joint Research Centre)



Area 4. Silicon Photovoltaic Materials and Devices

Pierre Verlinden (Trina Solar)



Area 10. Power Electronics and Grid Integration

Barry Mathers (NREL)



Area 5. Characterization Methods

Marina Leite (Univ. of Maryland)



Area 11. Solar Resource for PV and Forecasting

Skip Dise (Clean Power Research)



Area 6. Perovskite and Organic Solar Cells

Woojun Yoon (Naval Research Laboratory)



Area 12. PV Deployment and Sustainability

Mike Woodhouse (NREL)

44th IEEE PVSC Keynote and Plenary Speakers:

Please see [PVSC-44 website](#) for the most up to date list of keynote, plenary and invited speakers!

Area 1: Fundamentals and New Concepts for Future Technologies

Chair: Peichen Yu, *National Chiao Tung University, Taiwan*

Co-Chairs: Kylie Catchpole, *Australian National University, Australia*
Jeremy Munday, *University of Maryland, USA*

Area Description

Paradigm shifts in solar cell technology are invariably preceded by breakthroughs arising from basic scientific research. In recent years, there have been a number of exciting results in the fundamental arena, including the demonstration of two-photon absorption processes in nanostructured solar cell devices, and sophisticated optical management designs resulting in world record single-junction and dual-junction cell efficiencies. Area 1 comprises fundamental research and novel device concepts that will provide a platform for the development of future photovoltaic technologies. Papers are sought describing research in basic physical, chemical and optical phenomena, in addition to studies of new materials and innovative device designs. Subjects of particular interest include, but are not limited to, nanostructures, hybrid tandem devices, advanced optical management approaches, new materials and synthesis processes, and unconventional conversion mechanisms.

Sub-Area 1.1: Fundamental Conversion Mechanisms

Sub-Area Chair: Jacob Krich (University of Ottawa, Canada)

Sub-Area 1.1 captures both experimental and theoretical work exploring new paradigms for solar energy conversion. Papers submitted to this Sub-area would explore the fundamental physics or present initial experimental demonstrations related to novel energy conversion mechanisms. Papers on modeling and simulation of new device architectures to enable these conversion mechanisms are also encouraged. Areas of interest include, but are not limited to, non-conventional PV conversion processes based on quantum confined or nanostructured systems, engineered band alignments, intermediate band concepts, multiple exciton generation (MEG), thermophotonics or hot-carrier effects. Also of interest are concepts and demonstration of new materials and material science related to energy conversion. Finally, cross cutting science approaches involving novel physics, innovative device structures, and modeling and simulation are solicited.

Sub-Area 1.2: Quantum-well, Wire, and Dot-Architected Devices

Sub-Area Chair: Ian Sellers (University of Oklahoma, USA)

In recent years significant advancements in optoelectronics have been achieved via the implementation of low-dimensional systems. Sub-area 1.2 focuses on using quantum-engineered structures to improve and facilitate the performance of photovoltaic devices. The use of quantum-dots, wells, and wires have the potential to increase the efficiency of solar cells in excess of 50% when used in novel third generation technologies and multi-junction solar cells. To continue recent momentum in these fields, papers are sought on both the theoretical and experimental progress in the development of quantum-engineered materials and devices. Submissions including novel designs, new material compositions,

implementation of new uses of quantum confinement, and the exploitation of varying dimensionality of confinement are encouraged. Ideal submissions will range from studies of fundamental physics to examples of working devices.

Sub-Area 1.3: Advanced Light Management and Spectral Shaping

Sub-Area Chair: W. Ivy Wang (University of Houston, USA)

In order to achieve high power conversion efficiency, a solar cell must effectively utilize most of the incoming photons. This process involves the efficient coupling of the incident light into the solar cell with minimum loss, and effective use of the energy imparted by each photon. This Sub-area will focus on novel concepts, including advanced anti-reflection coatings, spectrum splitting, textured light trapping surfaces (front and/or rear surface), luminescent (fluorescence) and nano-scale concentrator systems, and advanced photonic and plasmonic structures. With respect to plasmonics, both light trapping and hot carrier effects will be considered. In addition, ways to modify the spectrum of the incident sunlight using techniques such as up or down conversion either in planar layers or in waveguide structures will be considered. Papers submitted to this Sub-area should address one or more of these themes and may be theoretical or experimental in nature.

Sub-Area 1.4: Novel Material Systems

Sub-Area Chair: Louise Hirst (Naval Research Laboratory, USA)

Sub-Area 1.4 covers progress on the development of novel materials and processing techniques for improving the performance, functionality, reliability, and scalability of PV devices. Such materials, combinations, and processes may find application in single-crystalline, thin film, multijunction, and nanostructured PV devices or may enable an entirely new device class on their own. Papers are sought that describe theoretical and/or experimental development of materials displaying novel properties, including but not limited to semiconductors, substrates, coatings, barriers, transparent conductive oxides (TCOs), pseudomorphic and metamorphic photovoltaic materials. Developments in the field of graphene and carbon nanotubes are of interest in this Sub-area. Advances in growth, synthesis, deposition, doping and passivation schemes as well as new architectures that have the potential to lower material quality constraints are also solicited.

Sub-Area 1.5 (Joint with Areas 1-4, 6, 7*): Hybrid Tandem/Multijunction Solar Cells

Sub-Area Chairs: Adele Tamboli (National Renewable Energy Laboratory, USA)

Mariana Bertoni (Arizona State University, USA)

Bjorn Niesen (École Polytechnique Fédérale de Lausanne, Switzerland)

This wide-reaching joint-topic area solicits papers regarding materials, structures, and devices based on combinations of multiple materials classes — III-Vs, Si, chalcogenides/thin-films, organics, perovskites, etc. — toward the production and characterization of “hybrid” multijunction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy, deposition, and bonding. Characterization of these materials, structures, and devices, from the atomic scale to the device level (and

beyond) is also of interest. Papers on the theory and modeling of such devices are welcome. Work related to modules and systems consisting of such hybrid cells are also encouraged.

*(*Submit your abstract under the area that best matches the nature of your investigation*

Area 2: Chalcogenide Thin Film Solar Cells

Chair: Mike Scarpulla, *University of Utah, USA*

Co-Chairs: Thomas Unold, *Helmholtz Zentrum Berlin, Germany*
Takeaki Sakurai, *University of Tsukuba, Japan*
Jim Sites, *Colorado State University, USA*

Area description

In the past 5 years, thin film chalcogenide solar cells based on CIGSe, CdTe have achieved remarkable progress in terms of record conversion efficiencies >22% and manufacturing at the multi gigawatts-per-year scale. These exciting developments have been enabled by the decades of work by the worldwide community of dedicated research, development, and manufacturing professionals working on their science and technology.

Area 2 brings this community together yearly to present and discuss contributions on solar cells based on CdTe, Cu(In,Ga)(S,Se)₂ (CIGSSe), Cu₂ZnSn(S,Se)₄ (CZTSSe), and related materials. The aims of Area 2 are to provide a platform for presenting recent and on-going research leading to improved understanding of materials and devices, exploring new directions for more efficient production, and narrowing the gap between champion cell and module efficiencies. Topics typically range from insights into basic materials science, to analysis of device properties and new device structures, to discussions of the progress in deposition methods and growth control, and to long term performance and reliability. We look forward to an exciting, cutting-edge conference that helps advance the science and technology of these fascinating and technologically-important solar cells.

Sub-Area 2.1: Absorber Preparation and Material Properties

Sub-Area Chairs: Xiangxin (Shine) Liu (*Chinese Academy Of Sciences, Beijing, China*)
Alex Redinger (*Helmholtz Zentrum Berlin, Germany*)

Because minority carrier lifetime and collection in the absorber dominates efficiency in chalcogenide thin film devices, the preparation and properties of the absorber layer are of paramount importance. Sub-area 2.1 addresses progress in understanding thin film formation and the influence of processing on basic material properties and device performance. Examples of relevant topics include both experimental and theoretical aspects of: morphology, phase coexistence, microstructure, optoelectronic and transport properties, influence of substrates, compositional gradients and homogeneity, effects of material purity and contaminants, interrelation of properties and cell and module fabrication processes, in-situ, ex-situ and in-line methods of characterization, and impacts on short- and long-term performance.

Sub-Area 2.2: Contacts, Windows, Buffers, Substrates and Superstrates, Monolithic Integration, and Interfaces

Sub-Area Chairs: Naba Paudel (*REEL Solar, USA*)
Florian Werner (*University of Luxembourg, Luxembourg*)

The processing and properties of all of the layers in the thin film device stack as well as their integration into monolithically-integrated modules ultimately determine the cell and module performance. Sub-area 2.2 focuses on the functions, effects and properties of substrates/superstrates, contacts, buffer and window layers, and interfaces. Submissions describing advances in understanding these aspects and their effects on short-and long-term performance are welcome. Papers on progress in the cross-cutting areas of transparent conductors, moisture barriers, new or improved substrates, established and novel methods of cell scribing and interconnection in modules, and novel topics not listed are encouraged.

Sub-Area 2.3: Cell and Module Characterization, Analysis, Theory, and Modeling

Sub-Area Chairs: Aaron Arehart (Ohio State University, USA)

Heayoung Yoon (University of Utah, USA)

Continued progress in chalcogenide photovoltaics relies on continuing to gain insight into the origins of efficiency loss and concepts for overcoming them. Whereas Sub-areas 2.1 and 2.2 focus on the physical properties and processing of the layers making up cells and modules, Sub-area 2.3 addresses their net effects at the device and module level through measurement, analysis, theory, and modeling. These aspects enable feedback to continue improving cells and modules. Contributions are solicited in the areas of novel and established characterization methods, device analysis that yields insight into internal operation, one-, two- and three-dimensional modeling to understand current devices and guide progress, characterization of defects and recombination, and novel related topics not listed.

Sub-Area 2.4: Progress in Manufacturing and Deployment

Sub-Area Chairs: Gang Xiong (First Solar, USA)

Rouin Farshchi (Miasole, USA)

As installed capacity of CdTe and CIGS_{Se} modules is approaching 15 gigawatts and achieving cost-parity with other module technologies and fossil fuels, the field of chalcogenide thin film photovoltaics is rapidly transitioning from a focus solely on R&D into large-scale manufacturing and deployment. Sub-area 2.4 solicits contributions addressing module manufacturing and field deployment. Emphasis is placed on paths to continue improving long-term field performance and reliability while continuing to importance of cost and reliability (in addition to performance) as key drivers for developing a viable, thin-film module manufacturing capability. We encourage the community to share their experience and knowledge in areas focused on reducing the cost/watt of PV modules including higher throughput/yield and more energy and cost-effective processing, improvements in thin-film uniformity, improved cell integration and module architectures, important quality control metrology/diagnostics and information management applied during semiconductor deposition, integration, packaging, and reliability testing. Papers are also sought in the area of cell and module reliability, in particular field and laboratory-test procedures and results, qualification testing, degradation mechanisms, and transient behavior.

Sub-Area 2.5 (Joint with Areas 1-4, 6, 7*): Hybrid Tandem/Multijunction Solar Cells

*Sub-Area Chairs: Adele Tamboli (National Renewable Energy Laboratory, USA)
Mariana Bertoni (Arizona State University, USA)
Bjorn Niesen (École Polytechnique Fédérale de Lausanne; Switzerland)*

This wide-reaching joint-topic area solicits papers regarding materials, structures, and devices based on combinations of multiple materials classes — III-Vs, Si, chalcogenides/thin-films, organics, perovskites, etc. — toward the production and characterization of “hybrid” multijunction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy, deposition, and bonding. Characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond) is also of interest. Papers on the theory and modeling of such devices are welcome. Work related to modules and systems consisting of such hybrid cells are also encouraged.

*(*Submit your abstract under the area that best matches the nature of your investigation*

Area 3: III-V and Concentrator Technologies

Area Chair: Tyler Grassman, *The Ohio State University, USA*

Co-Chairs: Frank Dimroth, *Fraunhofer ISE, Germany*
Kenji Araki, *Toyota Technological Institute, Japan*

Area Description

Area 3 primarily focuses on the science, engineering, performance, cost, and reliability of III-V solar cells and the full range concentrator photovoltaic systems (CPV). III-V multijunction solar cells have been the basis for terrestrial high-concentration photovoltaic systems and papers that address all aspects of cell design are welcome (Sub-Area 3.1). Area 3 also covers CPV module (Sub-Area 3.2) and system (Sub-Area 3.3) development including optical design, solar cell receivers, modules and components, assemblies, and trackers. Low and medium concentrator systems that employ high efficiency non-III-V solar cells (e.g. Si) are also covered in Area 3.

Multiple jointly sponsored Sub-areas, with broad (and growing) interests spanning technical content outside of Area 3, are also available. One such joint Sub-area focuses on addressing the cost of III-V devices via lower-cost materials and alternative substrates, as well as ultra high rate epitaxial methods. Another joint area on the characterization of III-V single crystalline photovoltaic materials and devices is available. Finally, a broad joint area on the fast-growing field of hybrid tandem and multijunction solar cells, wherein devices are made up of multiple classes of photovoltaic materials, is available.

Sub-Area 3.1: III-V Solar Cells

Sub-Area Chairs: Ryan France (*National Renewable Energy Lab, USA*)
Won-kyu Park (*Korean Advanced Nanofab Center, South Korea*)

This Sub-area seeks to address all relevant aspects of the research and development of III-V multijunction solar cells for terrestrial applications. Topics of interest include (but are not necessarily limited to): epitaxial growth, materials design and development, solar cell architectures, single and multi-junction devices, cell-level theoretical modeling, cell-level photon management, wafer bonding, device processing, new manufacturing technologies, material and cell characterization, and III-V cell reliability.

Sub-Area 3.2: CPV Modules

Sub-Area Chairs: Simon Fafard (*University of Sherbrooke, Canada*)
Kensuke Nishioka (*Miyazaki University, Japan*)

This Sub-area seeks to address all relevant aspects of the research and development of concentrated photovoltaics module technologies. Topics of interest include (but are not necessarily limited to): primary optics, acceptance angle studies, performance modeling, module design, module-level environmental mitigation (heat, humidity, etc.), module reliability, manufacturing advances and concerns, and module-level integrated storage. All levels of optical concentration are of interest.

Sub-Area 3.3: CPV Systems

*Sub-Area Chairs: Matthew Lumb (Naval Research Laboratory, USA)
Ray Lin (Taichung, Taiwan)*

This Sub-area seeks to address all relevant aspect of the research and development of concentrated photovoltaics system technologies. Topics of interest include (but are not necessarily limited to): low/medium/high concentrator systems and system design, concentrator assemblies, trackers, system-level characterization, soiling, system reliability, environmental influences, maintenance, energy yield and performance modeling and prediction, system-level integrated storage, and economics, financing, and markets.

Sub-Area 3.4 (Joint with Areas 3, 5 and 7*): Characterization of Single-Crystal III-V PV Materials and Devices

Sub-Area Chair: Myles Steiner (NREL, USA)

Papers focusing on characterization and characterization methods for III-V materials and devices, where the single-crystalline nature of the III-V material is paramount to device performance, should be submitted here. Single- and multi-junction devices, as well as III-V sub-components (such as tunnel junctions), are welcome. Optical, electronic, and structural characterization as it applies to optical and/or electronic properties, is of interest. Characterization of large grain multi- and poly-crystalline III-V materials and devices, where the crystal grains are sufficiently sized to act as effective single crystals, is also appropriate for this Sub-area.

(Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 3.5 (Joint with Areas 1-4, 6, 7*): Hybrid Tandem/Multijunction Solar Cells

*Sub-Area Chairs: Adele Tamboli (National Renewable Energy Laboratory, USA)
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Bjorn Niesen (École Polytechnique Fédérale de Lausanne, Switzerland)*

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(Submit your abstract under the area that best matches the nature of your investigation*

Sub-Area 3.6 (Joint with Areas 3 and 7*): Low Cost III-V Materials and Solar Cells

*Sub-Area Chairs: Chris Bailey (Old Dominion University, USA)
Roberta Campesato (CESI, Italy)*

Topics of interest are broadly defined as technologies and approaches related to the achievement of low-cost III-V materials and solar cells, including the use of alternative

substrates, polycrystalline materials, and low-cost (high-rate) growth and deposition methods. Papers are solicited on the growth of crystalline and polycrystalline III-V materials on alternative substrates (i.e. not single-crystal Ge or III-V) where the substrate is not an active photovoltaic component. Papers are also sought on low-cost III-V growth and deposition techniques, such as HVPE and ultra-high-rate OMVPE/MOCVD. Papers on wafer and epilayer bonding approaches and substrate re-use are also solicited. Work on the characterization of associated materials and devices is encouraged.

()Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 3.7: Flexible, lightweight and cost-effective mobile solar power for terrestrial and space applications (Joint between Topic Areas 3, 7 and 8*)

*Sub-Area Chairs: Rao Tatavarti (Microlink Devices, USA)
Kimberly Sablon (Army Research Laboratory, USA)*

This Sub-Area covers progress on the development of Mobile Solar Power (MSP) systems and applications. The MSP system development includes flexible and lightweight solar cells, sheets and related integration systems. Papers are sought that describe the development of thin cell technologies including material growth, cell fabrication and testing. Papers covering developments of flexible solar sheet fabrication methods, studies on improvement of sheet durability; ruggedness and overall energy generation are invited. Papers discussing cost reduction technologies for both cell production and cell integration are encouraged. Developments of systems applications of photovoltaic sheets such as battery charging, portable power, powering flexible electronics and solar UAV (Unmanned Aerial Vehicles) covering both the military and civilian energy power application are of interest in this sub-area.

()Submit your abstract under the area that best matches the nature of your investigation.*

Area 4: Silicon Photovoltaic Materials and Devices

Chair: Pierre Verlinden, *Trina Solar, China*

Co-Chairs: Giso Hahn, *University of Konstanz, Germany*
Bram Hoex, *UNSW Australia*

Area Description

Area 4 invites contributions reporting on all aspects of silicon technology, including silicon material, standard crystalline silicon wafer-based technology, thin film silicon and silicon-based tandem structures, from fundamentals and device physics to processing and module integration. All contributions covering crystalline, or thin-film, silicon technologies and devices are welcome, including new silicon purification, feedstock and wafer production technologies (Sub-area 4.1); all standard pn-junction based crystalline silicon devices and processes such as Al-BSF, PERC, PERT, IBC, bifacial (Sub-area 4.2); surface passivation, optical coating and light management (Sub-area 4.3); passivated contacts, carrier selective contacts, heterojunction (HJ) structure and contacts (Sub-area 4.4); hybrid tandem/multijunction solar cells (Sub-area 4.5, joint with Areas 1-4, 6-8); metallization, contact formation and module integration (Sub-area 4.6); modeling, numerical simulation and device physics (Sub-area 4.7); thin-film silicon material and devices (Sub-area 4.8).

Sub-Area 4.1: Silicon Material, Feedstock and Wafers: Technology and Analysis

Sub-Area Chair: Pietro Altermatt (Trina Solar, China)

This Sub-area covers the first part of the value chain from silicon purification and feedstock production through crystallization and wafering, including high-performance multi-crystalline silicon wafers, kerf-less slicing technologies, alternative methods to produce silicon wafers such as direct wafer or wafers formed by epitaxy. Additionally, abstracts addressing the mechanical and electrical characteristics of the resulting wafers, including material quality, defects (e.g. carrier induced degradation) and defect engineering steps (e.g. gettering, hydrogenation, regeneration) of the silicon material are welcome.

Sub-Area 4.2: Standard pn-Junction Based Devices and Technologies

Sub-Area Chair: Stefan Glunz (Fraunhofer ISE, Germany)

This Sub-area covers all the different standard solar cell structures based on pn-junction doping technologies, including for example papers reporting on Al-BSF solar cells, PERC, PERT, IBC, MWT, bifacial cells, either p-type or n-type. Topics related to the junction formation, doping technologies (laser doping, ion implantation), film deposition methods, new designs, new process technologies and are all welcome in this Sub-area.

Sub-Area 4.3: Surface Passivation, Optical Coating and Light Management

Sub-Area Chair: Zachary Holman (ASU, USA)

With increasing quality of the silicon material, the surfaces of the solar cells are becoming more and more important. Optical coating and surface texturing are critical for light management as well as for surface recombination parameters. This Sub-area welcomes

abstracts covering all aspects of surface passivation like dielectric layers, organic/inorganic interfaces, surface cleaning and passivation mechanisms. Another important aspect related to the surfaces of silicon solar cells is improved light management. This Sub-area also welcomes submissions addressing enhanced photon absorption by classical, diffractive and plasmonic mechanisms, as well as black-silicon technologies.

Sub-Area 4.4: Passivated Contacts, Carrier Selective Contacts and Hetero-Junction Structures

Sub-Area Chair: Andres Cuevas (ANU, Australia)

This Sub-area welcomes all abstracts related to solar cells fabricated with heterojunction or passivated contacts. Papers reporting on the formation and characterization of all passivated contacts and carrier-selective contacts, including hetero-junction contacts and Metal-Insulator-Semiconductor (MIS) contacts, characterization of tunnel current, trade-off between surface recombination and contact resistance, as well as large volume processing issues should be submitted to this Sub-area.

Sub-Area 4.5 (Joint with Areas 1-4, 6, 7*): Hybrid Tandem/Multijunction Solar Cells

Sub-Area Chairs: Adele Tamboli (National Renewable Energy Laboratory, USA)

Mariana Bertoni (Arizona State University, USA)

Bjorn Niesen (École Polytechnique Fédérale de Lausanne; Switzerland)

This wide-reaching joint-topic area solicits papers regarding materials, structures, and devices based on combinations of multiple materials classes — III-Vs, Si, chalcogenides/thin-films, organics, perovskites, etc. — toward the production and characterization of “hybrid” multijunction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy, deposition, and bonding. Characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond) is also of interest. Papers on the theory and modeling of such devices are welcome. Work related to modules and systems consisting of such hybrid cells are also encouraged.

(): Submit your abstract under the area that best matches the nature of your investigation*

Sub-Area 4.6: Metallization, Contact Formation and Module Integration

Sub-Area Chair: Radovan Kopecek (ISC, Germany)

The final step of cell processing is the formation of contacts. This Sub-area welcomes manuscripts covering all current and novel techniques for contact formation, including but not limited to printed metallization, plating, evaporation, dispensing or other transfer techniques, conductive adhesives, soldering, laser and thermal alloying of metals, and transparent electrodes. The contacts are also the interface to the subsequent module integration. Therefore topics like mechanical adhesion, multi-wire technologies and the interconnection of advanced cell structures like back-contact cells are also addressed in this Sub-area.

Sub-Area 4.7: Device Physics, Simulation and Power Loss Analysis

Sub-Area Chair: Keith McIntosh (PV Lighthouse, Australia)

The development of advanced solar cell architectures requires an in-depth understanding of the underlying device physics. This Sub-area covers aspects like device physics, modeling, analysis of novel cell concepts, power loss analysis of solar cells and numerical simulation.

Sub-Area 4.8: Thin-Film Silicon Material Growth and Devices

Sub-Area Chair: Arno Smets (Delft University of Technology, Netherlands)

Thin-film silicon covers a class of materials that ranges from amorphous silicon and its group-IV alloys, over nano- and microcrystalline silicon, silicon-oxides and -carbides, to thin-films of crystalline silicon. Research and development in this active area addresses many solar cell devices, as well as fundamental concepts of material quality, recent insight into light-induced degradation in thin-film silicon material, passivation of internal interfaces and heterojunctions.

Area 5: Characterization Methods

Chair: Marina Leite, *University of Maryland, USA*

Co-Chairs: Laurent Lombez, *Inst. of Research and Dev. Photovoltaic Energy, France*
Masakazu Sugiyama, *University of Tokyo, Japan*

Area Description

The comprehensive understanding of how and why photovoltaic devices operate requires material and device characterization, ranging from measurements of the optoelectronic response of emerging and well-established materials to the role of defects on overall device performance and the characterization of PV modules. Area 5 focuses on novel characterization techniques, in situ monitoring of materials and devices, the relationship between structural and optoelectronic properties of materials in operating devices, and the characterization of PV modules. Joint sessions are planned with other areas for papers that are heavily characterization focused but with application to one area of technology.

Measurements are needed at all levels of R&D and production – from investigating the operating principles of solar cells to developing standards for the performance of installed photovoltaic (PV) systems. The relationship between structure, physical properties, and the resulting PV performance is fundamental to engineering PV materials with improved performance. Reliable and precise determination of the efficiency and thus power of solar cells and PV modules is crucial for the successful widespread deployment of PV and an ongoing challenge for flat-plate and concentrator PV technologies. We strongly encourage members of the PV community to submit their contributions addressing the full range of scientific and technological challenges in the field of characterization, including the following topics:

Sub-Area 5.1: New Methods and Instruments for the Characterization of Solar Cell Materials

Sub-Area Chair: Nancy Haegel (NREL, USA)

This Sub-area is intended to showcase the application of techniques for characterization of PV materials and to demonstrate their capabilities. Papers submitted to this Sub-area should be science or technology focused with strong technical content, rather than advertisements. Papers are sought that either present new characterization tools or that provide an overview and update on the state-of-the-art application of a particular technique or type of instrumentation. Papers should demonstrate the capabilities of the instrumentation, describe its operating principles, and/or relate how the technique extends existing measurement limitations.

Sub-Area 5.2: Optical and Electrical Characterization Techniques for PV

Sub-Area Chair: Marina Leite (Univ. of Maryland, USA)

Papers describing any aspect of the optical and/or electrical response of PV materials and full devices are welcome in the Sub-Area, including the application of scanning probe and scanning electron microscopies, and other imaging methods for the analysis of defects,

surface passivation, carrier recombination, light trapping effects, etc., on the overall device performance. For this Sub-Area, papers focusing on the technique rather than the material aspects are strongly encouraged.

Sub-Area 5.3: Characterization of Polycrystalline or Amorphous Thin Film PV

Sub-Area Chair: Talia Gershon (IBM Yorktown Heights, USA)

Sub-Area 5.3 focuses on the characterization of polycrystalline or amorphous thin film PV, with emphasis on their structure, properties, and how these relate to processing and performance, with a focus on the materials. The discussion of both well-established (such as chalcogenides) and emerging materials (such as earth abundant materials) is equally welcome.

Sub-Area 5.4: Characterization of Single Crystalline PV Materials and Devices (Joint between Topic Areas 3, 5, and 7*)

Sub-Area Chair: Myles Steiner (NREL, USA)

Papers focusing on characterization and characterization methods for III-V materials and devices, where the single-crystalline nature of the III-V material is paramount to device performance, should be submitted here. Single- and multi-junction devices, as well as III-V sub-components (such as tunnel junctions), are welcome. Optical, electronic, and structural characterization as it applies to optical and/or electronic properties, is of interest. Characterization of large grain multi- and poly-crystalline III-V materials and devices, where the crystal grains are sufficiently sized to act as effective single crystals, is also appropriate for this Sub-area.

(): Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 5.5: In-situ Monitoring and Processing Control

Sub-Area Chair: Mariana Bertoni (Arizona State University, USA)

This Sub-area is intended for papers describing how to monitor PV materials during the deposition or growth steps, and devices under operational voltage or light bias conditions and during manufacturing. Papers are sought that describe measurement techniques and/or data analysis methods that are particularly suited for determining material properties and for identifying manufacturing process excursions or that provide other manufacturing-related benefits.

Sub-Area 5.6: Characterization of Perovskite Solar Cells and Materials (Joint between Topic Areas 5 and 6*)

Sub-Area Chair: Marina Leite (Univ. of Maryland, USA)

The rapid progress of perovskite solar cells in the last years resulted in high efficiency devices; however, we are far from achieving complete understanding of why the material achieves near-perfect optoelectronic properties as initially grown, but is often unable to retain those near-perfect properties when exposed to light or atmospheres with oxygen/water. This joint Sub-Area encourages the submission of papers discussing the

characterization and analysis of perovskite solar cells, including the development of measurement techniques to probe its optoelectronic properties and their relationship to chemical structure. Characterization techniques that elucidate the degradation mechanisms are of particular interest. The understanding of what makes perovskites so easily achieve near-perfect properties as well as the chemical composition changes and how they affect the optoelectronic response of the devices is required for the rational design of stable perovskite solar cells.

() Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 5.7: Performance Testing and Standards

Sub-Area Chair: Greg Kimball (SunEdison, USA)

A key component of characterization, especially of modules and systems, is testing standards. This Sub-area is intended for submissions related to standard approaches to characterization. For example, standards for light flux measurement, calibration methods for simulators, testing temperatures, and other fundamental parameters of characterizations could be submitted here.

Sub-Area 5.8: Characterization Techniques for PV Modules and Systems (*Joint between Topic Areas 5 and 8)**

Sub-Area Chair: Bruce King (Sandia National Laboratory, USA)

Papers focusing on characterization of complete modules and systems where the nature of the device is dominated by the ensemble of microscopic behaviors distributed throughout a large area rather than the understanding of individual microscopic behaviors. For example, papers in this Sub-area could focus on methods such as LBIC or electroluminescence specifically as applied to understanding module performance rather than the same methods applied to small areas of device. Other examples of papers relevant to this area include adaptation of existing methods to characterize modules from emerging technologies such as perovskites or addressing the characterization of degradation mechanisms of modules or systems of those materials. Papers focusing on the development of novel methods or systems, such as solar simulators, module reliability characterization methods, and accelerated lifetime testing methods should be submitted here. In this case the focus should be on the technique rather than the application. Papers focusing primarily on the characterization technique or standard method for applying it should be submitted to Sub-areas 5.5 or 5.7, respectively. Papers describing methods for extracting model parameters from measurements should be submitted to Sub-area 8.3.

() Submit your abstract under the area that best matches the nature of your investigation.*

Area 6: Perovskite and Organic Solar Cells

Chair: Woojun Yoon, *Naval Research Laboratory, USA*

Co-Chairs: Sam Stranks, *Cambridge University, UK*

Area Description

This focus area covers the latest scientific and technical progress of perovskite, organic, and hybrid solar cells. These photovoltaic (PV) technologies have shown incredible recent progress and are being actively investigated within the research community. Solution processed perovskite solar cell efficiencies have rocketed to >22% with just a few years of research. This kind of solar cell is a prime example of interdisciplinary research drawing together expertise from chemistry, materials science, physics, and engineering. Based on abundant materials and scalable coating technologies, these emerging PV technologies show potential for low-cost, lightweight, and flexible solar power generation and will soon have to prove their viability in the market with an acceptable combination of efficiency, stability, and in some cases environmental benignity at scale. Many of the underlying physical processes are still being explored and this helps pave the path forward for uncovering the true potential of these emerging technologies. The goal of this focus area is to address issues ranging from fundamental science to technological advances and challenges associated with manufacturable scaling in the highly interdisciplinary Sub-areas outlined below. Furthermore, Area 6 will offer a unique possibility to strengthen interactions and integration between researchers from these emerging PV technologies and the greater PV community, something everyone will benefit from.

Sub-Area 6.1: Perovskite Solar Cells

Sub-Area Chair: Giles Eperon (University of Washington, USA)

Sub-Area 6.1 covers the latest developments in organic-inorganic hybrid and fully inorganic halide perovskite based solar cells. The rapid progress in this material class for solar cells has come as a surprise to many; power conversion efficiencies of perovskite solar cells are already comparable to those of established thin film technologies. The materials are highly tunable, making them attractive for a range of applications including building-integrated PV and tandem solar cells. This Sub-area focuses especially on the tunability offered by substitution of elements, which may enable better performance, new device architectures, advances in stability, and novel processing steps. We invite contributions from the broad range of topics relating to halide perovskite-based PV.

Sub-Area 6.2: Organic and Hybrid Solar Cells

Sub-Area Chair: Barry Rand (Princeton University, USA)

Sub-Area 6.2 focuses on organic solar cells. Concurrent efforts in novel materials and device architectures have led to numerous reports of efficiencies above 10%. A better understanding of how the molecular structure influences the optoelectronic properties of solar cells is often considered as key for the targeted synthesis of high performance absorber molecules. Additionally, optimal device design requires insight into the processes of free charge carrier generation, recombination and extraction as well as modeling of opto-

electronic device properties. Great strides in device stability have also been demonstrated and guidelines for designing stable absorbers and contacts are being sought.

Finally, the processing science of organic solar cells, with emphasis on scalable deposition methods, is important for the development of robust manufacturing methodologies. Therefore, this Sub-area welcomes a broad range of submissions from first principles design and synthesis of new donor and acceptor materials, methods of how to influence and characterize their microstructure in thin films to device optimization, stability and scalability.

Sub-Area 6.3: Device Stability

Sub-Area Chair: Yasuhiro Shirai (National Institute for Materials Science, Japan)

PV technologies of Sub-areas 6.1-6.2 have shown very encouraging efficiencies and accelerated lifetime testing shows the potential of lifetimes of more than 10 years. However, this is still far away from the targeted 25 years that conventional silicon PV guarantees. On the one hand, the understanding of the various degradation pathways has to be improved. On the other hand, a major challenge is reliably predicting solar cell and module operating lifetimes for the constantly changing materials sets and stack designs being investigated. Sub-Area 6.3 invites contributions on operating lifetime studies and concepts to improve the device stability, from more stable materials to high quality encapsulation.

Sub-Area 6.4: Scale-Up and Applications

Sub-Area Chair: Kethinni Chittibabu (Warner Babcock Institute for Green Chemistry, USA)

It is clear that on the way to large-scale production, correspondingly large-scale synthesis based on abundant materials and fast coating processes need to be developed. With the first real production systems in the final development phase, markets like building integrated PV and mobile energy are likely to be targeted first. Given the unique form factors, there are many more applications for these novel PV technologies, especially in areas where conventional PV reaches its limits. Sub-Area 6.4 deals with the challenges of scaling up their production and ways to access an affordable terawatt capacity that the technology should allow for. This Sub-area has potential overlap with Area 8 on PV Modules and Manufacturing. Depending on the number and nature of submitted abstracts, a joint session will be considered.

Sub-Area 6.5 (Joint with Areas 1-4, 6, 7*): Hybrid Tandem/Multijunction Solar Cells

Sub-Area Chairs: Adele Tamboli (National Renewable Energy Laboratory, USA)

Mariana Bertoni (Arizona State University, USA)

Bjorn Niesen (École Polytechnique Fédérale de Lausanne; Switzerland)

This wide-reaching joint-topic area solicits papers regarding materials, structures, and devices based on combinations of multiple materials classes — III-Vs, Si, chalcogenides/thin-films, organics, perovskites, etc. — toward the production and characterization of “hybrid” multijunction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy, deposition, and bonding. Characterization of

these materials, structures, and devices, from the atomic scale to the device level (and beyond) is also of interest. Papers on the theory and modeling of such devices are welcome. Work related to modules and systems consisting of such hybrid cells are also encouraged.

()Submit your abstract under the area that best matches the nature of your investigation*

Sub-Area 6.6: Characterization of Perovskite Solar Cells and Materials (*Joint between Topic Areas 5 and 6)**

Sub-Area Chair: Marina Leite (Univ. of Maryland, USA)

The rapid progress of perovskite solar cells in the last years resulted in high efficiency devices; however, we are far from achieving complete understanding of why the material achieves near-perfect optoelectronic properties as initially grown, but is often unable to retain those near-perfect properties when exposed to light or atmospheres with oxygen/water. This joint Sub-Area encourages the submission of papers discussing the characterization and analysis of perovskite solar cells, including the development of measurement techniques to probe its optoelectronic properties and their relationship to chemical structure. Characterization techniques that elucidate the degradation mechanisms are of particular interest. The understanding of what makes perovskites so easily achieve near-perfect properties as well as the chemical composition changes and how they affect the optoelectronic response of the devices is required for the rational design of stable perovskite solar cells.

()Submit your abstract under the area that best matches the nature of your investigation*

Area 7: Space and Specialty Technologies

Chair: Claus Zimmermann, *Airbus, Germany*

Co-Chairs: Jeremiah McNatt, *NASA, USA*
Mitsuru Imaizumi, *JAXA, Japan*

Area Description

Area 7 is concerned with all aspects of photovoltaic power generation in extreme environments. The space and near space environment combines UV light, particle radiation, extreme temperatures and vacuum, to name a few of the environmental factors. Papers are thus welcome that deal with the entire breadth of PV under these conditions, from cell and material technologies up to complete systems. The associated sub areas are advanced solar cells, solar panel and blanket technology and solar arrays and structures. With typical lifetimes of up to 15 years combined with the inability to service the space PV systems, reliability and the correct prediction of the on orbit performance is of key importance and will be covered in additional Sub-areas. Of particular interest are ground based degradation experiments, cell and material degradation studies, flight experiments, and on orbit measurements.

Two trends within this general context of space PV deserve special attention. The first one is "low cost". Currently constellations of several hundred satellites are envisaged to provide space based broadband services. For such constellations to be economically viable, the cost of space PV has to be reduced by a factor of 5-10. Therefore new blanket and array concept compatible with a low cost series production are of high interest. With approximately 50% of a space PV system cost originating from the cell, approaches to arrive at high efficiency, low cost cells are of particular importance and will be addressed in a joint Sub-area with Area 3. The second topic of special interest this year is high power systems. The largest space PV systems today are capable of delivering 20 - 30 kW of power. With the success of electric propulsion, there is growing interest in significantly higher power systems as an enabler for solar electric interplanetary science missions or near earth servicing capabilities. Therefore novel rigid and flexible planar solar array technologies as well as space solar concentrator array technologies are of interest, which can be scaled to 100 kW and beyond.

We highly encourage contributions, particularly from students who are working in relevant research areas. We invite your papers on any subjects related to space PV described above, and look forward to your contribution!

Sub-Area 7.1: Advanced Solar Cells, Including Radiation Effects

Sub-Area Chairs: Takeshi Ohshima (*JAEA, Japan*)
Paul Sharps (*SolAero, USA*)
Wolfgang Guter (*AZUR Space, Germany*)

This Sub-area focuses on novel photovoltaic device approaches and recent developments in high performance photovoltaic materials and devices for space applications. Although III-V multijunction architectures dominate space PV, this sub area is not limited to this material

system. Radiation hardening technologies that enable longer on-orbit capability are also sought. Papers on characterization and modeling of solar cells, including concentrator space solar cells are welcomed. Contributions dealing with the AM0 measurement and calibration of solar cells also belong to this area. Papers covering both space and terrestrial III-V solar cell development aspects will be included in a joint session with Area 3.

Sub-Area 7.2: Advanced Solar Panel and Blanket Technology, Including ESD Aspects

Sub-Area Chairs: Bao Hoang (Space Systems Loral, USA)
Shiro Kawakita (JAXA, Japan)
Phil Jenkins (NRL, USA)

This Sub-area focuses on technology developments associated with integrating space solar cells onto rigid panels and flexible blankets. Technologies required for electrostatic discharge control and stabilization against ionizing radiation (UV, particles), development of space solar concentrator technologies, incorporating both the optical concentrating element as well as the solar cell thermal control element are included as well. Of particular interest in this area are papers dealing with the behavior of module technology under the space environment. This includes studies on individual materials relevant for space solar modules. Also of interest are papers that describe approaches to lower cost, standardized solar panels, both fixed and deployable, for smallsat (including Cubesat) constellations.

Sub-Area 7.3: Advanced Solar Arrays and Structures

Sub-Area Chairs: Scott Billets (Lockheed Martin Space Systems, USA)
Mikael Thibaudeau (Thales Alenia Space, France)

This Sub-area aims to bring together the individuals who are developing advanced solar array concepts with the traditional photovoltaic technologists, in the hope that a fuller understanding of the mutual design restrictions will aid in developing higher reliability, higher performance space solar arrays. Contributions are sought for all power classes, from the microsatellite power range up to the several 100 kW range which is required for large spacecraft for new telecommunication services or solar electric propelled deep space missions. To this end, papers with a mechanical focus are explicitly encouraged in this area. Also welcome are contributions that deal with platform aspects and their interaction with the solar array.

Sub-Area 7.4 (Joint with Areas 3, 5 and 7*): Characterization of Single-Crystal III-V PV Materials and Devices

Sub-Area Chair: Myles Steiner (NREL, USA)

Papers focusing on characterization and characterization methods for III-V materials and devices, where the single-crystalline nature of the III-V material is paramount to device performance, should be submitted here. Single- and multi-junction devices, as well as III-V sub-components (such as tunnel junctions), are welcome. Optical, electronic, and structural characterization as it applies to optical and/or electronic properties, is of interest. Characterization of large grain multi- and poly-crystalline III-V materials and devices, where

the crystal grains are sufficiently sized to act as effective single crystals, is also appropriate for this Sub-area.

() Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 7.5 (Joint with Areas 1-4, 6, 7*): Hybrid Tandem/Multijunction Solar Cells

Sub-Area Chairs: Adele Tamboli (National Renewable Energy Laboratory, USA)

Mariana Bertoni (Arizona State University, USA)

Bjorn Niesen (École Polytechnique Fédérale de Lausanne, Switzerland)

This wide-reaching joint-topic area solicits papers regarding materials, structures, and devices based on combinations of multiple materials classes — III-Vs, Si, chalcogenides/thin-films, organics, perovskites, etc. — toward the production and characterization of “hybrid” multijunction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy, deposition, and bonding. Characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond) is also of interest. Papers on the theory and modeling of such devices are welcome. Work related to modules and systems consisting of such hybrid cells are also encouraged.

() Submit your abstract under the area that best matches the nature of your investigation*

Sub-Area 7.6 (Joint between Areas 3 and 7*): Low Cost III-V Materials and Solar Cells

Sub-Area Chairs: Chris Bailey (Old Dominion University, USA)

Roberta Campesato (CESI, Italy)

Topics of interest are broadly defined as technologies and approaches related to the achievement of low-cost III-V materials and solar cells, including the use of alternative substrates, polycrystalline materials, and low-cost (high-rate) growth and deposition methods. Papers are solicited on the growth of crystalline and poly-crystalline III-V materials on alternative substrates (i.e. not single-crystal Ge or III-V) where the substrate is not an active photovoltaic component. Papers are also sought on low-cost III-V growth and deposition techniques, such as HVPE and ultra-high-rate OMVPE/MOCVD. Papers on wafer and epilayer bonding approaches and substrate re-use are also solicited. Work on the characterization of associated materials and devices is encouraged.

() Submit your abstract under the area that best matches the nature of your investigation*

Sub-Area 7.7: Flexible, lightweight and cost-effective mobile solar power for terrestrial and space applications (Joint between Topic Areas 3, 7 and 8*)

Sub-Area Chairs: Rao Tatavarti (Microlink Devices, USA)

Kimberly Sablon (Army Research Laboratory, USA)

This Sub-Area covers progress on the development of Mobile Solar Power (MSP) systems and applications. The MSP system development includes flexible and lightweight solar cells, sheets and related integration systems. Papers are sought that describe the development of thin cell technologies including material growth, cell fabrication and testing. Papers covering developments of flexible solar sheet fabrication methods, studies on improvement of sheet durability; ruggedness and overall energy generation are invited. Papers discussing cost

reduction technologies for both cell production and cell integration are encouraged. Developments of systems applications of photovoltaic sheets such as battery charging, portable power, powering flexible electronics and solar UAV (Unmanned Aerial Vehicles) covering both the military and civilian energy power application are of interest in this sub-area.

()Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 7.8: Flight Experience and Reliability of Space Photovoltaic Power Systems

Sub-Area Chairs: Stephen Taylor (ESA, Netherlands)

Kyle Montgomery (AFRL, USA)

Hiro Toyota (JAXA, Japan)

This Sub-area deals with the on-orbit performance and reliability of space photovoltaic power systems and components. An essential aspect is the results from on-orbit experimentation and operation of PV power systems and their analyses. Reliability assessments via experimentally determined degradation behavior, e.g. due to particle irradiation or contamination, are encouraged. In this context, papers addressing the end of life performance with the help of degradation modelling are also of high interest. Papers dealing with reliability improvements due to particular qualification approaches and test standards are welcome. Papers covering cell and power system testing using CubeSats are also encouraged.

Area 8: PV Modules, Manufacturing, Systems and Applications

Chair: Anton Driesse, *PV Performance Labs, Germany*

Co-Chairs: Cliff Hansen, *Sandia National Labs, USA*

Thomas Reindl, *Solar Energy Research Institute of Singapore, Singapore*

Area Description

The remarkable decrease in the levelized cost of energy (LCOE) in photovoltaic modules is largely attributed to the significant improvements in module performance, engineering, and manufacturing over recent years. New materials and assembly technologies are being developed for PV modules and will further reduce costs and increase performance. Additionally, customers and operators are seeking and utilizing energy yield prediction methods to reduce investment risk. Improved energy yield estimates will reduce some of the soft costs in financing and thus further reduce LCOE.

Area 8 is seeking papers describing significant advances in PV module design and manufacturing, methods for modeling energy yield and performance, and techniques for component testing and system monitoring. We invite papers describing advances in technology and modeling for balance-of-system components such as trackers, inverters, and power optimizers, and for building integration of PV systems. Papers on innovative deployment of PV technologies are particularly encouraged. Finally, papers on innovative deployment and applications of PV technologies are also requested for a Joint Session on mobile power applications.

Papers reporting completed work that is accompanied by validation from the field, laboratory testing, or comprehensive modeling will be given preference for oral presentation.

Sub-Area 8.1: Module Materials, Design, Manufacture, and Production

Sub-Area Chairs: Michael Kempe (National Renewable Energy Lab, USA)

Xu Jianmei (Trina Solar, China)

In Sub-Area 8.1, abstracts are invited that describe new materials and methods for module production. Of particular interest are: new materials for backsheets, encapsulants, glass, or interconnects; new techniques or materials for module assembly to reduce cost, increase efficiency or enhance reliability; methods for materials or module characterization; and novel module electrical configurations. We also welcome submissions describing state-of-art methods or new methods for module manufacturing quality control, including: quality assurance of module materials and subcomponents; statistical process control; automation of module assembly; and module quality assurance.

Sub-Area 8.2: Modeling of System Components

Sub-Area Chairs: Joshua Stein (Sandia National Labs, USA)

Govindasamy TamizhMani (Arizona State University, USA)

Photovoltaic power systems include multiple components, and simulating system performance requires models for each component type. Work on developing, validating,

implementing or comparing models for modules, inverters, batteries or other components therefore fits in this Sub-area. The models could be electrical, mechanical, thermal, optical or any combination thereof. Of particular interest are abstracts describing methods for determining model parameters from laboratory or outdoor measurements, and for characterizing the effect of solar spectrum on module output.

Sub-Area 8.3: PV Performance Degradation and Spectral Impacts Due to Soiling (*Joint between Topic to Areas 8, 9 and 11)**

Sub-Area Chair: Alan Lyons (ARL Designs, USA)

Soiling can be a major factor in power plant performance. This Sub-area focuses on soiling, ground- and satellite-based forecasting of soiling rates, methods for evaluating such rates, and fundamental physics of soiling. Papers on novel anti-soiling technologies are also encouraged. Papers on permanent panel degradation caused by soiling and cleaning operations (e.g. glass abrasion) should be submitted to Sub-area 9.4 but may be considered for this session.

(Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 8.4: Simulation and Optimization of Systems

*Sub-Area Chairs: Jessica Forbess (Sunshine Analytics, USA)
Bodo Littmann (Independent Consultant, USA)*

Papers in this sub-area should focus on modeling complete PV systems. A number of simulation tools are available or being developed, but there is still room for improvement, and different types of projects may benefit from different approaches. Papers may discuss the development of the simulation tool or the application of a tool for improved understanding of system characteristics, possibly for design optimization. Complexities that arise from increased system size or real world requirements are of particular note; the former would include module shading, variation in array temperature, and their effect on module mismatch, as well as other BOS losses, while the latter would include mixed module type arrays, mixed orientations, or interactions with smart grids or other load profiles. Energy production is expected to be the most common focus for simulation, but other metrics like voltage or current may be studied as well. Investigations into simulation uncertainties, including uncertainties of measurement from instrumentation and/or spatial diversity would also be welcome.

Sub-Area 8.5: Measurement, Analysis and Rating of System Performance

*Sub-Area Chairs: David Moser (EURAC, Italy)
Achim Woyte (3E, Belgium)*

This Sub-area is designed for presentations and discussions about existing systems and real performance. What are the challenges in measuring the performance? How can the measurements be analyzed to identify faults, or to assess whether design goals are met? How can complex system performance characteristics be captured in meaningful ratings? We welcome abstracts describing: advances in or evaluations of methods for determining

performance and failure metrics of plant performance; procedures for conducting commissioning and acceptance tests; and issues related to data collection and quality assurance for such testing. We also solicit papers that compare different technologies or products in order to precisely quantify their performance in the field and methodologies that reduce uncertainties of the related performance metrics. We particularly invite abstracts reporting efforts to compare and/or harmonize among the various standards for system testing.

Sub-Area 8.6: PV for Buildings and Novel Applications

*Sub-Area Chairs: Francesco Frontini (SUPSI, Switzerland)
Christoph Mayr (Austrian Institute Of Technology, Austria)*

Sub-Area 8.6 welcomes abstracts describing advances related to materials, design, and manufacturing for building-integrated or building-applied PV (BIPV/BAPV) systems. The rapid market growth in net-zero buildings encourages incentives to architects and building owners alike to find new and innovative building power solutions. We welcome abstracts reporting new innovations, visions for future development, and advanced analyses of the cost reduction potential for building power applications. In particular, we invite abstracts reporting advances in building design tools with integrated PV modeling functionality, as well as reports of building power system performance in the field.

In this Sub-area we also welcome abstracts describing recent advances in off-grid PV systems, hybrid systems, mini/micro-grids, DC end-use systems, hydrogen generation by electrolysis (solar water splitting) and other advanced applications. We are particularly interested in results from fielded or demonstration installations, but also welcome topics covering design and engineering advances, results from system simulations as well as from laboratory testing and multifunctional characterization. We welcome papers covering innovative use of PV in non-traditional applications.

Sub-Area 8.7: Flexible, lightweight and cost-effective mobile solar power for terrestrial and space applications (Joint between Topic Areas 3, 7 and 8*)

*Sub-Area Chairs: Rao Tatavarti (Microlink Devices, USA)
Kimberly Sablon (Army Research Laboratory, USA)*

This Sub-Area covers progress on the development of Mobile Solar Power (MSP) systems and applications. The MSP system development includes flexible and lightweight solar cells, sheets and related integration systems. Papers are sought that describe the development of thin cell technologies including material growth, cell fabrication and testing. Papers covering developments of flexible solar sheet fabrication methods, studies on improvement of sheet durability; ruggedness and overall energy generation are invited. Papers discussing cost reduction technologies for both cell production and cell integration are encouraged. Developments of systems applications of photovoltaic sheets such as battery charging, portable power, powering flexible electronics and solar UAV (Unmanned Aerial Vehicles) covering both the military and civilian energy power application are of interest in this sub-area.

()Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 8.8: Characterization Techniques for PV Modules and Systems (Joint between Topic Areas 5 and 8*)

Sub-Area Chair: Bruce King (Sandia National Laboratory, USA)

Papers focusing on characterization of complete modules and systems where the nature of the device is dominated by the ensemble of microscopic behaviors distributed throughout a large area rather than the understanding of individual microscopic behaviors. For example, papers in this Sub-area could focus on methods such as LBIC or electroluminescence specifically as applied to understanding module performance rather than the same methods applied to small areas of device. Other examples of papers relevant to this area include adaptation of existing methods to characterize modules from emerging technologies such as perovskites or addressing the characterization of degradation mechanisms of modules or systems of those materials. Papers focusing primarily on the characterization technique or standard method for applying it should be submitted to Sub-areas 5.5 or 5.7, respectively. Papers describing methods for extracting model parameters from measurements should be submitted to Sub-area 8.2.

() Submit your abstract under the area that best matches the nature of your investigation.*

Area 9: PV and System Reliability

Chair: Tony Sample, *European Commission, Italy*

Co-Chair: Ingrid Repins, *NREL, USA*
Kent Whitfield, *Beamreach Solar, USA*

Area Description

The PV industry now attracts billions of dollars and euros of investment annually; thus it has become increasingly critical to have confidence in the long-term performance and reliability of these systems. This Area considers durability and reliability of all types of PV and Systems technologies as well as their impacts throughout the value chain. Topics especially critical to the success of the PV industry include: up-to-date understanding of what is being observed for deployed products, the physics of degradation and failure modes, the development of accelerated tests and the validation of those tests' ability to correlate with outcomes in the field, best practices in Design-for-Reliability and manufacturing Quality Assurance; and the development and industry acceptance of standards and test protocols to ensure safety and reliability of PV systems. This year we are convening a joint session on balance-of-system and system reliability with Area 10; we are also convening a joint session with Areas 8 and 11 regarding soiling. Submissions are invited for all types of PV technologies.

This area may host joint sessions with other Areas. Area 9 has been divided into five Sub-areas, as presented below. Submission of papers on detailed scientific research studies as well as visionary papers addressing the full range of these topics are invited.

Sub-Area 9.1: Reliability Field Experience

Sub-Area Chair: Dirk Jordan (NREL, USA)

This Sub-area focuses on statistics of types of failures, data analysis techniques for field data, analysis of mechanisms of observed degradation and failures, electrical and mechanical impacts of failures, degradation models, and long-term operation models of PV plants. Submissions may include (but are not limited to) observations and analysis of observations from deployments of all PV technologies, methods of analysis of such data, and models or reviews that paint the big picture of what is happening in the real world. *Papers on soiling should be submitted to Sub-Area 9.3 Joint topic to Areas 8, 9 and 11 on PV Performance Degradation Due to Soiling.*

Sub-Area 9.2: Device Reliability and Accelerated Testing

Sub-Area Chair: Max B. Köntopp (Hanwha Q-Cells, South Korea)

Both silicon and thin-film solar cells are subject to thermal, thermal cycling, humidity, electrical, ultraviolet light, and mechanical stresses that result in a variety of failure mechanisms such as light-induced degradation, potential-induced degradation, damage to device passivation layers, cell stack delamination, metallization fatigue, and corrosion. This Sub-area welcomes papers on identification and elucidation of the chemistry and physics of device-level failure mechanisms, accelerated stress tests and acceleration factors, modeling of degradation and failure rates, and critical controls in manufacturing. Papers concerning

device (cell) and packaging (panel) interactions may be submitted to either Sub-Area 9.2 or 9.4, and will be considered for both areas.

Sub-Area 9.3: PV Performance Degradation and Spectral Impacts Due to Soiling (*Joint between Topic Areas 8, 9, and 11)**

Sub-Area Chair: Alan Lyons (ARL Designs, USA)

Soiling can be a major factor in powerplant performance. This Sub-Area focuses on studies on soiling, ground- and satellite-based forecasting of soiling rates, methods for evaluating such rates, and fundamental physics of soiling. Papers on novel anti-soiling technologies are also encouraged. Papers on permanent panel degradation caused by soiling and cleaning operations (e.g. glass abrasion) should be submitted to Sub-Area 9.4 but may be considered for this session.

(Submit your abstract under the area that best matches the nature of your investigation.)*

Sub-Area 9.4: Panel and Materials Durability and Accelerated Testing

Sub-Area Chair: Atsushi Masuda (AIST, Japan)

Module and module components are also subject to thermal, thermal cycling, humidity, ultraviolet light, electrical, and mechanical stresses. These can result in a variety of failure mechanisms such as glass corrosion, encapsulant browning, backsheet cracking, bubbling and delamination, interconnect fatigue and corrosion, frame corrosion and fatigue, bypass diode failure, junction box failure, cable and connector failure. Submissions are encouraged on experimental elucidations of the chemistry and physics of these or other module failure mechanisms, accelerated stress tests and acceleration factors, modeling of degradation and failure rates, and critical controls in manufacturing. Papers concerning device (cell) and packaging (panel) interactions may be submitted to either Sub-Area 9.2 or 9.4, and will be considered for both areas.

Sub-Area 9.5: Reliability and Safety of Power Electronics and PV Systems (*Joint between Topic Areas 9 and 10)**

Sub-Area Chair: Greg Ball (SolarCity, USA)

The durability and safety of PV system power electronics is increasingly in focus. For example, new inverter safety requirements specified by the National Electric Code include arc /ground fault detection and rapid disconnect capability. The field durability of PV power electronics is also an important factor in overall system lifetime cost. Improved functionality and documentation of field reliability studies for power electronics will be the focus of this Sub-area, as well as novel methods for fire prevention, arc detection and mitigation, shock hazards, ground and series arc faults, mechanical integrity, and inspection procedures. Papers studying PV system-level availability and reliability are also encouraged.

(Submit your abstract under the area that best matches the nature of your investigation.)*

Area 10: Power Electronics and Grid Integration

Chair: Barry Mather, *National Renewable Energy Laboratory, USA*

Co-Chair: Olivier Stalter, *Fraunhofer ISE, Germany*

Area Description

As PV installations become more widespread, the demands on the power electronics designed to interface solar panels to the grid will continue to increase. Advanced inverter functionality and energy storage will improve the stability of the grid and enable increased penetration of renewables. Improved topologies and controls will continue to increase power converter performance and reduce balance of systems cost. Also, novel wide bandgap materials can enable higher-voltage interconnections and improved conversion efficiencies. The PV and power electronics community is encouraged to submit contributions addressing the full range of scientific and technical contributions to the field of PV power electronics. In particular, special sessions on Wide Bandgap semiconductors and a joint session with area 9 represent new opportunities for publication at the PVSC.

Sub-Area 10.1: Next Generation PV Power Converter Design and Control

Sub-area Chair: Chris Deline (*National Renewable Energy Laboratory, USA*)

This Sub-area solicits abstracts describing new inverter and power converter designs and control strategies, as well as novel component design and testing results. Topics of specific interest include the use of wide-bandgap materials such as SiC and GaN in converter designs, novel converter topology designs and control paradigms that increase converter efficiency, decrease system cost, reduce size, increase system functionality, etc.

Sub-Area 10.2: Grid Integration, High-penetration PV, Energy Storage, and PV in Smart Grids

Sub-area Chair: Barry Mather (*National Renewable Energy Laboratory*)

High penetration of both distributed and utility-scale PV systems on the electrical power grid and the variability and unpredictability of PV output introduce a host of challenges for electrical utilities to manage. This Sub-area solicits papers addressing all aspects of grid integration including: advanced inverter functionality (LVRT, Volt/VAR), battery storage technologies, PV in smart grids, detailed distribution feeder network analysis methods and related studies.

Sub-Area 10.3: Maximizing Power Output On and Off the Grid

Sub-area Chair: Carlos Olalla (*Universitat Rovira i Virgili, Spain*)

Novel topologies of PV systems have been proposed to increase generated power both on and off the grid. Distributed power electronics, improved maximum-power-point tracking algorithms, mismatch mitigation methods, system optimization software, higher system voltages and off-grid innovations can all improve the system level efficiency of PV systems. This Sub-area seeks papers describing and evaluating innovative system designs, and experimental results of new technologies.

Sub-Area 10.4: Solar Forecasting for Grid Integration of PV (Joint between Topic Areas 10 and 11*)

Sub-Area Chair: Gerd Heilscher (University of Ulm, Germany)

This topic focuses on the use of solar forecasts in ways to best integrate PV into the electric grid. Topics for both distribution and transmission level integration will be considered. Papers should focus on the modeling or measurement of the electric grid in the changing landscape of electric supply due to PV. Distribution grid papers will largely address the PV as a “behind-the-meter” application, whereas transmission-level research focuses on “utility-scale” PV plants. Preferred submissions in this topic area will target new insights into ways the electric grid can successfully operate under high penetration PV with the goal of causing minimal economic and technical impacts.

() Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 10.5: Reliability and Safety of Power Electronics and PV Systems (Joint between Topic Areas 9 and 10*)

Sub-Area Chair: Greg Ball (SolarCity, USA)

The durability and safety of PV system power electronics is increasingly in focus. For example, new inverter safety requirements specified by the National Electric Code include arc /ground fault detection and rapid disconnect capability. The field durability of PV power electronics is also an important factor in overall system lifetime cost. Improved functionality and documentation of field reliability studies for power electronics will be the focus of this Sub-area, as well as novel methods for fire prevention, arc detection and mitigation, shock hazards, ground and series arc faults, mechanical integrity, and inspection procedures. Papers studying PV system-level availability and reliability are also encouraged.

() Submit your abstract under the area that best matches the nature of your investigation.*

Area 11: Solar Resource for PV and Forecasting

Chair: Skip Dise, *Clean Power Research, USA*

Co-Chairs: Zhao Lu, *National University of Singapore, Singapore*
Elke Lorenz, *Fraunhofer Institute for Solar Energy Systems, Germany*

Area Description

Solar resource measurement and forecasting are essential for evaluating technical and financial performance in PV applications, and uncertainties related to the solar resource contribute directly to uncertainties in economic viability. Measurement using ground-based instruments provides the highest accuracy, but at a relatively high initial and operating cost, whereas remotely derived data can provide broad geographical coverage. This research area covers technologies and methods to quantify and model solar irradiance with a particular focus on applications in the PV sector. Technologies to quantify solar resource, either in actual or forecast, can overlap by time horizon and application. Research advances in measurement will target advancement on physically and empirically based models, whereas applications look to reduce the magnitude of PV operational risk. Forecasting submissions will target advancement in deterministic and probabilistic techniques, with specific emphasis on quantification of accuracy relative to persistence models.

Sub-Area 11.1: Solar Resource Measurement, Component Modeling and Spectral Decomposition

Sub-area Chair: Tom Stoffel (NREL Emeritus, USA)

Sub-Area 11.1 welcomes submissions that research techniques in solar resource measurement, either by ground-based or remotely-derived techniques. Solar resource measurements can be a critical component to all stages of PV projects, including development and operation. Submissions that present various technologies' ability to quantify solar resource and the associated uncertainty are preferred. Modeling of components targets the improvement in methods by which global irradiance measurement, either through ground- or remotely derived sources, is separated into individual components such as direct normal and diffuse. Submissions in the emerging topic of spectral decomposition are encouraged to focus on impacts on performance of the associated PV technology. Topics that address the use of ground-based tools for solar forecasting for energy forecasting and near-term applications should be submitted to 11.5.

Sub-Area 11.2: Solar Resource Characterization Specific to PV Development and Operational Applications

Sub-area Chair: Kelsey Yates (DNV-GL, USA)

This Sub-area focuses on the development of solar resource characterization related to long-term PV energy forecasting and PV system performance prediction. In the development of a PV project, generating a long-term energy forecast is a vital step in quantifying the project viability. Advances in the application of solar resource for long-term energy modeling will target contributions to reducing PV efficiency loss and modeling uncertainty. Novel techniques for quantifying holistic project risk for financing applications are encouraged.

Accurate resource characterization is chief among them but equipment function in the field is also of interest. Performance issues related to plant hardware function can be determined by comparison with PV model output (*i.e.* Performance index) or directly against solar resource (*i.e.* Performance ratio). Research in this area will focus on the development of modeling techniques that more accurately predict actual plant operation, leading to higher project performance and availability. Advancements specific to PV resource to power models should submit to Sub-Area 8.3. Topics that focus on soiling as a cause of plant underperformance should be submitted to Sub-Area 11.4.

Sub-Area 11.3: PV Performance Degradation and Spectral Impacts Due to Soiling (*Joint between Topic Areas 8, 9, and 11)**

Sub-Area Chair: Alan Lyons (*ARL Designs, USA*)

Soiling can be a major factor in powerplant performance. This Sub-Area focuses on field studies focused on soiling rates, ground- and satellite-based forecasting of soiling rates, methods for evaluating such rates, and fundamental physics of soiling. Papers on novel anti-soiling technologies are also encouraged. Papers on permanent panel degradation caused by soiling and cleaning operations (e.g. glass abrasion) should be submitted to Sub-Area 9.4 but may be considered for this session.

(Submit your abstract under the area that best matches the nature of your investigation.*

Sub-Area 11.4: Solar Forecasting for Grid Integration of PV (*Joint between Topic Areas 10 and 11)**

Sub-Area Chair: Gerd Heilscher (*University of Ulm, Germany*)

This topic focuses on the development and use of solar forecasts in ways to best integrate PV into the electric grid. Topics solely on solar forecasting models will also be considered, with preference given to submissions that thoroughly explore novel models and evaluate model performance against persistence. Topics related to PV to grid integration can include research in both solar forecast models and associated impacts on grid performance. These papers should focus on the modeling or measurement of the electric grid in the changing landscape of electric supply due to PV. Papers can address the PV as a behind-the-meter application or focus on utility-scale PV plants. Preferred submissions in this topic area will target new insights into ways solar forecasting will enable the electric grid to successfully operate under high penetration PV with the goal of causing minimal economic and technical impacts.

(Submit your abstract under the area that best matches the nature of your investigation.*

Area 12: PV Deployment and Sustainability

Chair: Mike Woodhouse, *National Renewable Energy Lab, USA*

Co-Chair: Robert Margolis, *Department of Energy, USA*
Chinho Park, *Yeungnam University, Korea*

Area Description

The PV Deployment and Sustainability area provides an opportunity to discuss aspects required to ensure the long-term success of the PV industry. It represents an extension of the traditional scope of the conference where current concerns and strategies to increase the adoption of PV as a major electricity source will be discussed.

Sub-Area 12.1: Government, Policy and Financing

Sub-area Chair: Dana Olson (Department of Energy, USA)

This topic focuses on strategies to sustain or accelerate high PV growth rates and rapid cost reductions through government, policy, and financing models that are critical to the success of PV deployment. The installed costs of a PV system have declined more than 60% since 2010, yet market barriers, and grid integration and policy issues, remain that may inhibit broad scale PV deployment. This Sub-area solicits papers that will help conference participants better understand the government, policy, and finance considerations that are paramount to overcoming these barriers.

Sub Area 12.2: Sustainability

Sub-Area Chairs: Dirk Weiss (First Solar, USA)
Annick Anctil (Michigan State University, USA)

This area seeks submissions with a broad, systems-level perspective on the sustainability of PV, throughout the life-cycle. These can include perspectives on material supply (*e.g.* improving efficiency of raw material extraction, concerns related to critical or scarce materials), manufacturing (*e.g.* dematerialization, efficiency gains), usage (*e.g.* influencing user behavior, encouraging adoption), end-of-life (*e.g.* recycling technologies, toxicity concerns, disposal pathways) and other aspects of the life-cycle. Novel approaches and results regarding assessing the environmental impacts of PV are particularly encouraged. Multi-disciplinary work combining economic and/or social impacts is also invited. Submissions that consider manufacturing sustainability and recycling are also invited.

Sub Area 12.3: Workforce Development and Education

Sub-Area Chair: Mike Woodhouse (National Renewable Energy Lab, USA)

This topic focuses on original education methods to prepare the workforce for jobs associated with various aspects of photovoltaic research, manufacturing and grid integration. Innovative education methods can include but are not limited to interdisciplinary approaches in education, new teaching methods, online education, and hands-on learning.
