CALL FOR PAPERS

THE 52nd IEEE PHOTOVOLTAIC SPECIALISTS CONFERENCE

June 9-14, 2024
Seattle, Washington, USA

Abstract deadline: January 22, 2024

Call for Papers

On behalf of the Technical Program Committee, I would like to invite you to submit an abstract on your latest achievements in photovoltaic (PV) research, development, applications, and impact to the 52nd IEEE Photovoltaic Specialists Conference (PVSC-52). PVSC-52 marks a milestone in the conference's longstanding tradition of covering the full spectrum of PV knowledge and innovation, from the basic science and engineering of materials, devices, and systems, to the examination of policy and markets and critical issues of social impact. PVSC is a highly interactive and inclusive venue for everyone, from seasoned PV experts to entry-level professionals to students alike. The conference provides a unique opportunity to meet, share, and discuss PV-related developments in a timely and influential forum.

Based on the popular response from last year, publication of a conference proceeding will be optional. Full papers are encouraged but short abstracts will otherwise be used as the publication of record. Authors will have the option of submitting their evaluation abstract or a longer conference proceeding by the **May 31, 2024** publication deadline. Exceptional submissions will be recommended for expedited review and publication in the IEEE Journal of Photovoltaics (JPV). You may also indicate that you would like your submission to be evaluated for JPV consideration.

New this year: Contributions on the use of artificial intelligence for PV research are collected under Area 5.

To have your paper considered for presentation at PVSC-52, submit:
1. An evaluation abstract (3 pages maximum for technical committee review);
2. A short abstract of 300 words or less for display on the PVSC-52 website and default publication in the PVSC proceedings.

Abstract submission is via the PVSC-52 website where templates are provided. Please follow the template when preparing your submission. Technical evaluation abstracts will be thoroughly reviewed, used to decide acceptance and determination between oral and poster presentations. **The deadline for abstract submission is January 22, 2024,** at midnight Pacific Standard Time (UTC - 8 hours). Contributing authors will be notified of the acceptance status of their papers around **March 15, 2024**, after which they **must confirm** their ability to present their work at the conference. Invitation letters for visa applications are issued after registration to the conference upon request.

I look forward to welcoming you at the 52nd IEEE Photovoltaic Specialists Conference in Seattle, Washington!

Ian Marius Peters
Technical Program Chair
2024 52nd IEEE PVSC

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*European Commission Joint
Research Centre*
Italy

Area 1: Fundamentals and New Concepts for Future Technologies

Area Chair: Ned Ekins Daukes, UNSW, Australia
Co-Chair: Louise Hirst, University of Cambridge, UK

Sub-Area 1.1:   Fundamental Conversion Mechanisms
Sub-Area 1.2:   Nanostructures, 2D materials, Quantum Materials, and Unconventional Absorbers and Devices
Sub-Area 1.3:   Advanced Light Management and Spectral Shaping
Sub-Area 1.4:   Hybrid Tandem/Multijunction Solar Cells

Area Description

Paradigm shifts in solar cell technology are invariably preceded by breakthroughs arising from basic scientific research. 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, studies of new materials and innovative device designs, as well as photon management methods. Subjects of particular interest include, but are not limited to, new materials for all parts of the photovoltaic device, advances in the understanding of basic phenomena, nanostructures, advanced optical management approaches, new synthesis processes, and unconventional conversion mechanisms.

Sub-Area 1.1:   Fundamental Conversion Mechanisms

Sub-Area Chair: TBD

Sub-Area 1.1 captures both experimental and theoretical work exploring new paradigms for solar energy conversion. Papers submitted to this sub-area should explore fundamental physics, modeling, or initial experimental demonstrations of novel energy conversion mechanisms, including novel materials and novel device architectures. Areas of interest include, but are not limited to, non-conventional PV conversion processes based on multiple exciton generation and molecular singlet-fission, hot-carrier effects, intermediate band concepts and engineered band alignments. Approaches to thermal conversion are also welcome, specifically thermophotovoltaics, thermophotonics, or thermoradiative concepts. Also of interest are concepts and demonstrations of new materials and material science related to these concepts. Crosscutting scientific approaches involving novel physics, photovoltaics for solar fuel generation, alternative solar energy storage mechanisms, and innovative device structures are solicited.

Sub-Area 1.2:   Nanostructures, 2D Materials, Quantum Materials, and Unconventional Absorbers and Devices

Sub-Area Chair: TBD

Sub-Area 1.2 covers progress in the development of novel absorber and contact materials, novel device architectures as well as processing techniques for improving the performance, functionality, reliability, and scalability of PV devices. Topics of interest include theoretical and/or experimental development of nanostructures such as quantum dots and nanowires, 2D and layered materials such as graphene and transition metal dichalcogenides, quantum materials, Earth-abundant absorber materials, perovskite-inspired materials, new contact materials including carrier selective contacts, p-type transparent conducting materials, and transparent conducting oxides. Advances in growth, synthesis, thin film deposition, material printing, doping and passivation schemes as well as innovative strategies to reduce the cost of more established technologies, such as novel substrates

and re-use processes are also welcome. Ideal submissions will range from studies of fundamental properties and materials to examples of working devices.

Sub-Area 1.3:   Advanced Light Management and Spectral Shaping

Sub-Area Chair: TBD

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, colored PV, spectrum splitting, textured light trapping surfaces from front and/or rear surface, luminescent and fluorescent systems, including up and down conversion, micro- 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. It will also include photon recycling, angular restriction techniques for achieving improved open-circuit voltages and strategies to implement ultra-thin devices. 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:   Hybrid tandem/multijunction solar cells

Sub-Area Chair: TBD

Tandem and multijunction solar cells made with two or more classes of materials have demonstrated potential for exceptionally high conversion efficiency. This Sub-Area solicits papers regarding materials, structures, and devices based on combinations of different materials (e.g., III-Vs, silicon, perovskites, chalcogenides, organics, etc.) toward the production of hybrid multijunction solar cells. The full range of integration methodologies are of interest, including but not limited to monolithic epitaxy and deposition, wafer/layer bonding, and mechanical stacking, as well as the characterization of these materials, structures, and devices, from the atomic scale to the device level (and beyond), as related to their hybrid nature. Papers on the theory and modeling of such devices are welcome, as is work related to new module and system architectures optimized for such hybrid cells. Oral sessions in this topic may be organized with Areas 2, 3, 4, and 6, as appropriate.

Area 2: Chalcogenide Thin Film Solar Cells

Area Chair: *Shubhra Bansal, Purdue University, USA*
Co-Chairs: *Santosh Swain, Washington State University, USA*
                    TBD

Sub-Area 2.1: **Absorber Preparation and Material Properties**
Sub-Area 2.2: **Contacts, Windows, Interfaces, and Substrates**
Sub-Area 2.3: **Cell and Module Characterization – Analysis, Theory, and Modeling**
Sub-Area 2.4: **Chalcogenides for Tomorrow and Beyond – Tandems, Recyclability, and Futuristic Innovations**

Area Description

In recent years, thin film chalcogenide solar cells based on CIGSe and CdTe have achieved remarkable progress in terms of record conversion efficiencies and manufacturing at the multi gigawatts-per-year scale. Several gigawatts of installations have demonstrated operating reliability in the field which has helped reducing the cost of installation as well as electricity from PV. Area 2 brings this community together yearly to present and discuss progress, challenges, and the future research avenues in evolution of CdTe, CuZnSnS, and CIGSe based photovoltaic materials and devices. It provides a platform to present current research to improve the understanding as well as exploring new directions for materials and devices and narrowing the gap between record efficiency small area devices and commercial scale modules. The topics range from basic and applied material science, to computational/analytical results, device characterization, as well as potential future innovations. 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 Chair: TBD
Sub-area 2.1 addresses progress in thin film fabrication, material properties, and their relationship with device performance. Topics include experimental and theoretical aspects of morphology, phase coexistence, microstructure, extended and point/bulk defects and their characterization, optoelectronic and transport properties, influence of substrates, compositional gradients and homogeneity, interrelation of properties, doping and passivation treatments etc.

Sub-Area 2.2: **Contacts, Windows, Interfaces, and Substrates**

Sub-Area Chair: TBD
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 performance are welcome. Progress in the cross-cutting areas of transparent conductors, moisture barriers, new or improved substrates, cell scribing and interconnection in modules, and novel topics not listed are also encouraged.

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

Sub-Area Chair: TBD
This sub-area complements topics addressed in sub-area 2.1 and 2.2 through research discussion aimed at measurement, analysis, theory, and modelling of cells and modules. Contributions are

solicited in the areas of novel and established characterization methods, device analysis that yield insights into internal operation, 1D, 2D and 3D modelling of current devices and studies that guide progress, characterization of defects, degradation mechanisms and reliability, and novel related topics not listed.

Sub-Area 2.4:   Chalcogenides for Tomorrow and Beyond – Tandems, Recyclability, and Futuristic Innovations

Sub-Area Chair: TBD

Sub-area 2.4 is aimed at providing a rich launchpad for discussion on next generation chalcogenide-based photovoltaics. This area solicits contributions for research that brings existing or projected technologies together for tandem device applications, modules as well as material recyclability and other innovations beyond the traditional device architectures as well as materials. The scope of this topic area is significantly wider and includes new topics not covered by other traditional topic areas such as n-type absorbers, p-type TCOs.

Area 3: III-V, Space, and Concentrator Photovoltaics

Area Chair: Myles Steiner, National Renewable Energy Laboratory, USA

Co-Chair: Pilar Espinet-González, The Aerospace Corporation, USA

Sub-Area 3.1: III-V Photovoltaic Cells

Sub-Area 3.2: III-V Cost Reduction Strategies & Terrestrial Applications Sub-Area 3.3:
Space Photovoltaic Modules, Systems, and Flight Experience Sub-Area 3.4:
Alternatives to III-V for Space Applications

Sub-Area 3.5: Photonic Power Converters

Area Description

III-V solar cells offer unparalleled photovoltaic conversion efficiency, an expansive palette of material properties, high absorption coefficients, resilience in extreme environments, as well as compatibility with a wide-range of growth and fabrication strategies. These attributes make III-Vs well-suited for a multitude of both terrestrial and space power applications, including concentrator photovoltaics (CPV), along with a range of emerging technologies, such as autonomous vehicle power, commercial solar electric vehicles, laser power beaming receivers, dismounted soldier power, consumer electronics, solar fuels generation and biomedical energy harvesters. Area 3 addresses all aspects of III-V materials, photovoltaic device design, growth, fabrication, and systems, as well as systems for space power, including emerging material system alternatives to III-Vs. Papers are encouraged on any of these subjects: methods to improve size, weight, power, and cost (SWaP-C) for any applications—land, sea, air, and space—as well as investigations of III-V system-level demonstrations.

Sub-Area 3.1:   III-V Photovoltaic Cells

Sub-Area Chair: TBD

This Sub-Area seeks to address all development up to the device-level for III-V photovoltaics, with the exception of low-cost strategies (see Area 3.2) and hybrid tandem/multijunctions of III-Vs with other active photovoltaic materials (see Area 1.4). Abstracts of interest include but are not limited to: epitaxial growth, materials design and development, device-level theoretical modeling, novel processing strategies, unique photovoltaic architectures, single and multijunction devices, device-level photon management, ultra-thin photovoltaics, III-V wafer bonding, materials/device-level characterization, III-V device reliability, and environmental effects testing at the materials-to-device level.

Sub-Area 3.2:   III-V Cost Reduction Strategies & Terrestrial Applications

Sub-Area Chair: TBD

Topics of interest in this Sub-Area concern all aspects of cost reduction strategies for III-V photovoltaics at the materials, device, or module level. This includes (but is not limited to) direct monolithic growth of III-Vs on low-cost templates; substrate re-use as well as other substrate cost mitigation strategies; high-throughput epitaxial growth; increased growth precursor utilization efficiency; low-cost device fabrication strategies, especially low-cost metallization processes; low-cost array- and module-level assembly; and automation of manufacturing steps. This Sub-Area includes conventional CPV and (terrestrial) micro-CPV, but more broadly includes all terrestrial applications and systems that involve III-V photovoltaics. These emerging opportunities include,

but are not limited to, photovoltaics for transportation applications; underwater photovoltaics; unmanned aerial vehicles.

Sub-Area 3.3   Space Photovoltaic Modules, Systems, and Flight Experience

Sub-Area Chair: TBD

Sub-Area 3.3 includes all module- and systems-level III-V photovoltaic development for space applications, as well as on-orbit reliability and performance. At the panel and array level, this includes the integration of space solar cells onto backplanes of interest—rigid or flexible blankets—as well as technologies required for electrostatic discharge control, stabilization against damage (e.g., UV, particles), and interactions with electric propulsion subsystems. Papers dealing with all aspects of micro-CPV module development for the space environment are encouraged. In addition, papers dealing with all aspects of flight experience and reliability are of high interest. This Sub-Area also seeks strategies to improve AM0 calibration of solar cells and panels. Space photovoltaic submissions—at all levels of development—related to alternative material systems to III-Vs, including perovskites, should instead submit to Area 3.4.

Sub-Area 3.4:   lternatives to III-V for Space Applications

Sub-Area Chair: TBD

This Sub-Area solicits papers regarding all aspects of photovoltaic materials, structures, devices, or systems based on alternatives to III-Vs (e.g. perovskites, silicon, chalcogenides, etc.) for the space environment. This may include (but is not limited to) novel AM0 cell and module designs, materials design of interlayers and interfaces for enhanced stability, environmental effects, reliability, testing standards, and performance reports.

Sub-Area 3.5:   Photonic Power Converters

Sub-Area Chair: TBD

Sub-Area 3.5 seeks abstracts concerning all aspects of photonic energy conversion involving primary light sources other than the Sun. Topics include single and multijunction laser power converters including module- and system-level laser power beaming, ambient light harvesting, implantable and biomedical systems and applications, all aspects of thermophotovoltaics (TPV), and other operational energy demonstrations.

Area 4: Silicon Photovoltaic Materials and Devices

Area Chair: *Ammar Nayfeh Khalifa University, Abu Dhabi United Arab Emirates*
Co-Chairs: *Ujjwal Das, University of Delaware*
                  Di Yan, University of Melbourne
                  Nick Rolston, Arizona State University

Sub-Area 4.1:   **Silicon Feedstock & Wafering, Thin Silicon & Advanced Light Management**
Sub-Area 4.2:   **Passivated, Carrier-Selective, and Heterojunction Contacts**
Sub-Area 4.3:   **New Material Integration with Silicon for PV Applications**
Sub-Area 4.4:   **Metallization, Interconnection, Module Integration, and Recycling/Sustainability and Novel PV Integrations**
Sub-Area 4.5:   **Device Physics, Modelling, New/Enhanced Characterization Techniques**

Area Description

Silicon has been the dominant photovoltaic technology for decades with market share exceeding 90% while technologically continuing to develop and scientifically entering the realm of innovative integrations. Commercial cell efficiencies exceeding 24% are becoming routine as manufacturers transition to TOPCon and SHJ structures and high-quality monocrystalline wafers. Module costs have fallen below $0.3/W and are now commonly a small fraction of an installed system's cost. The emergence of, for example, bifacial and shingled cells has broadened the module flavors now available, while the advent of vehicle integrated photovoltaics is expected to bring unforeseen innovation, and the dawn of silicon based tandems and multi-junctions are anticipated to yield an era of 30% plus efficiencies as the new norm. In this environment of rapid innovation, Area 4 invites contributions that define and shape the future of silicon photovoltaic science and technology in all its stand-alone and integrated permutations and combinations. Topics of interest span the breadth of the silicon solar photovoltaic field, ranging from silicon purity to thin-film deposition, from electronic transport through new contact structures to high-efficiency devices, from light management to loss analysis, and from interconnection to module field degradation caused by cell deterioration. In addition, new to area 4, we invite abstracts on topics related to new materials integrated with Si for solar cells applications. We also invite abstracts from industry addressing translation from lab to fab, challenges associated with manufacturing processes, recycling and sustainability, market trends and emergence of novel PV integrations, industry roadmaps, and challenges and opportunities the industry faces given the ever increasing focus on renewable energy.

Sub-Area 4.1:   **Silicon Feedstock & Wafering; Thin Silicon & Advanced Light Management**

Sub-Area Chair: TBD

This Sub-Area focuses on silicon and thin silicon with obvious overlaps. Silicon customarily includes silicon feedstock purification and production through crystallization and wafering, including high-performance multicrystalline and quasi mono silicon wafers, improved Czochralski growth, novel silicon growth techniques, and kerf-less technologies such as direct wafer or epitaxial wafer. Thin silicon—including those of amorphous silicon, microcrystalline silicon, epitaxial silicon, related alloys and thin flexible silicon wafers—pertain to thin silicon materials

properties, deposition/growth methods including top-down and bottom-up approaches, flexible silicon handling, cell design and performance, and degradation. In particular for thin film silicon, advanced light management is essential. This encompasses surface engineering of silicon to increase photon absorption by classical, diffractive, Mie scattering, photonic techniques and plasmonic mechanisms, as well as approaches to reduce front-surface reflectance, reduce parasitic absorption, and reject sub-bandgap infrared light. Additionally, relevant areas include mechanical and electrical characteristics of the resulting wafers/foils and their impact on device performance; material changes during subsequent processing and defect engineering steps; and application opportunities and challenges ushered by the flexible form factor of thin silicon.

Sub-Area 4.2:   Passivated, Carrier-Selective, and Heterojunction Contacts

Sub-Area Chairs: Hariharsudan Sivaramakrishnan Radhakrishnan (imec)
This Sub-Area focuses on contacting methods to simultaneously passivate the surface of crystalline silicon (maintain high quasi-Fermi-level splitting and thus high implied open-circuit voltage) and selectively extract charge carriers of one type (minimize the drop of the majority QFL across the contact). This also includes contacting strategies for patterned/textured surfaces and partial coverage such as the areas below the fingers of the metallization. We invite abstracts addressing fabrication, characterization, commercialization, and the underlying device physics of these contacts. The sub-area will also give a forum to discuss properties of alternative materials for passivating contacts and the performance of cells with contact layers such as amorphous silicon, tunnel oxides and polysilicon.

Sub-Area 4.3:   New Materials Integration to Silicon PV

Sub-Area Chairs:Dr Ammar Nayfeh, DEWA United Arab Emirates and Dr Ammar Nayfeh Khalifa University
This sub area focuses on new materials integration to Si PV, which can either form heterojunctions, provide surface passivation, or both with silicon. This can include emerging nitrides, oxides, alkaline/alkaline-earth metal compounds, rare-earth compounds and chalcogenides, etc.. . In addition, new methods for exfoliation, deposition, and characterization of materials, interfaces, and devices.   Abstracts focusing on other novel ways to integrate new materials with silicon PV are welcome. In addition, simulation and modeling studies of new materials, and Si interfaces are welcome. Abstracts concerning hybrid tandem/multijunctions of silicon with other active photovoltaic materials should be submitted to Area 1.4

Sub-Area 4.4:   Metallization, Interconnection, Module Integration, and Recycling/Sustainability and Novel PV Integrations

Sub-Area Chair: TBD
This Sub-Area covers techniques for electrode formation, including printed metallization, plating, evaporation, dispensing or other transfer techniques, conductive adhesives, soldering, laser and thermal alloying of metals, transparent electrodes, selective doping, and contact opening for metallization. Electrodes also comprise the interface to subsequent module integration, and thus the Sub-Area also welcomes abstracts on mechanical adhesion, multi-wire technologies, and the interconnection of advanced cell structures like back-contact cells and silicon-based tandems. Abstracts area also welcome on sustainability, recycling, and life-cycle assessment (LCA) topics for silicon solar cells and modules; novel module constructs for various applications (like agri-PV,

floating-PV and others) and innovative PV integrations in buildings, vehicles or infrastructure.

Sub-Area 4.5:   Device Physics, Modelling, New/Enhanced Characterization Techniques

Sub-Area Chair: Sabina Abdul Hadi, University of Dubai, United Arab Emirates
This Sub-Area focuses on understanding, quantifying, and modelling phenomena in silicon based solar cells, including new interpretations of device physics, multi-dimensional models, numerical analysis of novel cell concepts, power loss analysis and mitigation strategies, computational simulations, and associated means of validation. Abstracts are also welcome on the development of new device characterization techniques, which may be based on, e.g., photoluminescence, impedance, or capacitance measurements etc.

Area 5: Characterization Methods

Area-Chair: *Johnson Wong, Aurora Solar Technologies, Canada*
Co-Chairs: *Ziv Hameiri, University of New South Wales, Australia*

Sub-Area 5.1: In-situ and In-Line Metrology, Data Analysis, and Machine Learning
Sub-Area 5.2: Characterization Instruments and Techniques
Sub-Area 5.3: Characterization of Photovoltaic Materials and Cells
Sub-Area 5.4: Characterization of Photovoltaic Modules and Systems

Area Description

Measurement is the backbone of research development, process optimization, process control, quality assurance and field monitoring. This area focusses on the continuous development, adaptation and new applications of characterization techniques throughout the PV value chain. It also emphasizes the data interpretation, analysis, statistical inference, and machine learning that relate measured information to the material/device properties, process conditions, experimental guidance and other practical consequences, which make them useful.

Sub-Area 5.1: In-situ and In-Line Metrology, Data Analysis, and Machine Learning

Sub-Area Chair: TBD

Findings related to in-situ monitoring (e.g. thickness determination during thin film deposition, optical emission spectroscopy), high sampling rate inline metrology (e.g. electroluminescence or photoluminescence imaging, wafer resistivity), or the analysis of high volume data combining multiple information that are relevant to PV manufacturing or field monitoring contexts. The novelty may be related to the measurement technique itself, or its modification to capture data at high throughput, or new insights on high volume data obtained by statistical analysis/model-based analysis/machine learning.

Sub-Area 5.2: Characterization Instruments and Techniques

Sub-Area Chair: TBD

Measurement techniques that elucidate the material, functional, optical or electrical properties of PV materials and devices (PV cells or modules). Topics of interest may include methods based on interferometry, spectroscopy, microscopy, imaging, electrical probing, scanning probes, etc. Reports that focus on the measurement principles, arrangement or routines and how they relate practically to PV processing and performance, are preferred. Development of operando measurements are also welcome in this Sub-Area.

Sub-Area 5.3: Characterization of Photovoltaic Materials and Cells

Sub-Area Chair: TBD

Findings related to the measurement, interpretation and analysis of PV materials and devices (PV cells). For materials, examples of topics that would fit into this area include study of defect states, material composition, electrons and ion transport, interface properties. For devices, examples include study of device transients, instability and degradation in device performance, and the impact of defects and operating conditions on cell level electrical characteristics.

Sub-Area 5.4: Characterization of Photovoltaic Modules and Systems

Sub-Area Chair: TBD

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. For example, papers in this Sub-Area could focus on methods such as LBIC, photoluminescence or electroluminescence specifically applied to understanding module performance. Statistical inference linking those microscopic behaviors in materials and devices to PV module performance are also welcome. In addition, this Sub-Area is also intended for submissions related to standardization approaches to characterization, e.g. standards for irradiance measurement, calibration methods for simulators, testing temperatures.

Area 6: Perovskite and Organic Materials and Solar Cells

Area-Chair: *Shijing Sun, University of Washington, USA*
Co-Chairs: *Armi Tiihonen, Aalto University, Finland*

Sub-Area 6.1:   **Single Junction and Tandem Perovskite Solar Cells**
Sub-Area 6.2:   **Stability, Reliability and Manufacturability of Perovskite Solar Cells and Modules**
Sub-Area 6.3:   **Advances in Perovskites, Organic and Interfacial Materials**
Sub-Area 6.4:   **Big Data, High-throughput Methods and Artificial Intelligence Techniques for Perovskite, Organic or Dye-sensitized Solar Cells**

Area Description

Halide perovskite materials are making significant strides in the field of solar cell and optoelectronic applications. These emerging photovoltaic (PV) technologies, which leverage plentiful materials and scalable coating technologies, hold the promise for cost-effective, lightweight, and flexible solar power generation. With a certified power conversion efficiency of 26.1% in single junction devices and 33.7% in tandem solar cells with silicon, perovskite solar cells are demonstrating impressive advancements. However, to establish their market viability, these promising materials need to balance performance, stability, and low toxicity at a large scale and under real-world conditions. This conference area, Area 6, is an ideal forum for researchers in the field to present progress in halide perovskite and organic materials and devices for photovoltaics. It highlights the rapid progress of these technologies and provides a platform to promote widespread commercialization. Topics range from device architectures, fabrication methods, manufacturing, outdoor performance, and reliability, to novel applications, fundamental materials insights, and the development of alternative materials. In addition to the development of materials, devices, and modules, this area also invites researchers who are working on innovative methods that can accelerate the development of these technologies. These methods include but are not limited to machine learning, automated testing, and advanced data analytics, which are becoming increasingly crucial in the rapid and efficient advancement of solar cell technology.

Sub-Area 6.1:   **Single Junction and Tandem Perovskite Solar Cells**

Sub-Area Chair: TBD
Sub-Area 6.1 delves into the design, development, and performance of both single junction and tandem perovskite solar cells, with a focus on achieving high power conversion efficiencies. The area explores exceeding the efficiency limit of single junction cells through high-efficiency perovskite photovoltaics and tandem/multijunction architectures. This Sub-Area emphasizes the importance of material design, solar cell fabrication, and module implementation in achieving high efficiency. We welcome contributions that showcase both experimental and theoretical work on new concepts, materials design for multijunction devices, device design and implementation, and the interaction between various absorber films and interlayers in the cell layout. Topics of interest may include (but are not limited to) innovative AM0 perovskite cell and module designs for space, the impact of environmental factors, testing standards, and performance reports. Please note that abstracts related to hybrid tandem/multijunctions of perovskites with other active photovoltaic materials should be submitted to Area 1.4.

Sub-Area 6.2:   **Stability, Reliability and Manufacturability of Perovskite Solar Cells and Modules**

Sub-Area Chair: TBD

As the demand for utility-scale implementation of perovskite solar cell modules increases, Sub-Area 6.2 is dedicated to exploring advancements in their manufacturability, stability, and reliability. This includes a focus on strategies for scaling up production, fabricating large-area cells, and developing eco-friendly manufacturing methods for perovskite solar cells. This Sub-Area also delves into the design of perovskite modules, examining aspects such as module testing and fabrication techniques. It also addresses the challenges of degradation mechanisms and efficiency loss, and the importance of long-term durability testing. Furthermore, Sub-Area 6.2 encompasses the evaluation of the entire process chain, from the initial stages of manufacturing to the final product, recycling and beyond. This includes a life cycle assessment to understand the environmental impact of perovskite solar cells and modules throughout their lifespan. By focusing on these areas, we aim to advance the field towards more sustainable and efficient solar energy solutions.

Sub-Area 6.3:   **Advances in Perovskites, Organic and Interfacial Materials**

Sub-Area Chair: TBD

Sub-Area 6.3 delves into the latest advancements in materials and interfaces for hybrid, fully inorganic, and organic solar cells. This includes the study of active and interfacial materials, aiming to boost performance, stability, and ease of production.

These materials, known for their highly tunable optoelectronic properties, are increasingly appealing for a range of applications, such as building-integrated photovoltaics and tandem solar cells. Innovations in these materials could lead to enhanced performance, the development of novel device architectures, the design of interfaces within the layer stack, progress in fabrication methods, and the creation of new processing steps. We welcome a wide array of contributions, including both computational and experimental studies. Topics of interest include but are not limited to low-dimensional perovskites like Ruddlesden-Popper and Dion-Jacobson phases, lead-free perovskites, perovskite-inspired materials, the use of fullerene and non-fullerene-based molecules, and new charge transport materials, among others.

Sub-Area 6.4:   **Big Data, High-throughput Methods and AI for Perovskite, Organic or Dye-sensitized Solar Cells**

Sub-Area Chair: TBD

Sub-Area 6.4 invites researchers and experts to share their latest advancements in the intersection of solar cells, automation, and AI. This sub-area emphasizes high-throughput experiments for the synthesis, characterization, testing, and manufacturing of perovskite and organic materials and devices, with the goal of accelerating the development of efficient and stable solar cell technologies. A key aspect of this sub-area is the performance and stability prediction in perovskite, organic, and dye-sensitized solar cells. The use of machine learning techniques for analyzing material and device performance presents new opportunities for optimizing solar cell efficiency and stability. Furthermore, the prospect of experimental and computational AI-assisted materials discovery offers exciting possibilities for uncovering new and highly efficient solar cell materials. This sub-area also highlights the importance of advanced data management systems, which enable

the efficient handling and sharing of large datasets generated from experiments and simulations, all in the pursuit of enhancing solar cell technology.

Area 7: PV Modules, Manufacturing, Systems and Applications

Area Chair: *Mengjie Li, University of Central Florida, USA*
Co-Chairs: *Jennifer Braid, Sandia National Laboratories, USA*
Co-Chairs: *Veronica Shabunko, Grenzebach Envelon GmbH, Singapore*

Sub-Area 7.1:   **Module Manufacturing and Production, Novel Application and Integration**
Sub-Area 7.2:   **System Design, Power Electronics and Energy Storage**
Sub-Area 7.3:   **Modelling and Predicting Energy Yield**
Sub-Area 7.4:   **Big Data Analytics, Deep Learning Application and Strategies for Performance Analysis**

Area Description

This area is dedicated to exploring the latest advancements and breakthroughs in PV module manufacturing and production, novel application and integration; system designs, especially power electronics and energy storage solutions; energy yield prediction; and novel performance analysis strategies assisted by big data analytics and deep learning applications.

Sub-Area 7.1:   **Module Manufacturing and Production, Novel Application and Integration**

Sub-Area Chair: Veronica Shabunko, Grenzebach Envelon GmbH, Singapore

In Sub-Area 7.1, abstracts are invited that describe new materials and methods for module production with particular interest on: new materials for backsheets, encapsulants, glass, or interconnects; new techniques for module assembly to reduce cost, increase efficiency or enhance reliability; new designs for bifacial applications; module adjustments and optimization for extreme environments; and novel module electrical configurations. This area also welcomes abstracts describing recent advances in building integrated or applied PV systems (BIPV or BAPV), off-grid PV systems, hybrid systems, mini/micro-grids, DC end-use systems, mobility and transportation systems, infrastructure-integrated PV, agrivoltaics, floating solar, "wearable" PV, and other not-traditional PV applications. In particular, we welcome abstracts reporting innovations, visions for future development, advances in building design tools with integrated PV modelling functionality, as well as reports of building power system performance.

Sub-Area 7.2:   **System Design, Power Electronics and Energy Storage**

Sub-Area Chair: Zheyu Zhang, Clemson University

Sub-Area 7.2 is dedicated to system design, power electronics, and energy storage solutions that enhance the performance and grid integration of PV systems. Presentations in this sub-area will cover topics like grid-tied and off-grid system designs, power converter technologies, maximum power point tracking, and energy storage integration. Researchers will discuss their work in improving system efficiency, reliability, and grid stability, contributing to the overall growth and sustainability of solar energy systems.

Sub-Area 7.3:   **Modelling and Predicting Energy Yield**

Sub-Area Chair: Jennifer Braid, Sandia National Laboratories, USA

In Sub-Area 7.3, we delve into the critical aspect of accurately modeling and predicting the energy yield of PV systems. Researchers will present their studies on advanced modeling approaches, including meteorological data integration, climate-specific models, and uncertainty analysis. This

sub-area aims to foster discussions on developing reliable methods for assessing PV system performance, facilitating optimal system design, and increasing overall energy output.

Sub-Area 7.4:   Big Data Analytics, Deep Learning Application and Strategies for Performance Analysis

Sub-Area Chair: Mengjie Li, University of Central Florida, USA

Sub-Area 7.4 is dedicated to exploring the potential of big data analytics and deep learning techniques for PV performance analysis. Researchers will share their experiences in using data-driven approaches to optimize operations, diagnose faults, and develop predictive maintenance strategies for PV systems. This sub-area aims to highlight the significance of data-driven insights in ensuring long-term performance and maximizing the return on investment for PV installations.

Area 8: Module and System Reliability

Area Chair: Gernot Oreski, Polymer Competence Center Leoben, Austria
Co-Chair: Laura Bruckman, Case Western Reserve University, USA

Sub-Area 8.1:   PV Materials, Module and System Components Durability and Accelerated Testing Methods
Sub-Area 8.2:   Field Experiences in PV Systems
Sub-Area 8.3:   Performance, Reliability and Yield of Emerging Technologies (Tandem cells, Perovskites, OPV)

Area Description
Long-term durability and reliability of PV systems is critical for reliable, efficient, and sustainable energy production as the share of renewables – especially PV - increases in our energy mix. Moreover, systems delivering the expected return on investment for all players along the value chain provide the industrial driver for continued growth. PV system lifetimes are extending to 30-40 years and module are often deployed in harsh weather conditions. The industry is both risk averse, requiring all new technologies (from cell through system elements) to prove their robustness in extensive testing before field deployment, and rapidly adopting new technologies faster than they can be field tested.

Within this context, Area 8 takes a holistic approach considering the reliability and resiliency of all types of PV systems, their components, and technologies as well as impact of materials, processing, installation, and operations throughout the value chain. Inverter and BOS failures are frequently reported in the field and are of special interest in this Area. Taking the growing market of storage systems into account, Area 8 is now also encouraging papers on the reliability solar + energy storage systems and related components.

Sub-Area 8.1:   PV Materials, Module and System Components Durability and Accelerated Testing Methods

Sub-Area Chair: Sona Ulicna, NREL, USA;
Sub-Area Chair: Chiara Barretta, PCCL, Austria
Sub-Area Chair: Karl Anders Weiß, Fraunhofer ISE, Germany
PV modules and system components are exposed to a wide range of stresses, such as high temperatures, temperature fluctuations, humidity, ultraviolet light, electrical or mechanical stresses and media loads. These can result in a variety of failure mechanisms such as glass corrosion, glass breakage, discoloration, backsheet cracking, bubbling and delamination, interconnect fatigue and corrosion, frame corrosion and fatigue, bypass diode failure, junction box failure, cable and connector failure, and failed inverter electronics. Additionally, the number of electrical storage systems connected to PV systems is increasing and the reliability of these systems becomes relevant. Submissions are encouraged on experimental studies of the chemistry and physics of these or other failure mechanisms of PV materials, modules, or other system components, accelerated stress tests and method to extract acceleration factors, modelling of degradation and failure rates, and interfacial and multi-scale module simulations. Reports linking failure modes to material, module manufacturing, process parameters, and insights in critical controls are invited. Studies of degradation rates in recently developed high performance modules using high efficiency mono, bifacial and/or tandem cells (PERx, n-type, HIT, IBC, large wafers/cells), high density module

designs (shingling, tiling, cut cells, close spacing, bifacial, large modules), and next generation module materials (AR-coatings, backsheets, encapsulants) are of interest, as are studies demonstrating field-relevant accelerated testing. Papers regarding detailed Failure Mode and Effect Analysis (FMEA) to assess the potential failure modes and development of adapted tests are also of interest as well as studies presenting reliability of modules and materials for novel applications and conditions (lightweight, floating, tracked), and integrated PV solutions (BIPV, VIPV, IIPV).

Sub-Area 8.2:   Field Experiences in PV Systems

Sub-Area Chair: Marios Theristis, Sandia, USA
Sub-Area Chair: Leonardo Micheli, Sapienza University of Rome, Italy
Sub-Area Chair: Claudia Buerhop Lutz, HiERN, Germany
This Sub-Area focuses on statistics of types of reversible and irreversible performance losses and failures, including soiling and degradation, data analysis techniques for field data for large-scale and small-scale systems, analysis of mechanisms of observed losses and failures, electrical and mechanical impacts of failures, safety and operational failures from large PV systems, expected vs. actual field performance, PV performance and loss monitoring, mitigation and prevention, and long-term operation models of PV plants. Submissions may include, but are not limited to, analysis of field observations from deployments of all PV technologies, methods of analysis of such data, experimental approach and energy yield predictions, best practices and technical/economic insights into operations and maintenance, and models or reviews. This Sub-Area also calls for papers presenting novel techniques, progress on deploying, as well as improved analysis and best practice, and acquisition and interpretation of inspection data/measurements from existing and emerging field characterization techniques. Papers studying innovations in the fields of inspection data analytics and diagnostic algorithms, remote failure detection and wide-area inspections for PV systems are also of interest. Also encouraged are papers studying PV system-level availability, in diverse climatic and site conditions, reliability related to extreme environmental events, mounting methods, and interactive effects. Innovations in the field of system data analytics and remote failure detection are also of interest. This area encourages submissions of field experiences with inverter or BOS failure, repowering, field repair, energy storage, varying DC/AC ratios, and bifacial field performance. Also studies and field-results related to various aspects of soiling are welcome: software and hardware solutions for both ground- and satellite-based monitoring, estimating and forecasting of soiling losses and rates, methods for soiling loss mapping for different climate conditions and site characteristics, novel or improved cleaning solutions, algorithms for cleaning frequency optimization, and investigations on anti-soiling coatings development and testing. These can include natural and artificial soiling to test functionality and abrasion testing to test for durability, and studies on the fundamental physics of soiling deposition and removal mechanisms and their modelling.

Sub Area 8.3:   Performance, Reliability and Yield of Emerging Technologies (Tandem cells, Perovskites, OPV)

Sub-Area Chair: Ina Martin, Case Western Reserve University, USA
Reaching a high level of reliability and durability is key to deployment of perovskite, organic solar cells, and tandem cells at scale. Hence, this sub-Area is dedicated to the progress of stability in the context of individual devices and device components, as well as the wide range of efforts to determine reliability and yield in real-world settings. Discussed topics thus include intrinsic and extrinsic degradation mechanisms, efficiency loss issues in perovskite and organic photovoltaic

modules, long-term durability testing, field performance, performance ratios, and novel applications, as well as deployment related issues that are not listed.

Area 9: Power Electronics and Grid Integration

Area Chair: *Adriana Luna, University of Puerto Rico-Mayaguez, USA*
Co-Chairs: *Aleksandra Lekić, Delft University of Technology, Netherlands*
                    Nelson Diaz, Universidad Distrital F.J.C, Bogotá, Colombia

Sub-Area 9.1:   **Power Converter Design, Modelling, and Control**
Sub-Area 9.2:   **Ancillary Services and Grid Support Functionalities**
Sub-Area 9.3:   **Microgrids and Distribution System Operation and Control**
Sub-Area 9.4:   **Reliability of Power Electronics and PV Effects on Grid Reliability**

Area Description

As photovoltaic (PV) installations become increasingly widespread, the demand for power electronic converters designed to interconnect solar panels to the grid will continue to rise. Moreover, the rapid integration of massive levels of distributed PV penetration poses new challenges for managing grid operations. At the component level, advanced inverter functionality and energy storage will enhance grid stability by enabling rapid response to control and stabilize the grid during rapidly changing phenomena. Furthermore, the development of advanced topologies and controls will further improve converter performance and reduce system costs. At the system level, optimization and management of distributed PV and other grid resources will continue to support the integration of large amounts of renewable energy and enable more advanced grid services and support functions. The evolving nature of power distribution systems will motivate new methods for microgrid and distribution grid operations, requiring proactive management of variable generation resources. Therefore, the power electronics and power systems community is encouraged to submit contributions that address the full range of scientific and technical aspects related to PV grid integration.

Sub-Area 9.1:   **Power Converter Design, Modelling, and Control**

Sub-Area Chair: TBD

New converter designs for DC-DC and inverter applications in PV power conversion promise significant advances, including higher efficiencies, improved power densities, increased switching frequencies, and extended operating voltage ranges. The focus is on novel circuit designs, magnetics, wide bandgap semiconductor materials, and other innovative approaches to component-level converter design. In addition, advanced power electronics control at the level of individual converters, multi-converter-based microgrids, and large-scale PV power plants plays a critical role in accommodating fast dynamics, nonlinearities, and complex system interactions. This Sub-Area welcomes contributions on various aspects of design, modelling and control of power electronics for PV converters, microgrids, and power systems. Submissions that include circuit analysis, experimental validation, and field-testing will be featured.

Sub-Area 9.2:   **Ancillary Services and Grid Support Functionalities**

Sub-Area Chair: TBD

The widespread integration of distributed PV generation and fast-acting inertia-less power converters introduces unprecedented variability and unpredictability for grid operators at both the distribution and transmission system levels. While PV power converters can have advanced control functionalities, these capabilities currently remain untapped because the primary function of the PV system is to deliver the maximum power to the grid. In order to increase PV integration and

achieve 100% renewable energy penetration in electric power systems, a new control philosophy needs to be adopted for PV converter control. This involves mimicking the behavior of conventional synchronous generators and providing ancillary services to support the grid. These new Ancillary Services include synthetic (virtual) inertia, voltage and frequency regulation, reactive power provision, fault current provision to maintain power system protection, ramp rate limiting, or power smoothing to prevent frequency events, harmonic mitigation, and operation of PV converters as active power filters to improve power quality. In this way, new paradigms need to be established and the cost/benefit of implementing such systems should be identified so that these ancillary services can become tradable quantities in future electricity markets. This Sub-Area invites papers that address the above-mentioned ancillary services that can be provided by PV converters to support the grid and achieve higher PV penetration levels in future electric electricity systems.

Sub-Area 9.3: Microgrids and Distribution System Operation and Control

Sub-Area Chair: TBD

Microgrids offer an effective way to combine and control renewable energy sources, such as solar PV, allowing operation in both islanded and grid-connected modes. However, the extensive integration of distributed PV generation and fast-acting power converters introduces variability and unpredictability into the operation of the distribution systems. Consequently, the implementation of appropriate control techniques is necessary to leverage the benefits of integrating PV generators into these systems fully. This Sub-Area seeks papers that address the challenges of integrating PV into microgrids and distribution systems, including topics such as voltage and frequency regulation, volt-var optimization, power quality, stability, protection, PV sizing and placement, dispatching, and other pertinent issues.

Sub-Area 9.4: Reliability of Power Electronics and PV Effects on Grid Reliability

Sub-Area Chair: TBD

As the penetration level of PV systems into the power grid increases, an accurate assessment of the reliability of power converters and the impact of PV systems on the reliability of power grids for system-level analysis becomes critical. At the equipment level, recent experiences have shown that converters are frequent failure sources in various applications, such as wind and PV systems, as their reliability is highly dependent on operating and climatic conditions. At the system level, with the growing share of PV systems, the availability of the PV system should be included in power system reliability models to obtain accurate results. This Sub-Area focuses on reliability assessment approaches and metrics at two levels: the equipment level, especially dedicated to PV power converters, and the system level, aimed at assessing the reliability of power systems that include a significant amount of PV generation.

Area 10: Solar Resource Assessment for PV and Forecasting

Area Chair: *Joshua S. Stein, Sandia National Laboratories, USA*
Co-Chairs: *Adam R. Jensen, Technical University of Denmark (DTU), Denmark*

Sub-Area 10.1: Solar and Meteorological Measurement and Modeling
Sub-Area 10.2: Solar Resource and PV Power Forecasting

Area Description
Solar resource measurement, modeling, and forecasting are essential for evaluating technical and financial performance in PV applications. In particular, uncertainties related to the solar resource contribute directly to uncertainties in PV yield and economic viability. This research area covers technologies and methods to quantify and model solar irradiance with a particular focus on applications in the PV sector.

Sub-Area 10.1: Solar and Meteorological Measurement and Modeling

Sub-Area Chair: TBD
Accurately measuring and modeling the available solar resource is essential for technical and economic planning of a PV system and for evaluating the performance of existing systems. This Sub-Area covers innovations in radiometer design, radiation models, solar resource assessment methodologies, and variability and uncertainty quantifications. The chief objective is to reduce uncertainties in PV performance modeling and monitoring. Analyses of all relevant factors for PV modeling are included here, for example, spectral and rear-side irradiance, albedo, soiling, temperature, precipitation, and snow, as well as their impacts on PV system performance.

Sub-Area 10.2: Forecasting of Solar Irradiance and PV Power

Sub-Area Chair: TBD
As PV generation increases, the role of irradiance and power forecasting becomes ever more important to the successful integration of renewable energy on the grid. Highly accurate forecasting of the expected power output and its uncertainty is required for grid management and economic assessment. This encompasses forecasting on various time scales, from seconds to days, and spatial scales, from system level to regional. In this Sub-Area, all topics related to improvements in our ability to predict future PV power output and solar resource are invited.

Area 11: PV Deployment, Policy and Sustainability

Area Chair: *Arnulf Jäger-Waldau, European Commission Joint Research Centre, Italy*
Co-Chairs: *Marta Victoria, Aarhus University, Denmark*
                 Hope Wikoff, NREL, USA

Sub-Area 11.1:   **Economics, Policy, and Energy Justice**
Sub Area 11.2:   **Environmental Sustainability**
Sub Area 11.3:   **User Behavior, Education in Institutes of Learning, and Workforce Development**
Sub Area 11.4:   **The Role of Photovoltaics in the Transition to a 100% Renewable Energy Supply**

Area Description
The PV Deployment, Policy and Sustainability area provides an opportunity to discuss aspects required to ensure the long-term success of the PV industry. This includes discussions on three themes focusing on 1) economics and policy, 2) environmental sustainability, and 3) social interventions. Recognizing the importance of student engagement for sustained growth in the industry, we encourage students to submit papers focusing on outreach and education efforts in educational institutes.

Sub-Area 11.1:   **Economics, Policy, and Energy Justice**

Sub-Area Chair: TBD
This sub-area focuses on the economics and policy developments critical to expanding PV deployment and/or energy justice. Topics of interest include policy impacts, market drivers, and financial considerations that are paramount to overcoming barriers in PV deployment and providing equitable and affordable access to solar energy. While we encourage researchers to present international efforts and discuss potential areas for expanded collaboration in this sub-area, unique case studies that would be of interest to conference participants are also welcomed.

Sub Area 11.2:   **Environmental Sustainability**

Sub-Area Chair: TBD
This sub-area seeks submissions with a broad, systems-level perspective on the sustainability of PV throughout the life cycle. Topics of interest include discussions on current and future PV technologies through life-cycle assessment, material supply, manufacturing, and end-of-life management. Results from simulations, surveys, and focus group discussions on these topics are welcomed.

Sub Area 11.3:   **User Behavior, Education in Institutes of Learning, and Workforce Development**

Sub-Area Chair: TBD
This sub-area focuses on increasing solar PV adoption through a two-pronged approach involving 1) user behavior, and 2) developing a skilled workforce for the solar PV industry through early engagement of students and workforce development. Topics of interest include studies on influencing user behavior and encouraging adoption as well as early engagement of students at all levels (e.g., high school, vocational training, technical school and university), innovative solar

education and workforce development. Abstracts with results are highly encouraged for submission.

Sub Area 11.4:   The Role of Photovoltaics in the Transition to a 100% Renewable Energy Supply

Sub-Area Chair: Nancy Heagel (tbc)

In countries accounting for 82% of the global electricity generation, photovoltaics and wind are already the cheapest source of electricity. It took 66 years to install 1 TW of solar photovoltaic systems. However, the second TW will be installed in roughly three years only and an annual TW market will be reality before the end of the decade. This has a significant impact not only for the electricity system, but for our global energy supply as well. In this Sub-Area, we want to address which technologies and concepts are available and most beneficial in addressing the challenges of the energy transition. During the upcoming conference all topics relevant to the role of photovoltaics in this transition should be discussed. We especially encourage contributions from students and aim to cover diverse regions and approaches.