Track 6: Photonics for Energy
Shanghai Hall, 2F

13:30-15:30 • November 05, 2023 • Sunday
Hybrid photovoltaics
Presider: Haizheng Zhong, Beijing Institute of Technology, China

13:30-14:15 • ACPPOEM-0810-4 *Tutorial*
Printable Organic and Perovskite Solar Cells for Clean Energy
ALEX JEN
City University of Hong Kong, Hong Kong, China
Several novel interface/additive engineering approaches will be discussed to demonstrate high PCE (~26%) could be achieved in inverted perovskite solar cells and very efficient lead-capturing from decomposed perovskite devices. Their applications in various clean energy generation fields will also be discussed.

14:15-14:45 • ACPPOEM-0811-1 *Invited*
Minimizing voltage losses in organic solar cells
Feng Gao
Linköping University, Sweden
Recent advances in organic solar cells (OSCs) based on non-fullerene acceptors (NFAs) come along with reduced non-radiative voltage losses. We show that the non-radiative voltage losses in these state-of-the-art donor:NFA OSCs show no correlation with the energies of charge-transfer electronic states at donor:acceptor interfaces, different from conventional fullerene-based OSCs. Based on a combined temperature-dependent electroluminescence experiments and dynamic vibronic simulations, we have been able to rationalize the low voltage losses in these devices, where we highlight the critical role of the thermal population of local exciton states in decreasing the non-radiative losses. An important finding is that the molecular photoluminescence properties of the pristine materials define the limit of non-radiative voltage losses in OSCs, indicating that it is critical to design high-luminescence-efficiency donor and acceptor materials with complementary optical absorption bands extending into the near-infrared region. We further extend our understanding to ternary OSCs and paint a comprehensive picture of how the guest component affects the radiative and non-radiative related parts of the open-circuit voltage in ternary OSCs. We highlight that the thermal population of charge-transfer and local exciton states provided by the guest component based binary system has a significant influence on the non-radiative voltage losses. Ultimately, we provide two design rules for enhancing the open-circuit voltage in ternary OSCs.

14:45-15:15 • ACPPOEM-0801-74 *Invited*
Multi-Component Strategies for Enhancing Organic Photovoltaic Performance
Doo-Hyun Ko
Sungkyunkwan University, Korea
Extensive research on bulk-heterojunction (BHJ) optimization has significantly advanced organic photovoltaics (OPVs). However, addressing the issue of morphological instability and ensuring long-term durability remains a top priority for further investigation. To achieve stability while maximizing performance, researchers have strategically explored multi-component BHJ-based OPVs. In this study, we present the use of multi-component (ternary, quaternary, and beyond) BHJ active layers as a highly effective approach to enhance OPV performance. Experimentally optimized multi-component OPVs demonstrate a broadened spectral response and improved charge transport process, leading to suppressed recombination and overall improved OPV performance. Furthermore, these multi-component OPVs benefit from enhanced morphological stability, achieved by reducing the driving force for grain growth through increased entropy in the multi-component blend system.

15:15-15:30 • ACPPOEM-0814-33 *Industry Innovation Nomination*
Industrial silicon cell compatible efficient perovskite/silicon tandem solar cells
Lin Mao[1], Yang Tian[2], Zhang Hao[1], Liu Mingzhen[1]
1.University of electronic science and technology of China, China; 2.Sichuan Research Center of New Materials Institute of Chemical Materials China Academy of Engineering Physics, China
Perovskite/silicon tandem solar cells have made extraodiary progress in efficiency that exceeds all other two-junction tandem technologies including gallium arsenide. However, most highly efficient monolithic perovskite/silicon tandems are based on thick (≈250–300 μm) float-zone (FZ) silicon bottom cell with front-side flat-polished or sub-micro textured surface in order to be compatible with solution-processed perovskite films. For every change made over SHJ production process in coordination with fabrication of tandem cells, will certainly come along with notable rise in cost. Thus, despite their promises, these high-efficiency perovskite/silicon tandems based on the thick front-side polished or sub-micro textured silicon bottom cell are not favored in the current industrial production line. Here, a molecular-level nanotechnology is developed by designing NiOx/2PACz ([2-(9H-carbazol-9-yl) ethyl]phosphonic acid) as an ultrathin hybrid hole transport layer (HTL) above indium tin oxide (ITO) recombination junction, to serve as a vital pivot for achieving a conformal deposition of high-quality perovskite layer on top. The NiOx interlayer facilitates a uniform selfassembly of 2PACz molecules onto the fully textured surface, thus avoiding direct contact between ITO and perovskite top-cell for a minimal shunt loss. As a result of such interfacial engineering, the fully textured perovskite/silicon tandem cells obtain a certified efficiency of 28.84% on a 1.2-cm2 masked area, which is the highest performance to date based on the fully textured, production-line compatible SHJ. This work advances commercially promising photovoltaics with high performance and low costs by adopting a meticulously designed HTL/perovskite interface.

15:30-16:00 Coffee Break

16:00-18:00 • November 05, 2023 • Sunday
Organic photovoltaics I
Presider: Hae Jung Son, Korea Institute of Science and Technology, South Korea

16:00-16:30 • ACPPOEM-0725-11 *Invited*
Conjugated polyelectrolytes as a multifunctional interlayer for perovskite solar cells
Han Young Woo
Korea University, South Korea
The exceptional magnetic, electrical, and optical properties exhibited by metal halide perovskites (MHPs) have garnered significant interest from the optoelectronic research community in recent decades. These materials have found wide-ranging applications in photovoltaics, light emitting diodes (LEDs), lasers, photodetectors, field effect transistors, and solar concentrators. Perovskite solar cells (PeSCs) have attracted extensive attention because of their inherent advantages such as solution processability, band-gap tunability, high absorption coefficient, and long carrier diffusion length. It has been successfully demonstrated that their power conversion efficiencies exceed 25%, which becomes similar with the highest PCE for crystalline Si solar cells. For PeSCs applications, appropriate charge transport layers (CTLs) are crucial for device performance and stability. The CTLs should have suitable energy levels for effective charge injection/transport while blocking opposite charges. Moreover, the CTL below the perovskite layer is critical because it significantly affects the crystal growth of the perovskite layer and its interfacial defects. In this presentation, a new series of conjugated polyelectrolytes is reported as an ideal interfacial layer and CTLs in PeSCs.

16:30-17:00 • ACPPOEM-0804-3 *Invited*
Printed Flexible Organic Solar Cells with High Specific Power Ratio
Chang-Qi Ma
Printed Electronics Research Center, Suzhou Institute of Nano-Tech and Nano-Bionics, CAS, China
In this presentation, we will report our latest results on preparing high-performance printed flexible organic solar cells, which showed a high PCE of over 17% for 1 cm^2. We will also present a solution-processed ultra-thin encapsulation layer for polymer solar cells. With these, we are able to fabricate flexible polymer solar cells for near space applications, that was concept-proved by a high-attitude balloon testing system.

17:00-17:30 • ACPPOEM-0813-3 *Invited*
Aggregate Control of Organic Semiconductors toward High Performance Photovoltaics
Tao Wang
Wuhan University of Technology, China
The emergence of new organic semiconductors has driven the continuous development of organic solar cells, with the power conversion efficiency of single-junction devices having passed 19%. The strong intermolecular interactions between organic semiconductors lead to the self-assembly of them into hierarchical aggregates, which exhibits vastly different optoelectronic properties compared to those of the single molecules. Revealing and controlling the complex aggregation structure of organic semiconductors, and establishing the key relationship between structure and the power conversion process, is vitally important toward high performance organic solar cells, but remains as a grand challenge. Dedicating to this field, we have developed a number of physical and chemical approaches to tune the hierarchical aggregates of organic photovoltaic molecules: We developed the heating-induced aggregation strategy to suppress the large-size aggregation of crystalline semiconductors, realizing the conversion from large-size aggregation to small aggregation, which broadens the light absorption range and enhances exciton splitting; we developed the solution-induced aggregation strategy, realizing the conversion from random aggregation to ordered aggregation, which increases the light absorption intensity and improves charge transport; we also developed the small-molecular fibrillization strategy, realizing the conversion from short-range aggregation to long-range aggregation, which resolves the serious charge recombination issue during charge hoping and achieves a device efficiency of over 19%. The correlation between aggregates and light absorption, exciton dissociation and charge transport processes is eventually established to direct the future development of organic solar cells.

17:30-17:45 • ACPPOEM-0810-2
In situ Spectroscopy Study of Morphology Formation Process of Organic Photovoltaic Blends
Yanfeng Liu
Jiaxing University, China
The efficiency of bulk heterojunction (BHJ) based organic solar cells is highly dependent on the morphology of the blend film, which is a result of a fine interplay between donor, acceptor, and solvent during the film drying. In this work, a versatile set-up of in situ spectroscopies is used to follow the morphology evolution during blade coating of three iconic BHJ systems, including polymer:fullerene, polymer:nonfullerene small molecule, and polymer:polymers. the drying and photoluminescence quenching dynamics are systematically studied during the film formation of both pristine and BHJ films, which indicates that the component with higher molecular weight dominates the blend film formation and the final morphology. Furthermore, Time-resolved photoluminescence, which is employed for the first time as an in situ method for such drying studies, allows to quantitatively determine the extent of dynamic and static quenching, as well as the relative change of quantum yield during film formation. This work contributes to a fundamental understanding of microstructure formation during the processing of different blend films. The presented setup is considered to be an important tool for the future development of blend inks for solution-cast organic or hybrid electronics.

17:45-18:00 • ACPPOEM-0815-31
Recent progress in solution-processed flexible organic photovoltaics
Lulu Sun
RIkagaku KENkyusho/Institute of Physical and Chemical Research, Japan
The rapid development of narrow-bandgap small-molecule acceptors and wide-bandgap polymer donor materials has propelled laboratory-fabricated organic photovoltaics (OPV) to achieve certified power conversion efficiencies (PCE) exceeding 19%. The crucial next phase involves translating these gains into practical large-scale applications. This necessitates the OPV devices to be solution-processed and flexible, aligning with high-throughput production methods like roll-to-roll printing. We provide a concise yet comprehensive overview of recent advancements in solution-processed flexible OPV. By scrutinizing the behavior of narrow-bandgap acceptors and wide-bandgap polymer donors within solution-processed flexible devices, we delve into challenges and future directions. The focus lies in bridging the gap between laboratory achievements and industrial implementation, addressing issues of materials compatibility, stability, and scalable production. Through this analysis, we offer insights into the potential of solution-processed flexible OPV, paving the way for its integration into mainstream renewable energy technologies.

17:30-20:00 Welcome Reception

08:30-10:00 • November 06, 2023 • Monday
Organic photovoltaics II
Presider: Changqi Ma, Suzhou Institute of Nano-Tech and Nano-Bionics, CAS, China

08:30-09:00 • ACPPOEM-0810-6 *Invited*
3D Network Acceptors for Efficient Solar Conversions
Feng He
Southern University of Science and Technology, China
The morphology and organic photovoltaic materials are mainly decided by the secondary intramolecular/intermolecular interactions from their constructing components, which includes the types of backbones and substitution units. Over past five years, we have focused on the precise regulation of non-covalent intermolecular interactions, such as Cl-S and Cl-π, to achieve series of three-dimensional (3D) structures for elevated solar conversions. We have successfully realized the transformation of the molecular structures from the linear stacking to 3D network arrangement by precise positioning of chlorine atoms, which provided a promising pathway to design highly efficient non-fullerene acceptors with more isotropic electron transmission identity. The single-crystal X-ray diffraction shows that the 3D interpenetrating isomer has a better molecular planarity and a closer π-π interaction distance than the linear one. Recently, the trifluoromethylation has been proved to be an effective strategy to achieve an ultra-narrow bandgap acceptors (named BTIC-CF3-γ) with a 3D structure, a PCE of 15.59% has been achieved which is the highest value in reported ultra-narrow bandgap acceptors. The single crystal structure of BTIC-CF3-γ has also been successfully presented, which helps us to understand the charge transportation in blend films and provide a facile method for efficient solar conversion. The 3D network packing in those acceptors can promote the electron transport in acceptors, which is similar to the isotropic transport in fullerene acceptors for favorable charge transfer. An understanding of 3D networks could provide an insight into the electron transport behaviors for design of high-performance materials for next generation organic solar cells. Single crystals explored in this presentation could help the researchers in the organic optoelectronics to understand the charge carrier transportation processes in active layers. It also offers a guideline for development of new generation materials with improved and balanced device performance.

09:00-09:30 • ACPPOEM-1009-24 *Invited*
Charge generation mechanisms for efficient organic photovoltaics
Yuanping Yi
Institute of Chemistry, Chinese Academy of Sciences, China
For organic solar cells, the photoelectric conversion consists of a series of electronic processes, including light absorption, exciton diffusion, exciton dissociation, charge migration, and charge collection. At the same time, there also exist competitive energy loss processes including exciton decay and charge recombination. To achieve high yield of charge generation, the charge separation and charge migration processes should be maximized, while the charge recombination processes should be minimized. In this talk, we will discuss the effect of electronic polarization on charge separation, the super-exchange mechanism for charge transport, and the role of triplet states in modulating charge recombination, and then propose some effective strategies to improve organic photovoltaic efficiency.

09:30-10:00 • ACPPOEM-1009-28 *Invited*
Tethered Small-Molecule Acceptors for Stable Polymer Solar Cells
Zhiguo Zhang
Beijing University of Chemical Technology, China
In our pursuit to address the trade-off between device efficiency and durability in polymer device, we have introduced a novel ternary device design. This design combines two acceptor components: DY-P2EH, a tethered small molecule acceptor (SMA) with conjugated side-chains as the primary host acceptor, and BTP-ec9, a monomeric SMA serving as the secondary acceptor. Unlike previously reported tethered SMAs with flexible side-chains, DY-P2EH exhibits distinct thermodynamic properties, including a high Tg value of 136 , a surface energy of 31.71 mN/m, and hypo-miscibility with the polymer donor PM6. As expected, the PM6: DY-P2EH binary system demonstrated remarkable device stability under thermal stress. However, challenges such as severe phase separation and over-purification of mixed domains limited the JSC to 24.03 mAcm-2 and PCE to 17.09%. To overcome the limitations posed by the hypo-miscible host blend, we introduced BTP-ec9 as a secondary acceptor component. BTP-ec9 is optimally hyper-miscible with PM6 and possesses a narrow band gap, which allows for efficient harvesting of NIR solar energy, thereby significantly increasing exciton splitting and light harvesting ability. Consequently, the ternary device exhibited a hierarchical morphology, optimizing charge generation, transport, and suppressing recombination. With an impressive FF of 80.61%, the ternary device achieved an excellent PCE of 19.09%, ranking among the highest PCEs for PSCs. Remarkably, the ternary device demonstrated substantially reduced burn-in efficiency loss, retaining over 85% of the initial efficiency even after 1100 hours under 85 thermal stress. Our results demonstrate that a ternary device design with tethered SMAs and a suitable SMA as the dual acceptor component, each being hypo-miscible and hyper-miscible with the polymer donor, respectively, can yield ternary devices with a hierarchical morphology, resulting in simultaneous enhancements in photovoltaic performance and device stability. In recent times, significant progresses have been made in achieving long-term stability with acceptor clusters, including PSMA and GMAs. Just like TSMAs, they also demonstrate hypo-miscibility with polymer donors due to reduced entropic contributions compared to individual SMAs. As a result, the ternary design proposed in this study suggest to be a universal approach for enhancing both photovoltaic performance and stability in such systems.

10:00-10:30 Coffee Break

10:30-12:00 • November 06, 2023 • Monday
Organic photovoltaics III
Presider: Feng He, Southern University of Science and Technology, China

10:30-11:00 • ACPPOEM-1009-27 *Invited*
Modification of Metastable phase in Organic Solar Cells
Jie Min
Wuhan University, China
The performance optimization of organic solar cells is influenced not only by the design of the molecular structures but also by the regulation of the blend morphologies. Currently, there is a well-established understanding of how material design can regulate energy levels, film absorption, carrier mobility, and molecular crystallinity, leading to efficient device performance through the aggregation regulation of active layers. However, there is a lack of effective methods and investigations on the regulation of the metastable state of the active layer, the analysis of degradation mechanisms, and the improvement of operational stability. At present, organic solar cells are not only facing the basic problem of unclear metastable decay mechanism, but also facing the important challenge of synergistic development of "efficiency and stability". The development of physical and chemical methods of metastable regulation is an important breakthrough point for future work. On the basis of levelized cost of electricity analysis, this report will briefly indicate the performance requirements of organic photovoltaic materials and a brief analysis of performance improvement strategies and introduce the metastable morphology characteristics of active layer. By analyzing and revealing the attenuation mechanism of metastable morphology, combined with the intrinsic characteristics of small molecule materials, this report is used to understand the morphologic changes of the active layer under light/thermal stress, and explore the physical attenuation dynamics. Finally, the recent progress made by our research group in regulating the metastable state through physical and chemical methods, as well as the coupling strategies employed. This report aims to provide theoretical support for a deeper understanding of the mechanisms behind metastable morphology attenuation, and to offer valuable references for fellow researchers in the field.

11:00-11:30 • ACPPOEM-1009-25 *Invited*
Development of organic photovoltaics with excellent device efficiency and stability
Ning Li
South China University of Technology, China
As an important representative of the emerging photovoltaic technology, organic photovoltaics (OPV) can achieve excellent device performance and low-cost, continuous production and processing through solution printing technology, and are expected to make outstanding contributions to solar-driven multifunctional applications. In order to realize the industrialization and commercial application of OPV technology, research teams around world have made a lot of efforts. In the past few years, through the synthesis of new materials, optimization of thin film micro-morphology, and development of advanced processing technologies, the power conversion efficiency of OPV devices has been continuously improved. However, the stability of OPV devices is a key issue that still restricts the industrialization of OPV technology. In this contribution, I will discuss our recent progress on the stability of OPV devices, and propose some effective solutions to solving the instability problems, including the development of oligomer acceptors, the use of single-component OPV devices, and the use of multiple component strategy, etc., so as to further promote the new generation of OPV devices to achieve excellent performance and stability.

11:30-12:00 • ACPPOEM-0815-19 *Invited*
Organic photovoltaics based on functional third components
Pei Cheng
Sichuan University, China
Organic photovoltaics is a very potential technique for solar energy conversion. In recent years, we designed a variety of third components to construct high-performance organic photovoltaics through improving charge carrier generation efficiency, lifting carrier extraction efficiency, enhancing device stability, etc. Semitransparent organic photovoltaics is an important embranchment in organic photovoltaics. Lately, we introduced the strategies of constructing layer-by-layer active layer of wide-bandgap inorganic semiconductor/narrow-bandgap acceptor, adjusting the absorption peak of donor layer to redshift and narrow by small molecule additives, building the ternary blend active layer of wide-bandgap third component, mid-bandgap donor and narrow-bandgap acceptor to construct high-performance semitransparent organic photovoltaics, etc. while the mechanism of the differences between the performance of opaque and semitransparent devices are studied in detail.

12:00-13:30 Lunch Break

13:30-15:30 • November 06, 2023 • Monday
Hybrid electronics
Presider: Yuanping Yi, Institute of Chemistry, CAS, China

13:30-14:00 • ACPPOEM-0815-37 *Invited*
Optically Tunable Field-Effect Transistors with Conjugated Polymer Entailing Azo-group in the Side Chains
Zitong Liu
Lanzhou University, China
Semiconducting conjugated polymers with photos witching behavior are highly demanded for field-effect transistors (FETs)

with tunable electronic properties. Herein we present a new design strategy for photoresponsive conjugated polymers by incorporating photochromic azo-groups (azobenzene, arylazopyrazole, and tetra-ortho-methoxy-substituted azobenzene) into the flexible side alkyl chains. It is shown that azo-groups in the side chains of conjugated polymers can undergo trans/cis photoisomerization in fully reversible and fast manner. Therefore, optically tunable FETs with bistable states are successfully fabricated.

14:00-14:30 • ACPPOEM-0731-125 *Invited*
Fullerene-Based Heterojunctions For Transparent Photovoltaics
Ruiqian Meng, Qianqing Jiang, **Dianyi Liu**
Westlake University, China
Generally, absorption-selective semiconductor materials are the best choice for highly transparent photovoltaics. However, non-absorption-selective semiconductor materials may still be options for transparent devices. Here, we report a set of non-absorption-selective fullerene-based heterojunctions for transparent photovoltaics. The TPV devices with fullerene-based light-harvesting layers exhibit an AVT exceeding 80%.

14:30-15:00 • ACPPOEM-1009-26 *Invited*
Defects modulation and optoelectronic devices of perovskite single crystals
Qingfeng Dong
Jilin University, China
The single crystal perovskite materials exhibit excellent charge carrier transport properties and efficient photovoltaic conversion abilities. This report will introduce research on the stability of single crystal perovskite materials and devices, discussing ion defects and electron defects within perovskite materials, as well as their impact on the performance of radiation detector and photovoltaic devices.

15:00-15:15 • ACPPOEM-0731-157
Constructive pyridine molecular configurations for defect passivation of Printable Perovskite Solar Cells
Yue Ming[1], Weiqiang Wu[1], Jiale Liu[2], Jian Yang[2]
1.Shenzhen Polytechnic University, China; 2.HuaZhong University of Science and Technology, China
Continued endeavors are focused on advancing emerging printable mesoscopic perovskite solar cells (p-MPSCs), and many of these efforts are focused on composition engineering, intermediate phase engineering, and passivation engineering. In particular,the application of passivators to reduce defects in perovskite materials has been demonstrated as an effective approach to enhance the photovoltaicperformance and long-term stability of MPSCs. However, a lack of in-depth understanding of how the molecular configuration influences the passivation effectiveness is a challenge to rational molecule design. In this study, the chemical environment of a functional group activated for defect passivation was systematically investigated using Pyridine methanol molecules(ortho, para, and meta positions).Our research demonstrates that the different relative positions of the methanol group and the N atom on the pyridine ring result in distinct electron cloud distributions. The power conversion efficiency (PCE) of the prepared MPSCsdevices increased from 16.37% to 17.70% with the 4-pyridine methanol (4PM) molecule treatment.

15:15-15:30 • ACPPOEM-0813-11
Highly conductive PEDOT and its application on energy devices
Zaifang Li
Jiaxing University, China
Conducting polymer poly(3,4-ethylenedioxythiophene (PEDOT)-based materials have been extensively studied due to its excellent air, thermal stability, and high transparency in the visible spectral region and tunable conductivity from 10^{-4} to 10^{3} S/cm. This report will focus on the preparation, characterization and applicationof highly conductive PEDOT:PSS electrode- and itsapplications in organic solar cells, supercapacitors, thermoelectrics and photocapacitor devices.

15:30-18:00 Coffee Break & Poster Session

18:30-21:00 Banquet and Awards Ceremony