Presentation Type	Author Name	Title	Text
Invited Presentation	Adachi, Chihaya	Degradation mechanism for TADF based OLEDs and Perovskite Solar Cells	We report a way to greatly improve the stability of OLEDs having a green emitter exhibiting thermally activated delayed fluorescence (TADF) by introducing ultrathin (1-3 nm) interlayers between hole-blocking layer and its surrounding emissive and electron-transport layers. In our best device, LT95 was extended to 1300 hours. Thermally stimulated current measurements showed that the number of deep charge traps was reduced with the insertion of the ultrathin interlayer, indicating that reducing the number of deep traps is important for improving the operational lifetime and that exciton-polaron annihilation may be a source of the device degradation. Second, we introduce our activities regarding organic-inorganic hybrid halide perovskites showing excellent photovoltaic properties. Perovskite solar cells (PSCs) with power conversion efficiencies over 20% have recently been realized. However, the stability of PSCs is just beginning to be studied, and the actual degradation mechanisms of PSCs are not well understand. Thus, we investigated the degradation mechanisms of CH3NH3PbI3-based PSCs using a thermally stimulated current (TSC) technique. We show that a large density of hole traps is formed in PSCs degraded by continuous solar illumination and that the formation of hole traps is strongly related to the stability. We demonstrate enhanced stability of PSCs based on this analysis.
Invited Presentation	Amassian, Aram	Unraveling Interfacial Energetics in Organic Photovoltaics	The energy landscape in organic semiconducting materials greatly influences charge and exciton behavior, which are both critical to the operation of optoelectronic devices, such as solar cells. These energy landscapes can change dramatically depending on the phases of material present, including pure phases of one molecule or polymer and mixed phases exhibiting different degrees of order and composition. The coexistence of different phases and donor-acceptor (D-A) interfacial configurations in a bulk heterojunction (BHJ) layer is very likely and should impact the overall operation of the organic solar cell. Yet, it is experimentally very difficult to deconvolute the these different interfacial configurations and their associated energetics within a BHJ layer. In an effort to unravel the complex energy landscape present in the BHJ, we present two complementary approaches. The first part of this talk will discuss our recent work using model planar heterojunction (bilayer) devices to shed light on the roles of molecular orientation, stacking, mixing and crystalline order at the D-A interface on the interfacial energetic landscape, charge transfer state and on solar cell operation. For this, we make use of vacuum-deposition of small molecule donors and acceptors, as well as lamination of solution-processed conjugated polymers. The second part of this talk will discuss how scanning probe spectromicroscopy now allows us to directly map the energy landscape at the D-A interface in device-relevant blends, bringing us an important step closer to directly mapping the entire energetic landscape within a BHJ solar cell.
Invited Presentation	Blom, Paul	Elimination of trapping in organic semiconductors by dilution	Conjugated polymers are attractive candidates for electronic applications since they can be processed from solution. This enables the production of polymer light-emitting diodes (PLEDS) or solar cells using a fast roll-to-roll newspaper-printing-style process. However, their solution processibility enables another option that until now has been less exploited. A fundamental disadvantage of semiconducting polymers is that their charge transport is unbalanced because electron transport is hindered by traps. This electron trapping seems to be universal in organic semiconductors and is dominated by a trap located at ~3.6 eV below vacuum. This universal defect also quenches the excitons in conjugated polymers. However, electronic properties of a conjugated polymer can be changed, or even new ones created, by blending the polymer with other functional materials. We have found that by blending poly(p-phenylene vinylene) (PPV) derivatives with wide band gap polymers the electron traps are deactivated. PLEDs made from such a blend exhibit a balanced transport and enhanced efficiency due to the strong reduction of non-radiative trap-assisted recombination.

Invited Presentation	Bruetting, Wolfgang	Control of molecular orientation in organic light-emitting diodes	In contrast to their inorganic counterparts, the majority of molecular materials exhibit additional orientational degrees of freedom due their anisotropic shape. The microscopic orientation of molecules in thin film devices has a strong impact on macroscopic properties such as charge carrier transport and optical properties as well as on the efficiency of optoelectronic devices. This talk will present different approaches to control the orientation of emitter molecules in organic light-emitting diodes. We find that molecular orientation in vacuum-deposited thin films occurs at the surface of the growing film, however, with significant differences of the driving forces between fluorescent and phosphorescent guest-host systems. For the former type the glass transition temperature of the matrix in relation to the substrate temperature is the key parameter [1]. In the latter case, this parameter is of minor importance; it is rather the intrinsic molecular asymmetry of metal-organic Iridium complexes that lead to non-isotropic phosphor orientation at the boundary between an organic layer and vacuum [2]. We investigate the influence of different processing conditions and discuss consequences for device efficiency of OLEDs. [1] Control of Molecular Dye Orientation in Organic Luminescent Films by the Glass Transition Temperature of the Host Material, C. Mayr, W. Brütting, Chem. Mater. 27 (2015) 2759-2762; DOI: 10.1021/acs.chemmater.5b00062 [2] Understanding and Predicting the Orientation of Heteroleptic Phosphors in Organic Light-Emitting Materials, M. J. Jurow, C. Mayr, T. D. Schmidt, T. Lampe, P. I. Djurovich, W. Brütting, M. E. Thompson, Nature Materials 15 (2016) 85-91; DOI: 10.1038/NMAT4428
Invited Presentation	Burn, Paul	Probing interfaces in OLEDs with neutrons	The active film in all organic optoelectronic devices involves interfaces with a range of different length scales and types: molecular, bulk, organic-organic, and organic inorganic. Thus controlling the structure of the active film and the interfaces within organic optoelectronic devices plays an important role in optimising their performance. Neutron techniques such as neutron reflectometry and small angle neutron scattering are important methods for studying the physical structures of (macro)molecules and their interactions non-destructively in solution and/or the solid state. In this presentation I will introduce neutron reflectivity and illustrate how the measurement can be utilized to elucidate the structure of multilayer thin films typically used in organic light-emitting diodes. I will also show how time-resolved measurements can be used to follow the evolution of the film structure during thermal stress. Finally, where appropriate the structure of the films will be correlated with the photophysical properties of the films.

Invited Presentation	Gather, Malte C.	Switching life with light: Towards bio-integrated OLEDs for optogenetics	Most current research on OLEDs is aimed at applications in information displays and solid-state illumination. However, OLEDs are also highly attractive for biotechnology and biomedicine, due to their low toxicity, fast switching, high brightness, and ability to provide patterned illumination with very high spatial resolution. We recently demonstrated the use OLEDs to control the behaviour of living cells that are either naturally light sensitive or were rendered light-sensitive through optogenetic manipulation.□ In initial proof-of-concept experiments, we used OLED microdisplays to control the light-activated locomotion (phototaxis) of the green alga Chlamydomonas reinhardtii [1]. The microdisplays consisted of a silicon chip containing electronics that addresses > 100,000 individual top-emitting OLED pixels with µm dimensions deposited directly on the chip.□ More recently, we investigated OLED mediated optogenetic control on both the single cell level [2] and using optogenetic Drosophila larvae [3]. In comparison to naturally occurring light-sensitive systems, optogenetics is often relatively light inefficient requiring optical intensities on the order of mW/mm2 for robust activation. Maybe somewhat against common expectation, OLEDs can reliably achieve such intensities at acceptable voltages when using state-of-the-art fluorescent pin stacks.□ □ [1] A Steude et al, “Controlling the movement of single live cells with high density arrays of microscopic OLEDs” Advanced Materials 27, 7657-7661 (2015)□ [2] A Steude et al, “Arrays of Microscopic Organic LEDs for High Resolution Optogenetics ChR2 activation with OLED microarrays” Science Advances 2, e1600061 (2016)□ [3] A Morton et al, “High-brightness organic light-emitting diodes for optogenetic control of Drosophila locomotor behaviour” Scientific Reports (in press)
Invited Presentation	Huang, Jinsong	Enhancing the Efficiency and Moisture Stability of Perovskite Solar Cells	The instability of hybrid perovskite materials due to water and moisture arises as one major challenge to be addressed before any practical application of the demonstrated very high efficiency perovskite solar cells. Here we will first present our recent progress in understanding the degradation of perovskite film by moisture at grain scale. Then we will report several facile strategies that can simultaneously enhance the stability and efficiency of p-i-n planar heterojunction-structure perovskite devices. In one case, we should that insulating polymers can allow the tunneling of electrons between perovskite and electron transport layer, demonstrating the first tunneling contact in perovskite solar cells. Applying hydrophobic insulating polymers thus can enhance the water resistance of peroskite solar cells without scarifying the efficiency. In another case, crosslinkable silane molecules with hydrophobic functional groups are bonded onto fullerene to make the fullerene layer highly water-resistant. Methylammonium iodide is introduced in the fullerene layer for n-doping via anion-induced electron transfer, resulting in dramatically increased conductivity over 100 times higher. With crosslinkable silane-functionalized and doped fullerene electron transport layer, the perovskite devices deliver a maximum efficiency of 19.5% with a high fill factor of 80.6%. A crosslinked silane-modified fullerene layer also enhances the water and moisture stability of the non-sealed perovskite devices by retaining nearly 90% of their original efficiencies after 30 days exposure in an ambient environment.
Invited Presentation	Kim, Jang-Joo	High efficiency OLEDs	High efficiency OLEDs based on phosphorescent, thermally activated delayed fluorescent (TADF) and fluorescent emitters will be presented. We will show that EQEs over 50% is achievable without any extra light extracting structure if OLEDs are fabricated using organic semiconductors with the refractive index of 1.5 and emitters with fully horizontal emitting dipoles. We will also show that reverse intersystem crossing (RISC) rate plays an important role to reduce the efficiency roll-off in efficient TADF and fluorescent OLEDs and a couple to methods will be presented to increase the RISC rate in the devices. Finally we will discuss on the ultimate efficiency with OLEDs achievable with light extraction structures including the driving voltage of OLEDs.

Invited Presentation	Kippelen, Bernard	New Strategies for Controlling Interfaces in Organic Electronic Devices	New materials, unconventional device architectures and new processing techniques illustrate the versatility of organic and hybrid electronics, and the potential of this field to lead to disruptive innovations with flexible form factors. However, in order to reach their full potential these flexible devices must combine high performance, low cost, environmental and mechanical stability. These challenges can be addressed by paying a close attention to the science and engineering of the physical and chemical properties of interfaces. □ In this talk, we will present recent advances in strategies to tune and control the electronic properties (e.g. work function) of interfaces in various device platforms for flexible hybrid electronics, including organic light-emitting diodes, organic solar cells, photodetectors, sensors, and organic field-effect transistors. We will discuss how recent progress in controlling interfaces in devices can impact overall performance and stability, and is likely to further accelerate the deployment of organic and hybrid flexible technologies. Strategies to reduce the overall environmental impact of the new products enabled by this emerging technology during their life cycle will also be presented.
Invited Presentation	Lee, Chun-Sing	Applications of exciplex emission in thermally activated delayed fluorescent OLEDs	While exciplex emission had been considered to be harmful to performance of OLEDs in the 80-90s. More recent works show that using exciplex emitters as hosts for other emitting dopants in OLEDs can in fact leads to various performance enhancements. In this talk, the formation and advantages of exciplex emission will be introduced. Their applications in high performance OLEDs, in particularly those with thermally activated delayed fluorescence (TADF), will be discussed.[1-4]□ □ References□ X.K. Liu, Z. Chen, C.J. Zheng, M. Chen, W. Liu, X.H. Zhang, and C.S. Lee, “Nearly 100% Triplet Harvesting in Conventional Fluorescent Dopant-Based Organic Light-Emitting Devices Through Energy Transfer from Exciplex”. Adv. Mater., 27: 2025–2030 (2015). doi:10.1002/adma.201500013 □ X.K. Liu, Z. Chen, C.J. Zheng, C.L. Liu, C.S. Lee, F. Li, X.M. Ou and X.H. Zhang, “Prediction and Design of Efficient Exciplex Emitters for High-Efficiency, Thermally Activated Delayed-Fluorescence Organic Light-Emitting Diodes”, Adv. Mater., 27: 2378–2383 (2015). doi:10.1002/adma.201405062 □ X.K. Liu, Z. Chen, J. Qing, W.J. Zhang, B. Wu, H.L. Tam, F.R. Zhu, X.H. Zhang, and C.S. Lee, "Re-Management of Singlet and Triplet Excitons in Single-Emissive-Layer Hybrid White Organic Light-Emitting Devices Using Thermally Activated Delayed Fluorescent Blue Exciplex", Adv. Mater., 27, 7079-7085 (2015). □ W. Liu, J.X. Chen, C.J. Zheng, K. Wang, D.Y. Chen, F. Li, Y.P. Dong, C.S. Lee, X.M. Ou and X.H. Zhang, “Novel Strategy to Develop Exciplex Emitters for High-Performance OLEDs by Employing Thermally Activated Delayed Fluorescence Materials” Adv. Funct. Mater., 26, 2002-2008 (2016).
Invited Presentation	Lee, Jun Yeob	Molecular design approaches of blue thermally activated delayed fluorescent emitters	Thermally activated delayed fluorescent emitters have been developed as highly efficient emitters for organic light-emitting diodes and great progress of device performances has been reported for the last several years. Although the device performances of the thermally activated delayed fluroescent emitters are inferior to those of phosphorescent organic light-emitting diodes, recent studies developing new emitters provides promising results. In particular, the device performances of the blue thermally activated delayed fluorescent emitters are promising because several critical issues such as low efficiency, short lifetime and broad light emission are being improved step by step. In this work, we present our results about new blue thermally activated delayed fluorescent emitters overcoming the challenges of the current blue thermally activated delayed fluorescent emitters.

Invited Presentation	Lee, Tae-Woo	Highly Efficient Organometal Halide Perovskite Light-Emitting Diodes	Although organic/inorganic hybrid perovskites are emerging low-cost emitters with very high color purity, the low luminescent efficiency at room temperature is a critical drawback. In this work, we report a systematic approach for achieving highly bright and efficient green PeLEDs even in a simplified bilayer structure. The high efficiency PeLEDs were constructed based on effective management of exciton quenching by a modified MAPbBr3 emission layer that was achieved using (i) fine and controllable stoichiometry modification and (ii) optimized nanograin engineering by nanocrystal pinning. Slightly increasing the molar proportion of methylammonium bromide (MABr) in MAPbBr3 solution led to removal of exciton quenchers and reduced hole-injection barrier from self-organized conducting polymer (SOCP) anodes to MAPbBr3 layers with decreased ionization energy. Also, we suggest that the efficiency in PeLEDs can be increased by decreasing MAPbBr3 grain sizes and consequently improving uniformity and coverage of MAPbBr3 nanograin layers. Use of an optimized nanocrystal pinning process contributed to the change in the morphology of MAPbBr3 layers from scattered micrometer-sized cuboids to well-packed nanograins with uniform coverage, which greatly reduced leakage current and increased efficiency. Furthermore, A MAPbBr3 film with decreased grain size exhibited a very small exciton diffusion length. Finally, we demonstrated a highly flexible PeLED based on SOCP anodes and a first large-area PeLED. These results provide a strategy for developing a new low-cost and high-efficiency organic/inorganic hybrid LED as a promising alternative for conventional organic and inorganic LEDs.
Invited Presentation	Loo, Lynn	Single-junction, transparent organic solar cells with photovoltage >1.5 V	Recent work on tuning the chemical structures of contorted hexabenzocoronene (cHBC) in our group has yielded derivatives with a spectrum of energy levels and absorption profiles, greatly improving the utility of these materials as donor and/or acceptor constituents in organic solar cells. Here, we report planar-heterojunction solar cells comprising an extended heterocyclic cHBC donor and a halogenated cHBC acceptor. By harvesting primarily near-UV light, these devices exhibit a record open-circuit voltage of 1.6 V, corresponding to a voltage of 1.3 V at the maximum power point, that is higher than any previously reported value for a single-junction organic solar cell. These devices have a power-conversion efficiency of 1.9%, while transmitting 79% of all visible photons. Our active layers are molecularly smooth and pinhole-free; we have thus been able to make single-junction devices with a footprint as large as 10 cm2 without incurring substantial loss to performance. Development of this high voltage, semi-transparent, single-junction solar cell can enable vertical integration with electrochromic windows, where existing prototypes depend on tandem solar cells having near-infrared absorbers.
Invited Presentation	McCulloch, Iain	Development of Non-Fullerene Electron Acceptors for Organic Solar Cells	The power conversion efficiency (PCE) of single junction organic solar cells has increased significantly during the last decade and now approaching the threshold considered necessary for commercialisation. During this period, the structural diversity of semiconducting donor polymers for solar cells has increased dramatically, enabling accelerated development of bulk heterojunction (BHJ) organic solar cells based on polymer donor materials and molecular fullerene derivatives. However both the fullerenes, and the low bandgap polymers typically suffer from low absorption coefficients due to weak oscillator strength. Our approach is to use P3HT as a p-type hole acceptor, and design highly absorbing, low-bandgap n-type small molecules to replace fullerenes. These fullerene acceptors not only have weak absorption, but also poor tunability of absorption over the longer wavelengths of the solar spectrum; morphological instability in thin film blends over time; high synthetic costs and limited scope for synthetic control over electronic and structural properties. For these reasons, we have developed new, synthetically simple electron acceptor materials, based on rhodanine end groups, which have much larger absorption coefficients than fullerenes, coupled with high lying LUMO energy levels, to maximize cell voltages. In BHJ devices with P3HT donor polymer, the rhodanine molecules were demonstrated to outperform fullerenes. The highest performing devices have power conversion efficiencies approaching 8%, based on a ternary blend of two rhodanine acceptors. We also demonstrate performances of over 11% with one non-fullerene acceptors in combination with lower bandgap polymers, deposited from non-chlorinated solvents.

Invited Presentation	Meerholz, Klaus	Organic Memory Elements	Photochromic molecules provide an intriguing and relatively untapped alternative to traditional materials utilized in organic electronic devices. We have recently integrated a layer of crosslinkable dithienylethene photochromes (XDTE) into a solution-processed, multilayer OLED. The XDTE molecules undergo a change in both their UV-visible absorption and energy level position due to a photo- and/or electrically-induced ring-opening/-closing reaction. Exploiting the difference in HOMO and LUMO energies of both isomers and the subsequent change in hole-injection barrier we use this XDTE layer as an electrical controle layer within our OLED layer stack. Optimized devices have displayed ON/OFF ratios in both current and electroluminescence of greater than 10exp5. We investigate both optical and electrical programming of the OMEM devices and show that precise control of the ratio of both isomers in the active layer enables access to a multitude of intermediate states, demonstrating the potential of these devices for future multi-bit memory applications. We also discuss the difference in the molecular-scale mechanisms that are responsible for the optically- and electrically-induced switching effect in these devices by in-situ monitoring of the fraction of closed molecules as a function of the external stimulus. Finaly, we will discuss the impact of magnetic fields on the device performance.
Invited Presentation	Mei, Jianguo	Melt-Processing Complementary Semiconducting Polymer Blends for Organic Transistors	With charge carrier mobilities of organic semiconductors repeatedly surpassing 1 cm2 V−1 s−1, the main technological hurdle that limits the application of organic circuitry is no longer the commonly perceived low mobility, but is a simple and robust process that can provide excellent device yields with low cost. Solution processing is such a promising technology for organic electronics, but it is also associated with many intrinsic drawbacks. Melt processing—a proven technology in the plastic thin film industry—has received little attention. Because most high performance semiconducting polymers, if not all, will either breakdown before melting or have melting temperatures that are too high for practical use. In this article, we introduce melt-processable complementary semiconducting polymer blends (c-SPB) and develop a solvent-free process for fabricating organic field-effect transistors (OFETs). The melt-processed devices exhibited an average mobility of 0.4 cm2 V−1 s−1 and current on/off ratios higher than 105. In-situ temperature-dependent grazing incidence X-ray diffraction (GIXRD) and charge transport measurements provide the evidence that the c-SPB has a reversible morphology and device performance. Based on the reversible feature of melt processing, thermally healable OFETs were further demonstrated. This study opens up a new venue to melt-processable semiconducting polymers and bodes well for melt-processed organic electronics.
Invited Presentation	Nguyen, Thuc-Quyen	Understanding Fill Factor in High Voc Bulk Heterojunction Solar Cells	The power conversion efficiency (PCE) of solar cells, their open circuit voltage (Voc) and fill factor (FF) are directly related. In the majority of organic photovoltaics (OPV) the Voc is significantly lower than the energy of photon absorption, as determined by the donor material bandgap (Eg) in the case of most conjugated polymer:fullerene bulk heterojunctions (BHJ). Minimizing energy losses, from Eg to Voc, could significantly increase the PCE in organic solar cells. In this talk, I will discuss a BHJ system having very low Voc loss due to having small energetic offsets and still maintaining a PCE > 6%. Using a combination of characterization methods, we find that in a blend, the polymer has low energetic disorder. Structural characterization of the blend films show crystalline features not observed in polymer:fullerene blends, illustrating a high degree of structural order. These observations provide insight into a BHJ system that is able to efficiently generate charge carriers despite marginal energetic offsets. However, this blend system suffers from having a low FF caused by very fast charge recombination via triplet states.

Invited Presentation	Rand, Barry P.	Thin film electroluminescent devices: Improving outcoupling and employing new emitters	In this talk, I will discuss our work on thin film electroluminescent devices, including the use of novel emitters as well as improving thin film LED outcoupling. Hybrid organic-inorganic perovskite materials such as methylammonium lead iodide (CH3NH3PbI3 or MAPbI3) or methylammonium lead bromide (CH3NH3PbBr3 or MAPbBr3) have garnered significant interest in the thin film optoelectronics community due to their outstanding optical and electrical properties. However, solution processed perovskites commonly suffer from poor thin film quality, reproducibility, stability, and scalability. Our work has determined that the fabrication of MAPbI3 thin films displays all of the hallmarks of sol-gel processing. We directly correlate experimental observations with basic sol-gel theory to elucidate the critical steps and specifically target these steps to improve the quality of spin coated thin films, realizing films with roughness on the order of a few nm that allow us to demonstrate record LEDs. To improve thin film LED outcoupling, we are pursuing two main paths: (1) scattering layers with air voids embedded in transparent plastic films to reduce substrate-trapped mode loss, and (2) Ag nanowire-based transparent conductive electrodes embedded in a high refractive index planarization layer. Air voids in the plastic substrate take advantage of the refractive index contrast between air and the plastic host medium to effectively scatter the substrate-trapped light, while absorption in these voids is zero. We have used these strategies to allow for a 65% enhancement in light extraction.
Invited Presentation	Reineke, Sebastian	Active beamshaping with organic light-emitting diodes	Organic light-emitting diodes (OLEDs) are known as lightweight, ultrathin large-area light sources that find their application in displays – small or large –, general lighting, and more recently in the automotive sector for various purposes. The emitted light from such an area light source can be approximated by an Lambertian emission profile. Mostly known from inorganic LEDs, the emitted light is remotely shaped into a more usable beam using external optical elements like lenses and reflector geometries. In this talk, I report on our development of an OLED-based platform that allows for electrically controlled variation of the emitted light beam without the use of mechanically movable, external optics. It is possible to continuously tune the maximum intensity of emission from 0° to approximately 40° with respect to the device normal. Without further optical design, the sideward emission has radial symmetry, however this can be altered by applying further external, symmetry-breaking optics. This emission angle control is inherently robust as it does not involve moving parts and allows to make use of OLEDs in more advanced, interactive lighting schemes.
Invited Presentation	Reynolds, John R.	Conjugated Polymers in Redox Active Devices: Electrochromism and Charge Storage	We report on how the reversible redox switching of electron-rich polymers is used to demonstrate color changing electrochromism and electrical charge storage, potentially useful in supercapacitor applications. ProDOTx/EDOTy copolymers have been incorporated as active layers in solution processed thin film supercapacitors to demonstrate similar capacitance, stability, and voltage as those that use electrodeposited PEDOT as the active material with the added advantage of the possibility for large scale, and high-throughput processing. These Type I supercapacitors provide exceptional cell voltages (up to 1.6 V), highly symmetrical charge/discharge behavior, and promising long-term stability exceeding 50,000 charge/discharge cycles. The optical absorbance spectra of these polymers can be tuned to yield electrochromic materials of all colors that can be switched to highly transmissive forms as desired for absorptive/reflective (display type) and absorptive/transmissive (window type) devices. We will demonstrate how structural design and synthesis of fully conjugated polymers, along with mixing in polymer blends, has been used to complete the color palette of electrochromic polymers (ECPs) needed for subtractive color mixing. Using these polymers, we have developed a set of fast switching, high contrast black and brown ECP blends to demonstrate the attractiveness of ECPs as active materials in color changing eyewear. We combine our ECPs with organic photovoltaic (OPV) technologies for solar powered electrochromic windows and demonstrate a self-powered, solution processed and vertically integrated device, where the EC and PV components share common transparent conducting polymer electrodes.

Invited Presentation	Stingelin, Natalie	Using materials science tools for interface engineering of organic optoelectronic devices	In the past decade, significant progress has been made in the fabrication of organic optoelectronic devices, such as organic light-emitting diodes (OLEDs), organic field-effect transistors (OFETs) or organic photovoltaics (OPVs), predominantly due to important improvements of existing materials and the creation of a wealth of novel compounds. Many challenges, however, still exist. In the field of OPVs, real understanding of what structural and electronic features determine, for instance, the short-circuit current (Jsc), open-circuit voltage (Voc) and fill factor are still lacking; and the role of charge transfer states and which charge transfer states are critical for efficient charge generation are still debated. Here we attempt to obtain further insight of relevant structure/processing/performance interrelations using classical polymer processing 'tools'. We present a survey on the principles of structure development from the liquid phase of this material family with focus on how to manipulate their phase transformations, solid-state order and important interfaces (molecular and between different phase regions) with the goal to tailor and tune the final 'morphology' towards technological and practical applications, and establish correlations with relevant device characteristics. We will discuss interrelations of the presence of intermixed phases with charge transfer absorption, how we can manipulate the charge transfer energy and what structural features seem to influence Voc. Similar aspects in the OFET field will also be addressed.
Invited Presentation	Thompson, Mark E.	New Materials for Blue Phosphorescent OLEDs	A key limiter for OLED technology is the short operational lifetime for blue phosphorescent OLEDs (PHOLEDs), which can be attributed to the competition between emission and molecular dissociation with high energy excitons. Molecular dissociation in host materials such as those containing aryl-carbazoles are thought to be a key source of degradation in blue PHOLEDs. Host materials are needed which eliminate weak intramolecular bonds while maintaining high triplet energy, good HOMO/LUMO energy level alignment, and efficient carrier transport. Triphenylenes are good candidates as new host materials, meeting all of these parameters. To accelerate our materials discovery process, we have used high throughput computational modeling to screen a diverse set of materials from which two classes of tetracyclic compounds were identified for further study containing either two 6-membered rings and one 5-membered ring (H2P) or three 6-membered ring (H3). Through various degrees of aza-substitution H2P and H3 derivatives afford a wide degree of HOMO/LUMO tunability while maintaining high triplet energies. The computational study considered a library of 555 compounds, with a goal to identify a small subset of the most promising materials to prepare and study. Three compounds were identified in the H2P material set were synthesized, characterized and examined as blue PHOLED host materials. Gas phase molecular orbital calculations allowed us to identify the materials with the highest triplet energies, but we found that modeling amorphous solids was needed to understand the OLED behavior of these materials. The H3 and H2P compounds were also examined as ligands in blue phosphorescent emitters.
Invited Presentation	Vandewal, Koen	Charge-transfer states for organic solar cells and photo-detectors	Organic solar cells based on interfaces between electron donor and electron acceptor molecules have incident-photon-to-extracted-charge conversion yields of over 85%, and absorbed photon-to-extracted-charge conversion yields of 90-100%. Their power conversion efficiency is currently limited by their low operating voltage, as compared to the optical gap of the main absorber material, indicating large energy losses per absorbed photon. We explore possibilities for increasing the operating voltage and discuss the influence of the donor-acceptor interfacial area, electronic coupling and molecular reorganization. Charge transfer (CT) states at the donor-acceptor interface play hereby an important role. These states have interesting fundamental properties which will be exploited to enable narrow band, near-IR photo-detection. This new type of photodetector competes in the near-infrared (NIR) wavelength range with standard organic photodetectors but extends their detection range to longer wavelengths.

Invited Presentation	Wong, Ken-Tsung	Small Molecule-Based Organic Solar Cells	Organic photovoltaics (OPVs) have attracted considerable research interest due to their low cost and low energy consumption in fabrication and mechanical flexibility. While intensive interdisciplinary efforts have been dedicated to improving the power conversion efficiencies (PCEs) of solution-processed polymer bulk heterojunction (BHJ) solar cells, organic solar cells employing small molecules as electron donors have also received considerable attentions. To date, small molecule-based organic solar cells (SMOSCs) using p-type small molecules and n-type fullerenes have achieved remarkable PCEs by using either solution-processed or vacuum-deposited fabrication techniques. The search for new donor materials with promising physical properties such as low band gaps, suitable energy levels, high crystallinity, and decent solubility, etc., has taken the center stage. Along this line, a large number of donor molecules with interesting molecular architectures have been extensively investigated to perform varying degrees of success. We recently reported new organic molecules adopting a donor-acceptor-acceptor (D-A-A) configuration, in which an electron-donating moiety is connected to an electron-withdrawing dicyanovinylene moiety through another electron-accepting arene, exhibited narrow optical band gaps and lower HOMO levels, showing potential to concurrently enhance the short circuit current density (Jsc) and open circuit voltage (Voc) as employed in organic photovoltaics. In this symposium, vacuum-processed planar-mixed heterojunction (PMHJ) devices incorporating D-A-A type donors and fullerene (C70) acceptor achieved power conversion efficiencies exceeding 9% will be reported.
Plenary Presentation	Bredas, Jean-Luc	Organic Solar Cells: Understanding the Impact of Molecular Packing on Charge Separation and Charge Recombination Processes	In this presentation, we seek to provide a rationalization of the impact that inter-molecular arrangements and interactions at electron-donor (conjugated polymer or oligomer) – electron-acceptor (fullerene) interfaces have on the performance of bulk-heterojunction solar cells. We discuss the results of combined electronic-structure calculations and molecular-dynamics simulations and examine:□ □ The strength of the polymer/oligomer – fullerene molecular interactions and binding energies.□ The impact that the interfacial packing arrangements have on the energetic distribution of the charge-transfer (CT) interfacial electronic states and their localization/delocalization characteristics.□ The nature of the interfacial nonradiative charge-recombination processes from CT states to the ground state, which represents a major energy loss mechanism.□ □ This work is supported by King Abdullah University of Science and Technology, in the framework of its Solar Center and its Collaborative Research Grant Program (Award CRG3-62140391), and by ONR-Global (Award N62909-15-1-2003).
Plenary Presentation	Forrest, Stephen R.	Organic Light Emitting Devices: Challenges Ahead for the Coming Revolution in Displays and Lighting	Organic light emitting devices, or OLEDs, are rapidly approaching a dominant position in displays, with prospects of ultimately replacing liquid crystal displays for both mobile applications as well as in monitors and in televisions. Even more exciting is their imminent entry into the world of lighting due to their simplicity, flexible and lightweight form factor and ultrahigh efficiency. Yet before this revolutionary technology can clearly dominate these applications, there are still several challenges that must be overcome. These challenges include improving OLED lifetime, particularly that of deep blue phosphorescence, improving light outcoupling using cost effective and simple methods, and finding very low cost and rapid methods to pattern very high resolution and low cost pixelated displays. While considerable progress has been made, there is much that remains to be discovered, engineered and implemented. This talk will focus on these “grand challenges”, and will provide a perspective about the future of display and lighting technology based on advances yet to come.

Plenary Presentation	Kang, In Byeong	Technology and the Future Development Direction of LG Display OLED TV	As the launch of UHD OLED TVs began in full-scale this year, favorable reviews on the picture quality and design of the OLED TV continued to appear on the market and media. Such positive responses display the potential of OLED TV and are directly coupled with the recent rise of the OLED TV market share in the High End TV market at the same time. LG Display has made the mass-production of OLED TVs possible with the WRGB Oxide technology platform rather with the existing RGB LTPS which the market saw as impossible to succeed. Hence, WRGB Oxide technology will be introduced and further challenges that need to be addressed will be discussed.
Plenary Presentation	Mitzi, David	Perovskite Photovoltaics: Opportunities and Challenges for Materials Design	No Abstract
Plenary Presentation	Tang, Ching W.	OLED Displays – Prospects and Challenges	No Abstract
Poster	Awartani, Omar M.	A Perylene Diimide-Based Polymeric Acceptor Enabling Efficient All-Polymer Solar Cells Processed under Ambient Conditions	In this study we introduce a new PDI-based polymer acceptor (PDI-X) ideal for the fabrication of high efficiency all-polymer solar cells with power conversion efficiencies (PCE) exceeding 7.5 % when blended with polymer donor PTB7-Th. The improved planarity of the polymer backbone helps enhance charge transport in the backbone direction. In return, this increases mobility and consequently device performance. These devices can be fabricated in ambient air under 5% and 90% humidity and maintain a high PCE of 7.2 % and 7.0 %, respectively. Grazing Incidence Wide Angle X-Ray Scattering (GIWAXS) on neat PDI-X thin film reveals a well-defined (001)-like peak that corresponds to the polymer backbone with a spacing distance of 8.2 Å. This (001) feature is consistent with the high planarity of the PDI-X's backbone, and is maintained in the blend but is slightly suppressed by the PTB7-Th. Neither the neat or the blend films strongly favor a face-on or an edge-on orientation with a week (010) peak overlapping an amorphous band. While strong face-on orientation in organic solar cells typically improves out of plane charge transport and therefore PCE, this PTB7-Th:PDI-X system does not pack in such orientation. Therefore, it is very likely that this system can reach even higher efficiencies if a strong face-on orientation is achieved through further processing or by slightly altering the chemical structure to encourage face-on packing, however this is outside the scope of this study.
Poster	Balar, Nrup L.	The Role of Small Molecules on the Mechanical Behavior of Polymer:Small Molecule Organic Photovoltaics	For organic electronics to find broad commercial adoption, it is important to exploit the unique characteristics of these materials. One key advantage of organic semiconductors is the ability to make highly flexible devices. In this regard, understanding the mechanical behavior of organic semiconductors is critical to achieving highly flexible and mechanically stable devices. Currently, there is significant effort in developing polymer:small molecule blend films for organic photovoltaics (OPVs) with a focus on maximizing power conversion efficiency. Here, we consider the role of molecular structure and blend morphology of polymer: small molecule blends on mechanical behavior and how this is coupled to device performance. In this study, we focus on PTB7-Th donor polymer with a range of acceptors molecules including fullerenes and non-fullerene small molecules. The elastic modulus, crack onset strain, and cohesive fracture energy of the films will be reported along with how these properties relate to the molecule structure and film morphology. We will discuss how subtle difference in the small molecule acceptor can have a large impact on the mechanical properties of the blends, and the implications of this on flexible OPV device stability. Finally, we will discuss how the crack onset strain correlates with cohesive fracture energy, enabling a simple approach to screen mechanical behavior of these films quickly.

Poster	Barange, Nilesh	Enhanced Efficiency of Perovskite Solar Cell on Corrugated Substrate	Organometallic halide perovskites (OHPs) solar cells are fabricated on nano-scaled corrugated substrates using a sequential deposition method. The corrugated substrates are fabricated using colloidal lithography followed by reactive ion etching (RIE). The corrugated structure is found to accelerate the chemical reaction between the sequentially deposited lead iodide (PbI2) and methyl ammonium iodide (MAI) layers to form stoichiometric perovskite films, and the corrugated morphology is preserved at the interface of the hole transport layer (HTL) and the perovskite layer. The shunt resistance of the corrugated devices is found to be higher than that of the planar devices, leading to a higher open circuit voltage (VOC) and fill factor (FF) in the corrugated devices. Finite-Difference Time-Domain (FDTD) simulation is carried out on both planar and corrugated devices. The results revealed that light absorption is enhanced in the corrugated devices due to the corrugated HTL/perovskite interface, resulting in a significantly higher short circuit current (JSC) observed in the corrugated devices. As a result, the average power conversion efficiency (PCE) increases from 8.7% for the planar devices to 13% for the corrugated devices.
Poster	Barrette, Andy	Direct Study of Charge Transport in Perovskites Using Terahertz Spectroscopy	Electromagnetism has been a subject of fascination to scientists for centuries, and human technology has made amazing strides on the foundations of electromagnetic research. While the areas of electronics and photonics have prospered, THz response of materials has been neglected due to difficulties in THz generation, detection, and propagation (THz frequencies are highly attenuated in both metals and air). Despite these difficulties, information from time-domain terahertz spectroscopy (TDTS) is important because it contains information about phonon absorption, local carrier mobility, and scattering mechanisms. These properties allow us to construct a picture of local charge transport on picosecond time scales, which is highly relevant to macroscopic charge transport properties. We employ TDTS in the study of charge dynamics in lead-halide perovskites, which have recently proven to be a high-efficiency low-cost substitute for silicon solar cells.
Poster	Bauer, Nicole	Investigating the Potential of Non-fullerene Acceptors: A Case Study	Non-fullerene acceptors (NFAs) in organic photovoltaics have the potential to overcome the shortcomings of traditionally used fullerene derivatives, such as weak absorption in the visible region and restricted energy level tuning. However, many polymer:NFA blends yield a lower performance when compared to blends containing a fullerene derivative such as phenyl-C61-butyric acid methyl ester (PCBM). This study aims to investigate the non-fullerene acceptor SF-PDI2 to determine the cause of this difference in device performance. Two donor copolymers, one pairing benzodithiophene with fluorinated benzotriazole (FTAZ) and the other pairing benzodithiophene with a cyano-substituted pyridine-fused triazole (PyCNTAZ), were utilized to fabricate devices with either SF-PDI2 or PCBM as electron acceptor, and the photovoltaic parameters were measured. It was found that for both polymers the SF-PDI2 blend displays a higher open-circuit voltage (Voc) with lower short-circuit current (Jsc) and fill factor (FF), leading to an overall decreased power conversion efficiency. The increase in Voc is attributed to the higher-lying LUMO level of SF-PDI2 compared to that of PCBM. The SF-PDI2 blends exhibit a larger imbalance in the electron and hole mobilities (as measured by space-charge limited current), which is known to lead to a decrease in FF. To analyze the effects of morphology on device performance, RSoXS and GIWAXS measurements will be completed. Additionally, the charge transport properties will be further studied to determine the origin of the decreased Jsc for the NFA devices. The insights gained from this study will aid in the future development of higher-performing NFAs to compete with fullerene derivatives.

Poster	Cheng, Jiaqi	Efficient Hole Transport Layers with Widely Tunable Work Function for Deep HOMO Level Organic Solar Cells	Hole transport layers (HTLs) with large work function (WF) tuning ability for good energy level alignment with deep highest occupied molecular orbital (HOMO) level donor materials are desirable for high-performance and high open-circuit voltage (Voc) organic solar cells (OSCs). Here, a novel low-temperature and solution-process approach to achieve WF tuning in HTLs is proposed. Specifically, the HTLs made from 2,3,4,5,6-pentafluorobenzylphosphonic acid (F5BnPA) incorporated graphene oxide (GO) and molybdenum oxide (MoOx) solution (representing two possible classes of HTLs where carriers transport via valence and conduction bands, respectively) offer continuous WF tuning (the tuning range as large as 0.81 eV) by controlling F5BnPA's concentration. By employing a deep HOMO donor material, OSCs using the composite HTLs can achieve improved performances with largely increased Voc (0.92 V for GO:F5BnPA versus 0.65 V for pristine GO; 0.91 V for MoOx:F5BnPA versus 0.88 V for pristine MoOx). The enhanced performance can be experimentally and theoretically explained by the decreased hole injection barrier (HIB) for GO or equivalent HIB (i.e. electron extraction barrier) for MoOx and enhanced surface recombination velocity, which contribute to eliminating S-shaped current-voltage characteristics. Consequently, the incorporation of F5BnPA can efficiently tune HTL WF for high Voc OSCs and extend HTL applications in organic electronics.
Poster	Chung, Chin-Lung	Manipulation of Quinoidal Character in Ladder pi-System: An Effective Way to Adjust the Bandgap of Semiconductive Polymers	Bandgap engineering and energy level control of conjugated polymers are critical issues for organic electronics. To systematically study the impact of quinoidalization on optoelectronic properties in fused p-conjugation, three pentacyclic heteroacenes were designed and synthesized. These rigid electron-donating cores were further copolymerized with an electron-accepting unit 4,7-dibromo-5,6-difluoro-2-octyl-2H-benzo[d][1,2,3]triazole to furnish three novel donor-acceptor polymers, PBo, PBi and PT, respectively. The energy levels and bandgaps of polymers are successfully manipulated by structural modification resulting from gradual increase of quinoidal participation in fused electron-donating coplanar segment of polymers. From PBo to PT, the bandgap is progressively reduced as the highest occupied molecular orbital (HOMO) level destabilized. Among these polymers, the high propensity of quinoidalization and planarization of polymer backbone gives PT a small bandgap, which can harvest more solar photons. As a result, the PT-based photovoltaic device achieved a power conversion efficiency (PCE) of 6.04% along with a high short-circuit current density (Jsc) of 14.68 mA cm-2. With linear and coplanar conformation of backbone, PT-based field-effect transistor delivered a highest hole mobility of 0.09 cm2 V-1 s-1 among the three polymers.
Poster	Constantinou, Iordania	Effect of thermal annealing on charge transfer states and exciton dissociation in PCDTBT: PC 70 BM bulk heterojunction solar cells	The effect of thermal annealing on charge generation was investigated for PCDTBT:PC70BMdevices. Photocurrent spectral response and transient photoluminescence measurements wereused to confirm that device annealing leads to more effective carrier generation due to a higherdegree of charge transfer (CT) exciton delocalization. The delocalization of CT excitons was alsoaccompanied by an increase in the dielectric constant of the blend. Even though no obviousdifference in the film morphology was observed, the solar cell performance changedsignificantly after thermal treatment mostly due to a decrease in the device fill factor (FF). It wasshown that even though the photocurrent generated for the annealed PCDTBT:PC 70 BM device ishigher due to delocalization, a larger amount of generated photo-carriers are lost torecombination and do not contribute to the output current. Energetic disorder measurementsalong with recombination measurements at short and open circuit revealed negligiblebimolecular recombination for both devices. Finally, the decrease in FF was found to be due toan increase in the concentration of deep level traps causing an increase in Shockley-Read- Hallrecombination. Our findings suggest that thermal annealing can not only cause significantchanges in the film morphology and packing but also in the photo-generation process in organicbulk heterojunction solar cells.

Poster	Constantinou, Iordania	Photodegradation in High Efficiency Inverted Polymer Solar Cells	The effect of light on device stability was investigated for ITO/ZnO/p(DTG-TPD):PC71BM/MoOx/Ag solar cells. Upon 1 sun light exposure for 24 hours, a significant decrease was observed in all device parameters along with an overall decrease in EQE. Photodegradation was found to be due to the degradation of both the ZnO and MoOx interlayers rather than the p(DTG-TPD):PC71BM active layer. Steady state PL measurements confirmed the formation of a defect band in ZnO upon 1 sun light exposure for 24 hours causing a reduction in the workfunction and lowering the built-in field in the device. Additionally, photocurrent transients revealed the formation of a hole extraction barrier at the MoOx electrode that was shown to be responsible for the dramatic reduction in FF and JSC after light exposure. ZnO and MoOx degradation were shown to be due to exposure to UV light and can be prevented with the use of UV filters. Stability for devices kept under filtered 1 sun illumination for 24 hours was significantly increased, and photodegradation was mostly eliminated. Finally, our data show that in addition to air and temperature, light can also be detrimental for OPV device stability and with relatively high efficiency, good air stability and promising photostability, P(DTG-TPD) is a suitable candidate for roll-to-roll processing.
Poster	Constantinou, Iordania	The Effect of Polymer-Fullerene Intermixing on Dielectric Constant	Over the years, the effects of dielectric constant on organic photovoltaics has been a subject of continuous discussion. Even though various groups have tried to correlate the low dielectric constants of organic semiconductors with device parameters, direct experimental evidence and a consensus of opinions are still lacking. We showed that pristine polymer dielectric constant is not always an indication of device performance but instead device performance trends with blend dielectric constant. Additionally, we showed that blend dielectric constant can be larger than that of both the pristine polymer and fullerene. The increase in dielectric constant upon blending with PC71BM was shown to correlate with polymer-fullerene intermixing, due to the presence of a large amount of interface dipoles at the charge transfer states. Using transient photoluminescence, we showed that the increased blend dielectric constant and interface dipoles help exciton dissociation and delocalization which therefore improves device performance. Most importantly, we used electroabsorption spectroscopy to show an increase in the polarizability of the polymer's excited state after blending with fullerene. Since the increase in the static dielectric constant upon blending was small (~15%), we believe that the increase in the polarizability of the excited state upon blending with fullerene is responsible for most of the increase we see in device performance. In conclusion, we showed for the first time that pristine polymer dielectric constants are not directly relevant to device performance. Instead, good polymer-fullerene intermixing leads to high ground and excited state polarizability and therefore high blend dielectric constant and device performance.
Poster	Dinku, Abay G.	The role of film thickness on space-charge limited hole transport in organic films	Charge transport, which is highly dependent on material organization, is a central issue in any electronic device. Specifically, charge transport in organic films is crucially limited by the bulk morphology and material organization at the substrate/organic interface. The effect of substrate/organic interface on charge transport in diodes is not easily accessible since very thin organic films can easily be damaged by thermally sputtered top electrodes. In this report, we have successfully fabricated hole-only diodes, comprising thin (~15-300 nm) spin-cast organic films, and sandwiched between PEDOT:PSS layers. We observed that charge transport has a large gradient over the studied thickness range both in pure polymers and polymer:fullerene blends. Interestingly, while the hole mobility of P3HT drops dramatically near the substrate (decreasing film thickness), the trend is revered for the amorphous polymer MEH-PPV and its blend with PCBM. Such a significant difference in charge transport near the substrate interface is attributed to interface morphological. This investigation has a vital implication for development of efficient organic electronic devices including solar cells and light-emitting diodes.

Poster	Dirkes, David J.	Synthesis and Characterization of Novel Anthradithiophene Derivatives for Use in Organic Thin-Film Transistors	A series of novel functionalized anthradithiophene compounds have been synthesized and characterized by UV-Vis absorption, photoluminescence spectroscopy, and single crystal XRD. Functionalized anthradithiophene compounds have previously been studied for their potential use in low-cost organic electronics. In this work, several novel functionalized anthradithiophene compounds have been synthesized and evaluated for use in organic thin-film transistors. Organic thin-film transistor devices have been made from the these materials and their performance evaluated.
Poster	Dong, Chen	PbS quantum dots with long wavelength absorption for IR photodetectors	Lead Sulfide nanoparticles (PbS NPs) are widely used in short-wavelength infrared (SWIR) photodetectors and solar cells because of their excellent photosensitivity, bandgap tunability, and solution processability. For PbS NPs SWIR photodetectors, light sensitivity up to 2000 nm has been achieved by increasing the size of NPs.[1] However, PbS NPs SWIR photodetectors with light sensitivity beyond 2000 nm wavelength are still a challenge due to the difficulties in synthesizing larger PbS NPs. Larger PbS NPs require a higher reaction temperature and longer reaction time, during which the second nucleation, Ostwald Ripening leads to dispersity of the NPs size. In this work, we report a new method of synthesizing large mono-dispersed PbS NPs with an absorption peak over 2500 nm (Figure 1). The diameter of PbS NPs is up to 16 nm with good mono-dispersity as revealed by transmission electron microscope (TEM) (Figure 2). This work paves the way for fabricating broadband photodetectors with photo-response covering almost the entire visible and SWIR region. [Description: Macintosh HD:Users:chendong:Google Drive:Dr. Franky So:PbS Synthesis:TEM 2430nm 15nm:position6_100k.tif]Figure 1 PdS NPs absorption spectra ranging from 1000 to 2600 nm Figure 2 TEM picture of PbS NPs with absportion peak at 2430 nmReference[1] Jae Woong Lee, Do Young Kim, Sujin Baek, Hyeonggeun Yu and Franky So. Small 2016, 12, No. 10, 1328–1333
Poster	Fleetham, Tyler	Aza-substituted triphenylene derivatives as versatile and tunable OLED materials	The widespread adoption of OLEDs for displays and solid state lighting has been hindered by the lingering deficiency of stable and efficient blue OLEDs. This deficiency can be attributed to the competition between emission and molecular dissociation when high energy excitons are present, such as those resulting from triplet-triplet annihilation (TTA) or triplet-polaron annihilation (TPA). In particular, TPA between host anions and the high-energy dopant triplets is widely suspected to lead to molecular dissociation in many common host materials. New host materials are strongly desired which eliminate weak intramolecular bonds while maintaining high triplet energy, appropriate HOMO/LUMO energy level alignment, and efficient carrier transport. In this presentation we will discuss the development of a diverse class of materials based on triphenylene which have high triplet energies, efficient charge transport, and rigid structures. We used high throughput computational modeling to screen a diverse set of materials from which two general classes of tetracyclic compounds were identified for further study containing either two 6-membered rings and one 5 membered ring (H2P) or three 6 membered ring (H3) fused to a central ring. Aza-substitution of H2P and H3 derivatives afford a wide degree of frontier orbital tunability while maintaining high triplet energies necessary for blue OLEDs. Representative examples from these material sets were synthesized and characterized. Ultimately, several derivatives could be diversely used as transport materials, blocking layers, hosts or even as ligands for metal complexes. The computational studies, synthesis, photophysics, and device performance of these new materials will be discussed.
Poster	Fu, Xiangyu	Corrugated Substrates for OLED Light Extraction	Although the internal quantum efficiency of an organic light-emitting diode (OLED) can reached 100%, its external quantum efficiency (EQE) is limited to 30% because of low outcoupling efficiency. To break through this efficiency bottleneck, a corrugated structure can be used to extract waveguided mode and surface plasmon mode. In this research, we demonstrate the light extraction effectiveness of a corrugated substrate is related to both the corrugated morphology and the OLED structure being used. With additional hemi sphere lens to extract substrate mode, corrugated OLEDs with high outcoupling efficiency is fabricated.

Poster	Gautam, Bhoj R.	Exciton Management in Polymer Non Fullerene Solar Cells	The initial steps in organic photovoltaic cell (OPV) operation involve the formation of neutral excitons through photo absorption, exciton diffusion and separation into free charges at the donor acceptor interface. As the usable solar spectrum spans a large range from the visible to the infra-red (IR), an obvious direction for improved light harvesting is to synthesize donor and acceptor materials with complementary absorption. In such devices, specifically those involving polymer donors and small molecule acceptors (SMA), both electron and hole transfer from donor and acceptor moieties, and exciton transfer from high band gap to low band gap material are possible. In this work, using photoluminescence and transient absorption spectroscopy, we examine two different polymer/SMA bulk heterojunctions namely PffBT3T-E,A:SF-PDI2 and PffBT4T-2OD:SF-PDI2. Our results show that when charge and exciton transfer processes are present, the co-existence of excitons in both domains can hinder the charge separation of excitons in a low band-gap polymer. Our results further show that exciton lifetime in the lower bandgap material should be relatively long enough compared to the exciton transfer, in order to contribute to the charge separation. These observations provide significant guidance for design and development of new materials in OPV applications.
Poster	Ghasemi, Masoud	Sequentially-cast panchromatic ternary solar cells	Ternary Organic Photovoltaics (OPVs) that consist of one donor and two acceptors, or two donors and one acceptor have been considered as a simple strategy in increasing optical absorption window in OPVs. Due to complexity of interactions in ternary systems and tools needed to study these interactions, the most common approach to overcome the limitations is based on trial and error. In general, the complex morphological nature of the ternary device is the limiting factor and it needs to be understood well. Here we propose a unique sequential deposition strategy, for two miscible donors with disadvantageous interactions, that has a potential for eliminating the morphological complexities encountered in ternary OPVs and gives rise to an optimized geometry. The sequentially cast approach has dramatically improved device performance since it has allowed for making individually optimized binary morphologies. We studied the ternary blend of the high band gap PBnDT-FTAZ and the low band gap poly(diketopyrrolopyrrole-terthiophene) (PDPP3T) polymer. In ternary blends comprising these two polymers and a fullerene molecule [6,6]-phenyl C71 butyric acid methyl ester (PC71BM), the two polymers were found to be highly miscible while the fullerene molecule has little interaction with either polymer. The influence of polymer/polymer mixing on device performance was found to reduce dramatically after forming phase-segregated films trough sequential deposition processing. In conclusion, the sequential casting method has shown a great potential for fabrication of multilayer devices, with a potential for large scale production methods.
Poster	Hamze, Rasha	Luminescent Copper Carbenes	Luminescent copper complexes have been a subject of growing interest in electroluminescence owing to their high quantum efficiencies, their broad structural and electronic tunability, and the low cost of their metal precursors compared to their standard iridium and platinum counterparts. While a great deal of research has been done on 4-coordinate cationic copper complexes with bis-imine and bis-phosphine ligands, our lab has focused on carbenes as strongly-donating, monodentate ligands, which allowed us to make 2-, 3-, and 4-coordinate complexes that can be cationic or neutral. By employing different classes of carbenes: N-heterocyclic carbenes (NHC's), cyclic alkyl amino carbenes (CAACs), N,N-diamido carbenes (DACs) and mesoionic carbenes (MICs), we are able to achieve a broad range of tunability of photophysical properties (emission wavelength, type, efficiency, and lifetime). Judicious selection of carbenes and ancillary ligands has given us a good control handle on dynamic properties and stability to ambient conditions. This talk will cover the synthesis as well as the structural and photophysical properties of the luminescent copper carbene complexes prepared in our lab.

Poster	Hertel, Dirk	Charge Triplet Interactions in Solution Processed Devices	Charge-triplet-interaction are a severe loss channel limiting the efficiency at high brightness and lifetime in fluorescent and phosphorescent organic light-emitting diodes (OLEDs) [1]. Apparently, it is of importance for applications, however, it is also of interest for fundamental reasons. Recent Monte-Carlo simulations [2] show that the detailed mechanism by which charges and triplet interact is not clarified. This has implications for even more complex device simulations to understand state of the art OLEDs. The simulations often lack input parameters such as charge-triplet-interaction constant and radius for a number of materials systems. Additionally, the interaction of charges and triplets is invoked in a model of organic magnetoresistance (recent review see [3]). We use our previously reported method of quantifying charge-triplet interactions of a model system of polyspiro-bifluorene doped with platinumporphyrin [4] to study Ir-based guest-host sytems. We investigate charge triplet reactions in different systems of solution processed polymer/small molecule and evaporated small-molecule matrices doped with different Ir-based phosphorescent dyes. Our results show that the efficiency of triplet-triplet and triplet-charge annihilation depends on the nature of the matrix and processing method but less dramatic on the structure of the heavy-metal complex in opposite way. The interaction rates vary by an order of magnitude in for solution processing polymers/small molecules at most.[1] R Coehoorn, et al. Adv. Funct. Mater., 25 (2015), 2024.[2] M. Mesta, et al., Appl. Phys. Lett., 108 (2016), 133301.[3] R. Geng et al., doi: 10.1016/jsamd.2016.05.002[4] D. Hertel, et. al. J. Phys. Chem. B, 2007, 111, 12075.
Poster	Hertel, Dirk	Interplay of Morphology and Recombination in Solar Cells Based on Merocyanines	We investigate merocyanines (MC), a class of dipolar low-molecular-weight colorants, as donor material in organic solar cells. The efficiency of solution-processed devices is consistently lower compared with vacuum deposited devices, mainly due to a much lower fill factor. This hints to higher recombination losses, a result of insufficient domain formation in the device. Despite of recent advances concerning the understanding of charge transport and morphology the information about loss processes in MCs is rather limited. This is partly due to the tendency of MCs to form complex aggregates. Thus, MCs are interesting materials with respect to influence of microstructure on electronic properties. To aim towards higher PCEs it is imperative to gain more insight into material properties governing microstructure of films and fundamental processes in MC solar cells.We have systematically varied the side-chain of a prototypical donor-acceptor MC with a high ground state dipole moment and investigated its properties in BHJ devices with PCBM. The maximum efficiency is 4.5 % in the nonyl-derivative. By applying atomic-force microscopy, transmission electron microscopy and x-ray diffraction we are able to elucidate the thin film structure and show how side-chain variation reduces domain size and improves device data. Surprisingly, the fill-factor in solution processed devices almost doubles compared with conventional MC dyes for linear octyl-/nonyl side-chains but not for branches side-chains. This is due to a particular arrangement allowing for potential intercalation of PCBM. We have used transient extraction techniques to investigate the different transport and recombination mechanisms in these prototypical examples.
Poster	Ho, Szuheng	Interface Effect on Efficiency Loss in Organic Light Emitting Diodes with Solution Processed Emitting Layers	We compare the performance of multilayered OLEDs with a solution processed emitting layer (EML) and an evaporated EML and found that the interfacial energy changes at the EML and electron transport layer (ETL) interface is a key factor determining the device efficiency. From the results of exciplex photoluminescence emission at the EML/ETL interface and energetic disorder measurements, it is revealed that there is an energy shift in the solution processed EML along with a band tail broadening compared with the device with an evaporated EML, resulting in inefficient hole blocking at the EML/ETL interface and a decrease in device efficiency. Using an ETL with a deep highest occupied molecular orbital (HOMO) level can ameliorate this problem, resulting in a solution processed OLED with a high external quantum efficiency of 29%.

Poster	Hoffman, Ben C.	Temperature Controlled Electrostatic Disorder and Polymorphism in Ultrathin Films of alpha-Sexithiophene	
Poster	Hu, Huawei	Terthiophene-Based D-A Polymer with an Asymmetric Arrangement of Alkyl Chains That Enables Efficient Polymer Solar Cells	Tuning the energy levels and optical band gaps of the donor polymers using a donor-acceptor (D-A) copolymer strategy provide an important strategy to enhance the performance of solution processed polymer solar cells (PSCs). In addition, the selection of proper alkyl chains is essential because they have great influence on the molecular weights, intermolecular interactions, charge transport, and polymer:fullerene morphology, which all play significant roles in the performance of PSCs.A series of difluorobenzothiadizole (ffBT) and oligothiophene-based polymers with the oligothiophene unit being quaterthiophene (T4), terthiophene (T3), and bithiophene (T2) are synthesized and investigated. It was found that the T3 polymer with head-to-tail arrangement of alkyl chains on the first and second thiophenes exhibited a more favorable morphology and dramatically enhanced performance than the T3 polymer with mirror-symmetric alkyl chains on the first and third thiophenes, which enables the fabrication of 10.7% efficiency thick-film PSCs without using any processing additives. The polymer design rationales demonstrated in our work provide an effective approach to tune the energy levels and morphology that can be adopted to further increase the efficiency of PSCs.
Poster	Im, Yirang	Structural study of carboline based host materials with different nitrogen atom locations	To prevent reverse energy transfer from the guest to the host and effectively restrict triplet excitons on the guest molecules, triplet excited state energy of the host materials should be higher than that of the triplet emitters. Therefore, several bipolar type high triplet energy host materials were developed by introducing both electron donor and acceptor in the molecular structure. Bipolar host material is essential for hole and electron injection and recombination efficiency of phosphorescent organic-light emitting diodes (PHOLEDs).□ Carboline moiety has gained great attention because of high triplet energy and bipolar charge transport properties. However, there was little study about the photophysical properties of carboline derivatives. In this work, we synthesized three high triplet energy carboline derivatives, NmCP1, NmCP2, and NmCP3, as host materials to study the effect of heteroatom position. Triplet energy values of NmCP1, NmCP2, and NmCP3 were 2.88, 3.02, and 2.97 eV, respectively.□ To investigate correlation between intermolecular interaction and actual crystal structure, we also analyzed the crystal structures of host materials by single crystal X-ray diffraction (SC-XRD) method. X-ray crystallographic analysis revealed all NmCP1 molecules adopted regular and face-to-face packing on the whole. It can be assumed that the NmCP1 molecule exhibit higher transport capacity than NmCP2 and NmCP3.□ Within one column along b-axis, phenyl ring in the β-carboline unit adopt slipped face-to-face packing. The shortest C-C distance between adjacent β-carbolines is 3.300 Å. Thus, there is no typical π-π interaction. NmCP3 molecules have densely intermolecular interaction between adjacent molecules compare with NmCP1 and NmCP2.

Poster	Iwasaki, Yukiko	Observation of clear differences in PHOLED performances using similar TADF materials as phosphorescent host	Phosphorescent OLEDs (PHOLEDs) have been investigated because of their high efficiency. In recent years, highly efficient and stable PHOLEDs have been demonstrated by utilizing thermally activated delayed fluorescence (TADF) materials as the host with a reduced amount of dopant in the emitting layer.[1] However, the design strategies for TADF materials suitable for use as a phosphorescent host are not understood. To clarify the design strategies, we examined the device characteristics of PHOLEDs using three TADF materials of indolocarbazole (donor) and triazine (acceptor). They are 2,4-diphenyl-6-bis(12-phenylindolo)[2,3-a] carbazol-11-yl)-1,3,5-triazine (DIC-TRZ)[2], 5,12-dihydro-12-(4,6-diphenyl-1,3,5-triazin-2-yl)-5-phenylindolo[3,2-a]carbazole (PIC-TRZ2)[3], and 2,4-diphenyl-6-bis(12-phenylindolo)[2,3-b] carbazol-10-yl)-1,3,5-triazine (DIC-TRZ2). We fabricated PHOLEDs using them as the host, into which 1 wt% Ir(mppy)3 was doped. PHOLEDs using DIC-TRZ and PIC-TRZ2 exhibit external quantum efficiency (EQE) of over 20% and an expected half-life of about 10,000 h from an initial luminance of 1,000 cd/m2. On the other hand, PHOLEDs using DIC-TRZ2 exhibit EQE of about 15% and an expected half-life of only 1,000 h. To clarify the origin of the difference in device performances, we examined the energy transfer process from the host to Ir(mppy)3 in each emitting layer. We found that the differences in device performance originate from the differences in the luminescence properties of the host materials. On the basis of these results, we found a requirement for TADF materials suitable for use as a phosphorescent host.[1] H. Fukagawa et al., Sci. Rep., 5, 9855 (2015).[2]D. Zhang et al., Adv. Mater., 26, 5050-5055 (2014).[3]K. Sato et al., Phys. Rev. Lett., 110, 247401 (2013).
Poster	Jiao, Xuechen	Determination of Temperature-dependent Miscibility and Prediction of Phase Behaviors of Polymer Solar Cell Blends Using Optical Microspectroscopy	Polymer solar cells (PSCs) based on bulk heterojunction (BHJ) configuration recently receive extensive attention due to the continuous and rapid improvement of their power convention efficiencies (PCEs), which is mainly ascribed to the newly invented materials and the optimized morphology. The morphology of BHJ solar cells is highly dependent on processing conditions and the intrinsic properties of donor and acceptor materials. Thus a method of predicting the morphology is highly desirable to optimize the PCE for a given pair of donor and acceptor materials. From the perspective of thermodynamics, miscibility between donor molecule and acceptor molecule provides the driving force for morphology formation. Herein, we developed a convenient and widely accessible method to measure miscibility between polymer and fullerene at various temperatures based on a combination of visible light microscopy (VLM) and UV-Vis absorption spectroscopy. Through prolonged isothermal annealing of certain polymer:fullerene blend, the polymer volume fraction ϕ in the mixed region under local thermodynamic equilibrium can be evaluated using the widely accessible UV-Vis absorption measurement. The reliability of this UV-Vis method is further verified by the well-established scanning transmission soft X-ray microscopy (STXM) method.[1,2] Furthermore, temperature dependent Flory-Huggins interaction parameter (χ) can be extracted from the simulated χ-ϕ phase diagram. The χ-T relation enables us to predict phase behaviors at certain temperature. Using a non-crystaline PBDT-TS1 as prototype system and some additional systems, the effort of correlating device performance with χ at processing temperatures is underway.

Poster	Kawata, So	Singlet Fission of Thienoquinoidal compounds in Organic Photovoltaics	Singlet fission (SF) has been extensively studied in the context of organic photovoltaics (OPVs). However, most SF materials are limited to compounds with polycyclic aromatic structures and their derivatives. We synthesized non-polycyclic aromatic compounds, based on a thienoquinoidal compounds having fluorene end-cap (ThQs). These ThQs exhibited high thermal stability, as well as strong visible absorption and electron-donor properties, all of which are desirable for OPV applications. Single crystal X-ray diffraction analysis of these ThQs, in combination with quantum chemical calculations, revealed both close packing structures and energy levels for their triplet states that are below half of the energy level of their excited singlet states, which is an important prerequisite for SF. In the OPV devices, we used these ThQs as donor materials, and perylene diimide (PDIF-CN2) or fullerene (C60) as acceptor materials. Using PDIF-CN2, the magnetic filed response of the photocurrent of the OPV devices displayed distinct negative modulations, which is typical behavior for SF, while such a modulation was not observed when C60 was used. The external quantum efficiencies at the absorption of the ThQs was also acceptor-sensitive, due to the different energy level of the lowest unoccupied molecular orbital (LUMO) of each acceptor. Due to the low-lying LUMO of PDIF-CN2, the excitons dissociated into charges at the interface, but did not dissociate using C60 and its higher LUMO. These results suggest that those excitons should be ascribed to SF-generated triplet excitons. We were successful in the expansion of the SF materials.
Poster	Kempf, Maxim	Enhanced Organic Memory Devices (OMEM) with a photochromic perhydro DTE as a transduction layer	In modern electronic systems memory elements are of fundamental importance for data storage. Especially solution-processable nonvolatile organic memories, which are inexpensive and can be manufactured on flexible substrates, are a promising alternative to brittle inorganic devices. Organic photochromic switchable compounds, mostly dithienylethenes (DTEs) are thermally stable, fatigue resistant and can undergo an electrically- or/and photo-induced ring-opening and -closing reaction which results in a change of energy levels. Due to the energetic difference in the highest occupied molecular orbital (HOMO) between the open and closed isomer, the DTE layer can be exploited as a switchable hole injection barrier that controls the electrical current in the diode. We demonstrated that a light-emitting organic memory (LE-OMEM) device with a perfluoro DTE transduction layer can be switched electrically via high current densities pulses and optically by irradiated light, with impressive current ON/OFF ratios (OOR) of 10^2, 10^4 respectively.Currently we aim to minimize the barrier of the ON state and maximize the barrier of the OFF state by designing DTE molecules with larger differences in the HOMO energies of the two isomers yielding improved OOR values. By synthesizing perhydro derivates of DTE we achieved molecules with high HOMO levels and large ?HOMO energies providing OMEM devices with excellent physical properties (OOR 1.4 x higher than perfluoro DTE). Due to the high HOMO level of the perhydro DTE utilization of hole transport layers (HTLs) is not necessary and thus manufacturing of OMEM devices is simplified.
Poster	Kim, Gyeong Woo	Highly Efficient Hybrid Cool White OLED using Blue Thermally Activated Delayed Fluorescent Material	In this work, we investigate hybrid CWOLEDs by introducing blue thermally activated delayed fluorescence (TADF) emitter in order to surmount the limitation of conventional hybrid WOLED. The designed hybrid CWOLED structure is consisted of blue/ yellow/ blue multi-EML with yellow phosphorescent and blue TADF emitter. In this EML architecture, the blue TADF emitter is used as not only dopant for blue EML but also host for yellow EML. Such multi-EML structure with TADF blue emitter effectively is enhanced blue emission by converting blue triplet exciton generated in blue EML to blue singlet exciton through reverse intersystem crossing process, which results in very high efficiency with cool white emission due to balanced blue and yellow emission. The measured maximum external quantum efficiency and current efficiency of the fabricated device was 21.1% and 54.5 cd/A, respectively. Furthermore, this device showed cool white emission with (0.33, 0.37) color coordinates at the brightness of 1,000 cd/m2 and very good angular color stability.

Poster	Klump, Erik	Using Vapor Phase Halide Conversion to Control Morphology in Hybrid Perovskite LED Materials	Hybrid perovskite materials like methylammonium lead iodide (MAPbI3) have achieved great success in solar cell applications, quickly exceeding 20% efficiency. This family of materials is also promising for LED applications, though it has been difficult to achieve the smooth, uniform films necessary for high performance LEDs. In this work, we show that in solution deposited thin films of MAPbX3 perovskites, as the halide ion size decreases from I to Br to Cl, crystals grow significantly larger, thus hindering surface coverage and uniformity. To circumvent this, we demonstrate the ability to convert the halide in MAPbX3 perovskites using a vapor phase process. Using this process, we are able to convert MAPbI3 to either MAPbCl3 or MAPbBr3 as well as MAPbBr3 to MAPbCl3. In doing so, we are able to retain the favorable morphology of the films deposited as a larger halide ion while increasing their bandgap to emit either green (MAPbBr3) or blue (MAPbCl3) light. This favorable morphology leads to an increase in performance of LEDs fabricated using a vapor phase halide conversion as compared to those formed directly via solution processing.
Poster	Li, Mengmeng	Nanofibrillar morphology enables monolayer polymer FETs with mobility greater than 1 cm2/Vs	2D semiconductors, necessary for novel electronic applications of 2D materials, have to this point only been successfully produced from inorganics. Solution-processable, organic 2D semiconductors with high carrier mobility would lead to lower costs and facilitate larger scale production of these exciting electronic applications. We report the first such film, a (quasi-2D) monolayer of difluorobenzothiadiazole-oligothiophene copolymer (PffBT4T-2DT) with a thickness of 2.4 nm, fabricated by dip-coating. Field effect transistors employing these films achieved an average mobility over 1 cm2/Vs, with a maximum of 3 cm2/Vs, a record for organic monolayer transistors. Morphological characterization of films fabricated at differing coating speeds with AFM and GIWAXS shows that the record performance is facilitated by a nanofibrillar morphology with in-plane pi-pi stacking in the monolayer, which develops due to the strong temperature dependent aggregation properties of the polymer in solution. To demonstrate their potential for use in electronics applications, a 15-bit code generator was developed from the FETs.
Poster	Mukherjee, Subhrangsu	Charge creation and recombination in multi-lengthscale polymer:fullerene BHJ solar cell morphologies	While the extremes in organic photovoltaic bulk heterojunction morphology (finely mixed or large pure domains) are easily understood and known to be unfavorable, efficient devices often exhibit a complex multi-length scale, multi-phase morphology. The impact of such multiple length scales and their respective purities and volume fractions on device performance remains unclear. We have quantified the average spatial composition variations, i.e. volume average purities, at multiple size scales to elucidate their effect on charge creation and recombination in a complex, multi-length scale polymer:fullerene system (PBDTTPD:PC71BM).[1] The apparent domain size as observed in TEM is not a causative parameter. Instead, a linear relationship is found between average purity at length scales <50 nm and device fill-factor. Our findings [2] show that a high volume fraction of pure phases at the smallest length scales is required in multi-length scale systems to aid charge creation and diminish recombination in polymer:fullerene solar cells.Reference:[1] J. A. Bartelt, J. D. Douglas, W. R. Mateker, A. E. Labban, C. J. Tassone, M. F. Toney, J. M. Fréchet, P. M. Beaujuge, M. D. McGehee, Advanced Energy Materials 2014, 4, 1301733.[2] S. Mukherjee, X. Jiao, H. Ade, Advanced Energy Materials 2016, 10.1002/aenm.201600699.
Poster	Oh, Chan Seok	Stable blue phosphorescent host molecular design by CN modification	9-(3''-(carbazol-9-yl)-[1,1',3',1''-terphenyl]-3-yl)-carbazole-3-carbonitrile (TCzCN) was designed a blue host phosphorescent organic light-emitting diode. Terphenyl core was introduced for high triplet energy and thermal stability and CN was introduced for electron transport properties. Triplet energy and glass transition temperature of TCzCN were 2.77 eV and 126 oC. The maximum quantum efficiencies of blue PHOLED with devices of TCzCN and mCBP hosts were 26.6 %, 24.4 %, respectively. The lifetime of the blue PHOLEDs having TCzCN:Ir(dbi)3 was longer than that of the blue PHOLEDs based on the mCBP:Ir(dbi)3 due to stabilized chemical bond by CN substituent.

Poster	Park, Mi Jin	New Transparent Cathode for Top-Emitting Organic Light Emitting Diodes	Top-emitting organic light emitting diodes (TEOLEDs) are utilizing for active matrix display appliactions due to a merit of high aperture ratio. Such TEOLEDs are consisted of a thin metal cathode as the semi-transparent electrode and a highly reflective anode. Strong micro-cavity effects in such TEOLEDs are generated between top and bottom metal electrodes, which improves the color purity and applified the current efficiency toward the surface normal. The magnesium silver alloy (Mg:Ag) electrode was reported as the semi-transparent cathode due to a good electron injection property by the small work function of magnesium although its abosorption is too high. MoO3 mixed with aluminium (Al:MoO3) and MoO3 and WO3 mixed with silver (Ag:MoO3 and Ag:WO3) were investigated as the new electrodes.[1,2] Among them Ag:MoO3 possessed the higher transmittance and lower absorbance than Mg :Ag film. Hence, we investigate Ag:MoO3 film as a transparent cathode for strong micro-cavity TEOLEDs.In this work, Ag:MoO3 film transmittance and sheet resistance was measured with glass/ETL (20 nm)/Ag: 60% MoO3/capping layers (CL) structure. Characteristics of fabricated new cathode film were investigated by varing differenent capping layers (CLs). When the organic CL was used, our cathode sample showed the average transmittance (T) of 71 % and the average reflectance (R) of 22 % while no CL sample had 63 % (T) and 13 % (R). We fabricated TEOLEDs with our new cathode. The efficiency of fabricated green device is enhanced by 113 % compared with Mg :Ag reference device but the red TEOLED shows the similar performance.
Poster	Peng, Cheng	Corrugated Organic Light Emitting Diodes Using Low Tg Electron Transporting Materials	A corrugated organic light emitting diode (OLED) with enhanced light extraction is realized by incorporating a corrugated composite electron transport layer (ETL) consisting of two ETLs with different glass transition temperatures. The morphology of the corrugated structure is characterized with atomic force microscopy (AFM). The results show that the corrugation can be controlled by the layer thicknesses and annealing temperature. Compared with the control planar device, the corrugated OLED shows a more than 35% enhancement in current efficiency and a 20% enhancement in external quantum efficiency (EQE) at 100 cd/m2. In addition, the corrugated OLED also has a greatly improved operational stability. The LT90 lifetime of a device operated at 1000 cd/m2 is improved as much as 40 times in the corrugated OLED.
Poster	Roy, Biswadev	Contactless time resolved conductivity measurement using millimeter wave probes	We present initial measurements from a contact- and cavity-free time resolved millimeter wave conductivity (TRMMWC) system that characterizes charge transport in conjugated polymers over largely unexplored length scales by filling the frequency gap between microwave and THz methods. In this TRMMWC system, the photoinduced change in transmission of a continuous wave probe tunable from 110 GHz to 170 GHz is characterized by a high speed zero bias diode coupled to a 6 GHz digitizer. This method allows collection of time-dependent transmission data over a very wide (sub-nanosecond to millisecond) time range with each laser excitation pulse, limited at short times mainly by the digitization rate and at longer times by the amplifier electronics. We report here analysis of the sensitivity of the system using n- and p-doped silicon wafers of known resistivities, and preliminary of time dependent conductivity data in P3HT-PCBM blends.
Poster	Salehi, Amin	Highly efficient solution processed green organic light emitting diode using a Cu(I)-complex singlet harvesting thermally activated delayed florescence emitter.	Thermally activated delayed florescence (TADF) materials are a promising type of emitters which benefit from reverse intersystem crossing (RISC) due to small difference in triplet-singlet energy and are able to have spin mixing which yields to extremely high electroluminescence (EL) quantum yield devices. These emitters have the potential for inexpensive highly efficient and long lifetime organic light emitting diodes (OLEDs). In this work, a highly efficient solution processed (OLED) with 27% external quantum efficiency (EQE) is demonstrated using Cu(I)-complex singlet harvesting TADF emitter. The emitter is synthesized with copper as a central metal which is more abundant than expensive rare earth metals like Iridium. The photoluminescence quantum efficiency (PLQE) is higher than 70%. With optimal hole and electron transport layer (HTL/ETL), we are able to achieve a maximum current efficiency of 65 Cd/A (corresponding to 27% EQE), which might be attributed to energy transfer from exciplexes to the TADF dopant and low refractive index of the ETL.

Poster	Saris, Patrick JG	Blue organic LED materials with stabilized frontier orbital energies	Blue emitting phosphorescent organic light emitting diodes (OLEDs) suffer from shorter operational lifetimes than their green to red emitting counterparts, but new materials will enable robust device architectures for more resilient blue luminescence. Chemical decomposition of the active layer of an OLED, consisting of a conductive organic host material doped with a luminescent organometallic complex of Ir or Pt, is the primary source of luminance loss in state of the art devices. The instability particular to blue OLEDs stems from the molecular design principle for blue shifting the luminescence of known green dopant phosphors: widening the HOMO-LUMO gap. Destabilization of the LUMO by any means necessitates conduction band energies well shallow of -2 eV, limiting the choice of suitable host materials to inherently unstable structure classes such as phosphine oxides or to materials with suboptimal band alignment for high power efficiency. Alternatively, stabilization of the HOMO by fluorine substitution leads to electron promoted decomposition of the dopant phosphor by fluoride loss. Rather than substitution of CH with more electronegative CF, isoelectronic transmutation of CH with more electronegative N is a robust strategy for tuning frontier orbital energies. Here, we demonstrate sky blue phosphorescence from benzophenanthroline, a fluorine free tetracyclic heterotriphenylene ligand, with similar properties to the ubiquitous difluorophenylpyridine ligand (e.g. Firpic), without the potential for dehalogenative degradation mechanisms. We will present the underlying structure-property relationships that we have developed for our tetracyclic structure class that allow us to tune hosts together with dopants for long lived blue OLEDs.
Poster	Sen, Pratik	Oriented polymer semiconductor photodetectors for polarized light characterization	Organic semiconductor materials show tremendous promise in the area of photodetection due to their large absorption spectrum, ease of processing and large photogeneration yield. Imaging polarimetry is a useful photodetection technique that helps obtain the 2-D Stokes parameter of light. These set of values provide information on light's polarization characteristics that have broad application from biomedical imaging to pollution characterization. The current state of polarimetry detection techniques involve complicated optical systems that rely on instantaneous measurements after light passes through different polarization sensitive elements. These current technologies possess sensing errors due to temporal and spatial misregistration. We propose a novel organic photodetector (polarimeter) that uses the intrinsic polarization sensitivity of oriented polymers to characterize the polarization state of light.□ A set of cascaded semitransparent organic photovoltaic (OPV) devices are placed optically in series and designed to measure the 2-D Stokes parameters of incoming light. This technique improves on the current state of the art by measuring the complete polarization state at a single spatial location within a single integration time.□ In this presentation, we will discuss the device design and fabrication approach used to achieve the organic polarimeters. We will demonstrate the capabilities of the device to measure the Stokes parameters of incident light, and discuss the unique advantages of this approach for optical detection and implementation into imaging techniques.

Poster	Shewmon, Nathan T.	Liquid-Phase Heteroepitaxial Growth of MAPbI3 on MAPbBr3	Over the past few years, organolead halide perovskite materials, especially methylammonium lead iodide (MAPbI3) and methylammonium lead bromide (MAPbBr3), have been the focus of intense research due to their excellent optoelectronic properties and low-temperature processing. Polycrystalline thin films of these semiconductor materials are easily fabricated by spin-coating from solution in organic solvent, which are typically deposited on top of organic or oxide transport layers such as PEDOT:PSS or TiO2. However, recent reports on the optimization of thin-film perovskite photovoltaics generally agree that device performance is limited by defects at grain boundaries and interfaces, and studies on large MAPbI3 and MAPbBr3 single crystals confirm that the bulk electronic properties including carrier lifetime and mobility are far superior to what has been observed in polycrystalline thin films. To that end, we explore the possibility of using heteroepitaxy to grow thin single-crystal perovskite films.□ □ In this work, we demonstrate liquid phase epitaxial growth of perovskite films. We show that the formation of the epitaxial layer is dominated by ion exchange between the crystal and the solution that it is dipped in, leading to uniform, single-crystal surface layers with strong photoluminescence in the near infrared. Further, we demonstrate optoelectronic devices using perovskite films grown by the liquid phase epitaxy method, and compare their performance to analogous spin-coated polycrystalline devices. We believe that the reduction in defect density as a result of the elimination of both grain boundaries and interface defects make this growth method promising for future high efficiency devices.
Poster	Volyniuk, Dmytro	Sky blue and orange exciplexes of new carbazole derivative containing cyano groups for effective OLEDs	Mixtures of electron donating and accepting materials which exhibit exciplex emission in the solid state are depicted as emitters for efficient organic light-emitting diodes (OLEDs). Exciplex emitters allow to overcome the emitting limit of fluorescent organic emitters (25%) due to the thermally activated delayed fluorescence (TADF) [1]. However, efficiency of exciplex-based OLEDs is still far from the theoretical maximum. One approach of the increase of OLED efficiency is the search for new donor and acceptor exciplex forming compounds applicable as emitters for OLEDs.In this presentation we report on sky blue and orange TADF exhibiting exciplexes of the mixtures of the new carbazole derivative containing cyano groups and commercial donor materials tris(4-carbazoyl-9-ylphenyl)amine (TCTA) and 4,4',4''-tris[3-methylphenyl(phenyl)amino] triphenylamine (m-MTDATA). The thermal, photophysical, electrochemical, charge-transporting and exciplex forming properties of the synthesized compound were studied. In addition, we have utilized the exciplexes as emitters in effective yellow organic light emitting diode (OLED) with CIE color coordinates of (0.4, 0.52). The yellow exciplex based OLED exploiting the TADF effect had maximum luminance of ca. 6000 cd/m2 and external quantum e?ciency of 5.8 %.AcknowledgementThis research was supported by H2020-ICT-2014/H2020-ICT-2014-1 project PHEBE (grant agreement No 641725).References[1] Goushi, K.; Yoshida, K.; Sato, K.; Adachi. C. Nat. Photon. 2012, 6, 253-258.

Poster	Xiong, Yuan	High Efficiency Organic Solar Cells Blade-coated in Air from a Single Green Solvent	Along with the steady progress in PCE achieved by spin-coating photovoltaic materials with mixed or chlorinated solvents in protective atmosphere, a central issue in the development of OPVs is pursuing a greener and simpler manufacturing protocol[1-3], which particularly allows for large-area processing in an ambient air. The later demands both replacing spin-casting by other printing techniques using extremely low-toxicity, halogen-free solvents that don not impose environmental and health problems. Here, nanomorphology and microstructure based on transmission R-SoXS, DSC, and 2D-GIXRD observations indict o-MA, an extremely low toxicity solvent and also a certified food additive, yields similar crystalline features, analogous domain length/composition, and thus comparable device performance with those achieved by a widely-used binary halogenated solvents (CB/DIO) in spin-coated OPV film. To move a step forward, we further present the potential of o-methylanisole as processing solvent in the blade-coating of several cases of OPVs in air. Remarkably, this single nonhazardous solvent yields ~8.4% and ~5.2% efficiency in OPVs by respectively blade-coating PBDT-TSR:PC71BM and all-polymeric PBDT-TS1:PPDIODT in ambient air. This simple nonhazardous solvent approach will be also applicable in the industrial scale printing of high-efficiency OPVs in air.Reference[1] J. Zhao, Y. Li, G. Yang, K. Jiang, H. Lin, H. Ade, W. Ma and H. Yan, Nat. Energy, 2016, 1, 15027.[2] H. Zhang, H. Yao, W. Zhao, L. Ye, J. Hou, Adv. Energy Mater. 2016, 6, 1502177.[3] S. Li, H. Zhang, W. Zhao, L. Ye, H. Yao, B. Yang, S. Zhang, J. Hou, Adv. Energy Mater. 2016, 6, 1501991.
Poster	Yan, He	Fast charge separation in a non-fullerene organic solar cell with a small driving force	Fast and efficient charge separation is essential to achieve high power conversion efficiency in organic solar cells (OSCs). In state-of-the-art OSCs, this is usually achieved upon a significant driving force, defined as the offset between the bandgap (Egap) of the donor/acceptor materials and the energy of the charge transfer (CT) state (ECT), which is typically greater than 0.3 eV. The large driving force causes a relatively large voltage loss that hinders performance. Here, we report non-fullerene OSCs that exhibit ultrafast and efficient charge separation despite a negligible driving force, as ECT is nearly identical to Egap. Moreover, the small driving forces is found to have minimal detrimental effects on charge transfer dynamics of the OSCs. We demonstrate a non-fullerene OSC with 9.5% efficiency and nearly 90% internal quantum efficiency (IQE) despite a low voltage loss of 0.61 V. This creates a path towards highly efficient OSCs with a low voltage loss.
Poster	Yan, He	Morphology control leads to multiple cases of efficient polymer solar cells	The field of polymer solar cell (PSC) has seen great progress in device performance in the past few years, several limitations are holding back its further development. An important fundamental issue for the PSC field is how to control the morphology of polymer:fullerene blends to achieve the best PSC performance. We demonstrated that a near ideal morphology that contains highly crystalline yet reasonably small polymer domains could be controlled by the temperature-dependent aggregation behavior of the donor polymers. Based on this strategy, a verity of high-efficiency donor polymers were developed, especially, the polymer namely PffBT4T-C9C13 exhibited a PCE up to 11.7% when processed with environmentally hydrocarbon solvents. The uncovered aggregation and design rules will allow further synthetic advances and matching of both the polymer:fullerene systems, potentially leading to significantly improved performance.Reference:1. Yan, H. et al. Nat. Commun. 2014, 5, 5293.2. Yan, H. et al. Adv. Energy Mater. 2015, 5, 1501282.3. Yan, H. et al. Nano Energy 2015, 15, 607.4. Yan, H. et al. J. Mater. Chem. A 2016, 4, 5039.5. Yan, H. et al. Nat. Energy 2016, 1, 15027.

Poster	Ye, Long	Temperature Dependent Molecular Interaction Parameter and Its Predictive Power in Polymer Solar Cell Performance	Polymer solar cells (PSCs) are colorful, lead-free, and can be processed from benign solvents with high efficiency. Although highly desirable, predicting morphology and thus performance based on easily measured fundamental molecular interactions remains elusive. Utilizing synchrotron-based soft X-ray microscopy (STXM) at Beamline 5.3.2.2 of the Advanced Light Source (ALS) as a tool, the temperature-dependent molecular interaction parameter χ(T) of several high-efficiency polymers and fullerenes were extracted from binodal compositions that were determined by measuring the residual fullerene concentrations within phase separated domains after long-term annealing at various temperatures and corrected for the estimated degree of crystallinity. The accuracy of STXM miscibility-derived χ(T) is further verified by comparison to the result derived from melting point depression as observed with differential scanning calorimetry (DSC). Highly variable χ(T), i.e upper and lower critical solution temperatures, were observed. Moreover, device fill factor correlates positively with χ at processing temperature in multiple cases of PSC devices, indicating higher χ is a prerequisite to achieve higher fill factor in PSC devices and is a driving force towards purer mixed domains even if the morphology might be quenched by aggregation during casting.□ Additionally, the established methodology enables us to predict the optimal processing temperature for a record-efficiency PffBT4T-C9C13:PC71BM blend in blade-coated PSCs, thus making our concept more widely useable. We propose that the precise determination of χ(T) will aid in establishing property-performance relationships and screening new material combinations/optimal processing conditions creating a morphology that can support high performance.
Poster	Yi, Xueping	Effects of interaction of nonfullerene acceptor and donor on the efficient organic solar cells	Over the past several years, considerable efforts have been dedicated to the synthesis of new non-fullerene small molecule acceptors but device efficiencies remained low compared to PC71BM-based devices. Recently, a breakthrough has been made and polymer solar cells using a non-fullerene acceptor, ITIC, reached efficiencies over 11%. Why is ITIC so much better than the rest of the previously published non-fullerene acceptors? We previously showed that the interaction between polymer and fullerene plays an important role in device performance. However, the impact of donor-acceptor interactions for non-fullerene acceptors on device performance has never been studied before.Here we compare the effects of donor-acceptor interactions for fullerene and non-fullerene acceptors. For this study, we chose commonly used PTB7 as the donor material and three different electron acceptors: ITIC (a champion acceptor with efficiency over 11%), SP-PDI4 (a newly synthesized acceptor with a 3D structure that resembles fullerene) and PC71BM. The goal of this study is to determine the effect of the acceptor material on the dielectric environment of the blend and correlate that to device performance. The dielectric constant is obtained by capacitance-voltage measurement, morphology information is given by atomic force microscopy and transient photoluminescence is utilized to analyze the charge generation efficiency. Finally, electroabsorption spectroscopy is used to study the excited state polarizability in blends. Donor-acceptor interaction has proven to be critical for high blend dielectric constants and high device performance. This comparative work attempts to expand our knowledge of donor-acceptor interaction beyond fullerenes for even higher device performance.

Poster	Younts, Robert	Control of back-recombination by reducing triplet formation in all-polymer solar cells	Reduction of geminate and non-geminate recombination is known to increase the short-circuit current density and open-circuit voltage by prolonging excited-state lifetime of the charge-transfer (CT) and charge-separated (CS) states. During device operation under solar illumination equilibrium is reached between the CT and CS states. However, in some donor/acceptor materials, the donor triplet excitonic state is energetically aligned with the CT state causing further backwards recombination. Currently, it is unknown whether triplet formation significantly impacts the equilibrium condition between CT and CS states and whether it can be manipulated at the interface. In this work, we examine sub-nanosecond triplet formation in PBDTTTPD:PCBM and PBDTTTPD:P(NDI2HD-T) bulk-heterojunction thin films by using femtosecond transient absorption spectroscopy. We demonstrate that triplet formation from nongeminate recombination can be reduced by controlling the CT state energy with respect to the triplet state of the donor. By utilizing newly synthesized naphthalene diimide based n-type polymers instead of conventional fullerene PCBM, further energetic control at the interface can eliminate loss from triplet formation.
Poster	Yu, Hyeonggeun	Infrared-to-Visible Up-Conversion Light-Emitting Phototransistor with high external quantum efficiency	Direct integration of an infrared quantum dot (QD) photodetector and an organic light-emitting diode (OLED) enables low cost pixelless infrared imaging. However, the external quantum efficiencies (EQEs) are very low due to the low photon-to-electron conversion efficiency of the OLED when integrated with a quantum dot photodetector. Up-conversion devices are two-terminal devices and the electric fields in the photodetector and the OLED are not controlled independently. As a result, connecting a high efficiency photodetector and a high efficiency OLED in series does not necessarily results in a high efficiency up-conversion device. Here, we first demonstrate a novel high gain vertical phototransistor with a perforated indium tin oxide source electrode and report an EQE up to 10^5 % and a detectivity of 1.2×10^13 Jones. The short vertical channel enabled low power operation and strong electric field. The phototransistor structure consists of ITO gate/PbS QD layer/HfO2/perforated ITO source electrode/C60 channel/Al drain. IR photons impinging upon the PbS layer through the ITO gate electrode generate photo-carriers, inducing a strong field-effect in the perforated ITO region where C60 is in contact with HfO2 gate dielectric layer. As a result, the electron injection from the ITO source electrode to the C60 channel layer is highly modulated, resulting in a high photocurrent gain. By combining a phosphorescent OLED with this phototransistor, an infrared-to-visible up-conversion light-emitting phototransistor (LEPT) with an external quantum efficiency over 1,000% is demonstrated.
Poster	Yu, Hyeonggeun	Solution-Processed Copper Oxide Hole Transporting Layer for Air-Stable, High-Sensitive PbS Quantum-Dot Photodetector	Metal oxide interlayers have been under fervent research for optoelectronic applications due to solution processibility, optical transparency, and good charge selecting property. Solution-processed metal oxide interlayers have been used for high efficiency, air-stable quantum dot photodetectors, but the processing temperatures of the metal oxide layers were very high. In this work, we report low temperature-processed PbS photodiodes by employing solution-processed CuOx interlayer. With the low processing temperature, the photodiode still exhibits a low dark current of 10 nA/cm2, infrared detectivity over 10^13 Jones, bandwidth of 17 kHz, and air stability up to 3 month without encapsulation. Flexible PbS photodiode could be demonstrated on polyethylene terephthalate substrate due to the low processing temperature.

Poster	Yu, Hyeonggeun	Vertical Field-Effect and Light-Emitting Transistors Enabled by Perforated Indium Tin Oxide Electrode	Direct integration of a vertical field-effect transistor (VFET) and an optoelectronic device offers a single stacked, low power optoelectronic VFET with high aperture ratios. However, a functional optoelectronic VFET could not be realized because of the difficulty in fabricating transparent source and gate electrodes. Here, we report a VFET with on/off ratio up to 105 as well as output current saturation by fabricating a transparent gate capacitor consisting of a perforated indium tin-oxide (ITO) source electrode, HfO2 gate dielectric, and ITO gate electrode. Effects of the pore size and the pore depth within the porous ITO electrodes on the on/off characteristic of a VFET are systematically explained in this work. With an optimized VFET structure, two kinds of optoelectronic VFETs can be fabricated: a vertical light-emitting transistor with luminance on/off ratio of 10^4 and a vertical infrared phototransistor with the external quantum efficiencies over 10^4 %.
Poster	Zhang, Qianqian	Fluorinated Thiophenes in PBnDT-TAZ: Synthesis, Characterization and The “Fluorine” Impact	Fluorination of conjugated polymers has been a widely adopted approach to tune optoelectronic properties of conjugated polymers, aiming for enhancing the power conversion efficiency (PCE) of their solar cells. Most fluorinated donor-acceptor polymers have the fluorine atoms placed on the acceptor unit; for example, in the well-studied PBnDT-FTAZ, two fluorine atoms are substituted onto the benzotriazole (TAZ) unit. Compared with the non-fluorinated counterpart (PBnDT-HTAZ), PBnDT-FTAZ shows one order of magnitude higher hole mobility in its bulk heterojunction (BHJ) blend with phenyl-C61-butyric acid methyl ester (PC61BM), which directly translates into a remarkable improvement in fill factor (FF) of its BHJ device, leading to the observed efficiency of over 7% (vs. 4% for PBnDT-HTAZ).□ In this study, we intend to direct our attention to the fluorination of these two connecting thiophene units in between the TAZ unit and the BnDT unit. Four structurally related polymers based on PBnDT-HTAZ were then designed and successfully synthesized, featuring fluorinated thiophene and/or fluorinated TAZ. It was found that the fluorination positions on thiophene units (3 vs 4 position) has a strong impact on the conformation and twisting angles between adjacent units, and the energy levels of the new polymers. More interestingly, the fluorination of thiophene units can efficiently deepen the HOMO level and increase hole mobility of these new polymers. When these newly designed polymers were tested for their photovoltaic performance, remarkably high Voc (as high as 0.99 V) and high fill factor were achieved owing to the deep HOMO levels and high hole mobility, respectively.
Presentation	Bondarev, Igor	Theory of the Frenkel-Charge-Transfer Exciton Intermixing in Crystalline Copper Phthalocyanine (CuPc)	Theoretical work on organic molecular crystals has predicted that intramolecular Frenkel excitons couple strongly with charge transfer excitons between adjacent molecules.[1] In particular, extensive work was done on organic crystals such as PTCDA, whose general results can be extended to a large class of molecular crystals. Recent experiments have indeed indicated a coupling between Frenkel and charge transfer excitons in CuPc (Copper Phthalocyanine). One of the key differences between CuPc and PTCDA is the fact that for CuPc one has two Frenkel excitons of similar energy that form when the CuPc crystalizes, as opposed to having one. The binding energy of such Frenkel excitons have been found to be in the range of ~0.6 eV.[2] We formulate the Hamiltonian and use the (exact) Bogoliubov diagonalization procedure to calculate the energy dispersion spectrum for the lowest energy coupled Frenkel-CT exciton states in the CuPc lattice. According to our analysis, the CT exciton energy level is located in between the two Frenkel exciton energy levels, which are separated by 0.25 eV. The CT exciton is 60 meV above the lowest Frenkel exciton and 190 meV below the highest Frenkel exciton. Both Frenkel excitons are strongly hybridized with the CT exciton, showing the coupling constant (0.1 eV) of the same order of magnitude as the Frenkel exciton splitting itself. Our results can be used to interpret experimental absorption spectra of crystalline CuPc.[1] M.Hoffmann, et al., Chem. Phys. 258, 73 (2000); [2] M.Knupfer, et al., Phys. Rev. B 69, 165210 (2004)

Presentation	Byeon, Sungyong	Synthesis of stable host materials for blue phosphorescent and thermally activated delayed fluorescent organic light-emitting diodes.	Stable host materials for blue thermally activated delayed fluorescent (TADF) and phosphorescent organic light-emitting diodes (OLEDs) were successfully synthesized with stable chemical structure. In the molecular design of the host materials, sufficiently high triplet energy applicable in blue light-emitting devices, and chemically stable backbone structure were considered as key factors for long lifetime. Additionally, the host materials were required to have appropriate highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) energy levels for efficient charge injection and device operation. The newly synthesized host materials were applied to both blue phosphorescent and blue TADF based OLEDs. The electrochemical and photophysical properties of the host materials were measured by cyclic voltammetry, ultraviolet-visible and photoluminescence spectroscopy, and the result demonstrated that the host materials have high triplet energy and proper HOMO and LUMO energy levels enough to apply to blue light-emitting devices. The devices based on newly synthesized host materials were doped with blue phosphorescent emitter of tris[1-(2,4-diisopropyldibenzo[b,d]furan-3-yl)-2-phenyl-1H-imidazole] iridium(III) (Ir(dbi)3) and blue TADF emitter of 2,3,4,5,6-penta(9H-carbazol-9-yl)benzonitrile (5CzCN). The device results proved that, the synthesized host materials had long device lifetime in both phosphorescent and TADF based OLEDs due to the stable chemical structure.
Presentation	Cesarini, Matteo	Light-induced conductance switching in mesoporous TiO2 for imaging applications	UV detection encloses an interesting range of practical applications. Devices gain an even stronger appeal if developed by solution processable, scalable techniques. We demonstrate a UV sensor based on light induced conductance switching of solution processed TiO2, operating at less than 1 V bias, with a 60 dB switching after seconds of exposure. On a glass substrate, a semitransparent FTO contact is placed to allow bottom illumination and biasing of device. The active layer is mesoporous anatase titania (TiO2), in nanoparticle paste, requiring a sintering step. Aluminum top contact is evaporated. The switching mechanism is sensitive to oxygen partial pressure and is ascribable to a light induced stoichiometric change in the anatase TiO2 structure. The whole process acts as a sort of reversible n-photodoping. High performance is possible even at processing temperatures compatible with plastic substrates. Changing maximum sintering temperature (150 °C to 500 °C) varies recovery dynamic from minutes to almost permanent. XRD and Raman measurements show that this effect may be related to different configurations of the crystals and to the presence of organic ligands. Prototypes of crossbar pixel array imagers are developed with both spin coated and screen-printed (patterned) TiO2 between conductive stripes acting as top and bottom pixel addressing contacts. Imagers are able to reproduce a cross pattern.

Presentation	Chan, Paddy K.L.	Flexible temperature sensors based on organic/metal hybrid thermistor	The properties of the interface between the metal/organic semiconductors is closely related to the interactions between the materials and the band alignment. In the current work, we embedded silver nanoparticles into pentacene thin film to form a thermistor which can be used for temperature sensing purposes. By examining the thermal boundary conductance of the interface and the overall thermal conductivity of the film, we simulated the thermal response of the 2D temperature sensor array under different layout configuration. By integrating the thermistor with the active matrix organic transistor array, we fabricated a large area 16 × 16 temperature sensor which can be directly used for temperature mapping of objects with various shape. We applied anodization growth to deposit the alumium oxide (AlOx) dielectric insulator, and thus the 10 bits tempearture array can be powered under 5V. Furthermore, by carefully controlling the concentration of the silver nanoparticles and varying the combinations of the metal and organic semiconductors, we can modify the sensitivity of different temperature sensors. If the petancene thin film is separately embedded with Ag and Al nanoparticles, the sensitivity of the thermistor changes from 0.05 K-1 to 0.08 K-1. The proposed low voltage flexible thermal sensor array is suitable for novel portable electronic devices and potentially scale up for electronic skin applications.ReferenceX. C. Ren, K. Pei, B. Y. Peng, Z. C. Zhang, Z. R. Wang, X. Y. Wang, and P. K. L. Chan, “Low operating power and flexible active matrix organic transistor temperature sensors array”, Adv. Mat., 10.1002/adma.201600040, 2016
Presentation	Chiba, Takayuki	Solution-Processed Multi Photon Emission Organic Light-Emitting Devices	Organic light-emitting devices (OLEDs) have progressed rapidly due to their great potential for next generation energy saving lighting and TV applications. The OLEDs comprising plural light-emitting-units (LEUs) stacked in series, separated by a charge generation layer (CGL), called multi photon emission (MPE)-OLED, have been produced to achieve the high luminance and long operational lifetime simultaneously. However, they can be fabricated only by vacuum evaporation process due to the required multilayer structures, resulting in high cost of the product. Meanwhile, solution-processed OLEDs have also attracted attention for their large area processing, but low fabrication cost. Here, we have developed solution-processed MPE-OLEDs comprising two LEUs and a CGL. The individual components, 1st-LEU and 2nd-LEU are also fabricated independently. A zinc oxide nanoparticle (ZnO) and amine-based aliphatic polymer bilayer is used as the electron injection layer (EIL) and phosphomolybdic acid is used as the electron acceptor of the CGL for MPE-OLEDs with light-emitting polymer based LEU. In addition, we have also demonstrated solution-processed white MPE-OLEDs using phosphorescent materials and report their record-breaking high efficiency. Small molecule host materials and blue, green, and red phosphorescent dopants are used in the LEUs. Polymer additives can control the solubility of the LEUs. The bilayer of pristine poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) and neutralized PEDOT:PSS is used as an CGL. The phosphorescent two-staked MPE-OLEDs exhibit extremely high efficiencies: 69 cd/A and 28% EQE at 5000 cd/m2 for white phosphorescent devices. Development of these highly efficient solution-processed MPE-OLEDs paves the way to printable, low-cost, and large-area white lightings.

Presentation	Cho, Hyunsu	All phosphorescent tandem white organic light-emitting diodes with high color rendering index and high luminous efficacy	In lighting applications, color rendering index (CRI) and luminous efficacy are one of important parameters to evaluate the lighting quality. High values of these parameters are more favorable to the users. Light sources with high CRI can represent the more accurate colors of objects and those with high luminous efficacy can save more energy. Organic light-emitting diodes (OLEDs) have proved their great capacity to achieve high CRI and luminous efficacy. [1, 2] Unfortunately, there is a trade-off relation between them. [3] Here, we discuss the optimization of both in 2-stacked tandem white OLEDs. Based on the optical simulation for CRI and efficiency, emitting materials and OLEDs device structure (positions of emission layer and thickness of common organic layers) are selected. Tandem WOLEDs with a new phosphorescent blue dopant, which has deeper blue emission than Firpic [4], demonstrated higher CRI maintaining similar luminous efficacy than those with a Firpic. At a current density of 1.25mA/cm2 corresponding to a luminance of 1,000 cd/m2, Tandem WOLEDs achieve a luminous efficacy of 45.7 lm/W and a CRI of 90.1. In addition, with micro lens arrays, they achieve a luminous efficacy of 56.7 lm/W and a CRI of 91.0 at the same condition.Reference[1] S. Jang et al., SID Symposium Digest of Technical Papers 46, 661-663 (2015)[2] T. Zhang et al., Sci. Rep. 6, 20517 (2016)[3] P. Vandersteegen et al., Appl. Opt. 47, 1847-1955 (2008)[4] H. Cho et al., Org. Electron. 34, 91-96 (2016)
Presentation	Coropceanu, Veaceslav	Impact of static and dynamic disorder on charge recombination in organic solar cells	We study the role of electron-vibration coupling, electronic polarization, molecular packing, system size and electron delocalization on the nature of the charge-transfer states in model donor-acceptor systems. The morphologies range from a bilayer with flat interface to bulk heterojunctions with coarse and fine intercalated domains of donor and acceptor molecules. The implications of the charge-transfer states, active material morphology, density of states and charge carrier concentration on non-geminate recombination kinetics is investigated by means of a three-dimensional reaction-diffusion lattice model with the charge carrier hopping rate described by the Miller-Abrahams formalism.
Presentation	Curtin, Ian J.	Photocurrent loss in organic photovoltaic cells due to exciton-polaron quenching	Organic photovoltaic cell (OPV) performance is often limited in part by a low fill factor, typically the result of a steep reduction in photocurrent under forward bias. This reduction is usually ascribed to a reduction in the charge collection efficiency due to non-geminate charge carrier recombination. Here, we demonstrate that in a planar heterojunction OPV based on the electron donor-acceptor pairing of boron subphthalocyanine chloride (SubPc) and C60, this reduction in photocurrent is instead well-modeled by including excitonic losses due to exciton-polaron quenching. Using a photovoltage-based technique, we are able to measure the exciton diffusion length (LD) of SubPc and C60 as a function of forward bias voltage. The LD of SubPc and C60 decrease from (10.4±1.0) nm and (24.5±2.5) nm, respectively, at 0 V to (8.3±0.8) nm and (11.8±1.2) nm, respectively, at the maximum operating power point of the device at 0.68 V. Additionally, we are able to independently vary the exciton and charge densities in the active layer of interest by selective excitation of the donor or acceptor. These additional experiments have ruled out a potential role played by exciton-exciton annihilation. Using the extracted dependence of LD on voltage (and hence carrier density), we are able to model the photocurrent with a constant charge collection efficiency of 77%. The results of this work suggest that while a constant photocurrent loss is present in this device due to non-geminate recombination, the reduction in photocurrent as a function of voltage is caused by exciton losses due to polaron quenching.

Presentation	Diemer, Peter J.	Isomer Coexistence Induces Trapping States in Organic Field-Effect Transistors	Charge transport in organic field-effect transistors (OFETs) is enhanced upon separating the isomers within the organic semiconductor (OSC) layer. We analyze the spectra of the density of states (DOS) within the OSC bandgap for OFETs consisting of syn-, anti and co-existing isomers of 2,8-difluoro-5,11-bis(triethylsilylethynyl)-anthradithiophene and we correlate the results with the device performance. A lower field-effect mobility and a discrete trapping state located at ~ 0.4 eV above the valence band edge is found in the mix-isomer OFET. Ultraviolet photoelectron spectroscopic measurements and density functional theory calculations indicate that the isomers have very similar electronic structures, in spite of the differences in the crystal structures. We posit that the trapping state results from the fact that the dipole moment of the syn-isomer is locally shifting the highest occupied molecular orbital of the surrounding anti molecules, thereby inducing states that invade the bandgap. Our calculations suggest that the mix-isomer system energetically favors a molecular configuration in which the two isomers are separated, in agreement with our experimental results confirming that the concentration of the syn molecules among the anti is low in the transistor channel (~ 400 ppm). We show that we can phase separate the isomers and suppress the formation of the discrete trapping state by vibration-assisted crystallization of the OSC film. Consequently, the performance of the device is improved, with the resulting mobility reaching the values similar to those obtained in single crystals.
Presentation	Eze, Vincent Obiozo	Cu-phthalocyanine doped poly-3-hexylthiophene based hole-transporting layer for efficient mesoscopic CH3NH3PbI3 perovskite solar cells	For efficient charge extraction with minimal recombination losses, the perovskite light absorbing layer needs to be contacted with charge selective n-type and p-type materials, which exhibit low resistive losses. Currently, the best performing devices employ a p-type organic hole conductor, 2,2',7,7'-tetrakis(N,N-di-p-methoxyphenylamine)-9,9'-spirobifluorene (Spiro-OMeTAD) as the hole transport layer (HTL). However, it is essential to add lithium bis(trifluoromethane sulfonyl) imide (Li-TFSI) to the Spiro-OMeTAD solution to increase the intrinsic charge carrier mobility. Li-TFSI is a hygroscopic material and can moisture induce degradation of the perovskite solar cells, resulting in an overall compromise for the long-term stability of the device. Herein, we report the use of hydrophobic poly-3-hexylthiophene (P3HT) HTL to prevent moisture ingress in the device. Cu-phthalocyanine (CuPc) chlorobenzene suspension was introduced as a dopant for enhancing charge extraction. CuPc is thermally and chemically very stable material, and by mixing with a P3HT solution, the aggregation of CuPc nanoparticles was suppressed. Interestingly, the incorporation of the CuPc into P3HT solution could suppress leakage current and reduce recombination by an efficient hole transporting and electron blocking, resulting in the significant enhancement of the efficiency of the CH3NH3PbI3 perovskite solar cells from 7.90% for the pristine P3HT device to 10.10% for the P3HT:CuPc device measured under AM 1.5G solar simulations. References1.Severin N. Habisreutinger et. al., J. Phys. Chem. Lett. 2014, 5, 4207-42122.Tomas Leijtens et. al., ACS Appl. Mater. Interface 2016, 8, 5981-59893.Tatsuo Mori et. al., J. Photopolym. Sci. Technol. 2015, 28, 393-3984.Vincent Obiozo Eze et. al.,2016 Jpn. J. Appl. Phys.5502BF08

Presentation	Facendola, John W.	Studies of Structural Effects on Molecular Orientation of Organometallic Phosphors in Organic Light Emitting Diodes	Organic Light Emitting Diodes (OLEDs) have increasingly been used in display and lighting applications do to their high efficiencies and color tuning ability. The molecular orientation of phosphorescent emitters in an OLED has been studied as one pathway to further increase the external quantum efficiency of these devices. Although there are numerous examples of phosphors in the literature shown to undergo molecular orientation, there have been no conclusive studies defining how to design complexes to control alignment. Kido recently reported high efficiency OLEDs with tris-(1-mesityl-2-phenyl-1H-imidazole)iridium, Ir(pim)3, emitters and attributed the high efficiency to dopant alignment. We have found that Ir(pim)3 does align in the matrices used for Kido's OLEDs and a number of other host materials. We will discuss both OLED and optical studies that bear on the degree of emitter alignment in doped films for Ir(pim)3, as well as other Ir(C^N)3 and (C^N)2Ir(ancillary) complexes. We have also examined (C^N)Pt(ancillary) complexes and found that doped films of these planar dopants also spontaneously align in amorphous host materials. The mechanism of dopant alignment will be discussed.Reference: Kido, J., et al, Advanced Materials2014, 26, 5062-5066
Presentation	Flügge, Harald	Thermally activated delayed fluorescence for blue OLEDs: A status report	Currently, the mobile display market is strongly shifting towards AMOLED technology, in order to enable curved and flexible displays. This leads to a growing demand for highly efficient OLED emitters to reduce the power consumption and increase display resolution at the same time. While highly efficient green and red OLEDs already found their place in commercial OLED-displays, the lack of efficient blue emitters is still an issue. Consequently, the active area for blue is considerably larger than for green and red pixels, to make up for the lower efficiency. We intend to close this efficiency-gap with novel emitters based on thermally activated delayed fluorescence (TADF) technology. Compared to state-of-the-art fluorescent dopants, the efficiency of TADF-emitters is up to four times higher. At the same time, it is possible to design them in a way to maintain deep blue emission, i.e. CIE y < 0.2. These aspects are relevant to produce efficient high resolution AMOLED displays. Apart from these direct customer benefits, our TADF technology does not contain any rare elements, which allows for the fabrication of sustainable OLED technology. In this work, we highlight several of our recently developed blue TADF materials and demonstrate the grave impact of the stack architecture on the performance of TADF-OLEDs. Basic material properties as well as first device results are discussed. In a bottom-emitting device, a CIEx/CIEy coordinate of (0.16/0.17) was achieved with efficiency values close to 20% EQE.
Presentation	Gasparini, Nicola	Counterintuitive design rules yield ternary OPVs with reduced recombination	The concept of ternary blend bulk-heterojunction (BHJ) solar cells based on organic semiconductors consisting of two donor materials and one acceptor constitutes an exciting opportunity to further extending the spectral absorption of current generation organic photovoltaics and record efficiencies exceeding the commercially important 10% threshold are recently achieved. However, a deep study on understanding the recombination behaviour is still missing. Here, we demonstrate how to overcome those recombination thresholds by design of advanced material composites leading to an unprecedented high fill factor of 77% in ternary blends. Extending beyond the typical sensitization concept, we add a highly ordered polymer that, in addition to enhanced absorption, overcomes limits predicted by classical recombination models. An effective charge transfer from the disordered host system onto the highly ordered sensitizer effectively avoids traps of the host matrix and features an almost ideal recombination behavior. To shine light onto the microstructure and transport of our ternary devices, we performed various optoelectrical techniques such as current-voltage characterization with different light intensities, EQE measurement, photoinduced charge carrier extraction by linear increasing voltage (Photo-CELIV) technique, transient photovoltage (TPV) and charge extraction (CE) measurements in combination with structural analysis such as grazing incidence wide angle X-ray scattering (GIWAXS), soft X-ray scattering (R-SoXS), Secondary ion mass spectrometry (SIMS) and transmission electron microscopy (TEM).

Presentation	Gong, Xiong	Novel CH3NH3Pb1-xCoxI3 Halide Perovskite Based Photovoltaics	In this work, we report the utilization of cobalt (Co), which possesses a much smaller cationic radius (70 pm) than that of Pb2+ (119 pm), to partially substitute Pb for forming novel CH3NH3Pb1-xCoxI3 (where x= 0.1, 0.2 and 0.4) perovskite hybrid materials. It is found that the perovskite crystal structure is transited from the tetragonal phase (CH3NH3PbI3) to the cubic phase (CH3NH3Pb1-xCoxI3, where x= 0.1 and 0.2) with superior thin film morphology, and then to the mixture of cubic and tetragonal phases (CH3NH3Pb0.6Co0.4I3) with inferior thin film morphology. In addition, the CH3NH3Pb1-xCoxI3 thin films possesses enlarged grain sizes and both high electron mobilities and electrical conductivities. As a result, over 30% improved power conversion efficiency and triply increased photodetectivity, which are originated from the enhanced photocurrents and the restrained dark currents, are observed from photovoltaics fabricated by the CH3NH3Pb0.9Co0.1I3 thin film.
Presentation	Grazulevicius, Juozas V.	New organic luminophores showing thermally activated delayed fluorescence preferably for blue OLEDs	Metal-free organic luminophores exhibitting thermally activated delayed fluorescence (TADF) are very promising emitters capable of harvesting both singlet and triplet exactions, for efficient organic light-emitting diodes [1]. TADF can be observed for organic materials with the negligible energy gap between the their lowest singlet and triplet states leading to reverse intersystem crossing from triplet to singlet states and emitting long-lived (delayed) fluorescence [2]. For the fabrication of blue OLEDs with high internal quantum efficiency, blue TADF emitters which can provide high photoluminescence quantum yield (PLQY) are required.In this presentation the synthesis and characterization of the thermal, photophysical, electrochemical, electron photoemission, charge-transporting, and electroluminescent properties of several series of new TADF emitters will be reported. For instance, series of mono- and di-substituted perfluorinated biphenyls with donor units such as 9,9-dimethylacridane, phenoxazine, phenothiazine and 2,7-dimethoxycarbazole were synthesized and studied. PLQY of one TADF compound (?max=458 nm) was found to be as high as 72 % in host films at room temperature.AcknowledgementThis research was supported by H2020-ICT-2014/H2020-ICT-2014-1 project PHEBE (grant agreement No 641725).References[1] Lin, T.-A.; Chatterjee, T.; Tsai, W.-L.; Lee, W.-K.; Wu, M.-J.; Jiao, M.; Pan, K.-C.; Yi, C.-L.; Chung, C.-L.; Wong, K.-T.; Wu. C.-C. Adv. Mater., 2016, DOI: 10.1002/adma.201601675.[2] Uoyama, H.; Goushi, K.; Shizu, K.; Nomura, H.; Adachi, C. Highly Efficient Organic Light-Emitting Diodes from Delayed Fluorescence. Nature, 2012, 492, 234-238.
Presentation	Holmes, Russell J.	Probing dark exciton diffusion using photovoltage	Excitons are commonly tracked by measuring their end-of-lifetime products: either photons from radiative decay or charge carriers from exciton dissociation. While tracking luminescence provides a measurement of the exciton diffusion length (LD) for many materials, non-luminescent (dark) materials are inaccessible via such techniques. For dark materials, the charge carriers generated from exciton dissociation are tracked to estimate LD (e.g., by fitting device external quantum efficiency), despite the fact that photogenerated carriers are often subject to recombination events prior to collection as current. In this talk, we present an alternate method of measuring LD, equally applicable to luminescent and dark materials, that uses photovoltage to determine the number of excitons reaching the dissociating interface in an organic photovoltaic device. Use of the photovoltage sidesteps charge carrier recombination providing an unobscured measurement of LD. The approach can be further extended to probe the timescale for exciton harvesting at a donor-acceptor interface by measuring the transient photovoltage after short-pulsed optical excitation. Combining the value of LD extracted from photovoltage measurements with the diffusion time extracted from transient photovoltage, the diffusivity of the state responsible for photoconversion may be extracted, regardless of its luminescence efficiency. The ability to directly measure, using a straightforward technique, the diffusion of dark excitons offers the potential for a fuller characterization of excited state transport in organic semiconductors not accessible via luminescence-based probes.

Presentation	Kim, Ji Han	A new pyrrolocarbazole donor moiety for stable and highly efficient green thermally activated delayed fluorescent emitters	A new pyrrolocarbazole donor moiety was synthesized using the carbazole and pyrrol moieties. The new donor moiety, 3-phenyl-3,10-dihydropyrrolo[3,2-a]carbazole (PrCz), showed stronger donor strength than carbzole moiety and was relatively stable in comparison with acridine moiety. So, we synthesized a TADF emitting material, 10-(4-(4,6-diphenyl-1,3,5-triazin-2-yl)phenyl)-3-phenyl-3,10-dihydropyrrolo[3,2-a]carbazole (PrCzPTrz), using the PrCz donor moiety. Through the Gaussian simulation (B3LYP 6-31G* basis set), the highest occupied molecular orbital (HOMO) of PrCzPTrz was distributed on the PrCz moiety and the lowest unoccupied molecular orbital (LUMO) was widely distributed on the diphenyltriazine moiety. The HOMO and LUMO orbitals of PrCzPTrz was overlapped each other on the phenyl linker between the donor and acceptor group. The HOMO level of PrCzPTrz can be assumed to be -5.78 eV from the oxidation potential of cyclic voltammetry measurement and the LUMO level of PrCzPTrz was calculated to be -3.14 eV from the reduction potential. Solid PL emission peak of PrCzPTrz was observed at 458 nm and phosphorescent emission peak was detected at 470 nm. The singlet energy and triplet energy of PrCzPTrz were 2.70 eV and 2.64 eV from emission peak. A high maximum external quantum efficiency of 17.7 % was achieved in the PrCzPTrz based green TADF device, which was higher than that of the TADF device with a carbazole donor. Furthermore, the lifetime of the PrCzPTrz was longer than that of the TADF device with an emitter derived from acridine.
Presentation	Kim, Joo-Hyun	Understanding the influence of molecular weights on the morphology and photocurrent generation in low-bandgap organic photovoltaics	Conjugated polymers with diketopyrrolopyrrole (DPP) units have been widely used as low-bandgap materials. The PDPP3T has a very broad absorption up to 900 nm but the morphologies of its blend film should be optimized to produce the high photocurrent from the corresponding absorption ranges. Therefore, we have controlled the nano-morphologies of the photoactive layers by using PDPP3T with different molecular weights of 42K, 73K, and 102K. As the solution temperature was reduced during the film formation, high molecular weight PDPP3T induced fast aggregation because of its limited solubility, resulting in the small and impure domains. However, low molecular weight PDPP3T resulted in less aggregation and its blend film exhibit large domains with high average domain purity. The blend film with medium molecular weight PDPP3T exhibited the maximized photovoltaic efficiencies as high as 7.05 % from the optimized compromise in size and purity, which provides efficient exciton dissociation and charge transport, respectively. We could obtain the internal conversion efficiency as high as 80 % because optimum molecular weight of PDPP3T led the sophisticatedly controlled nanomorphology and produced high yield of polarons by reducing undesirable nongeminate recombination of charge carriers.
Presentation	Kwon, Jang Hyuk	Highly Efficient Thermally Activated Delayed Fluorescent Materials	In this study, we report our new designed and synthesized blue and green thermally activated delayed fluorescence (TADF) emitters with short exciton lifetime and high efficiency by incorporating structurally rigid goups and reduced non-radiative process . From the transient photoluminescence decay, we evaluated prompt and delayed fluorescence charateristics. The delayed fluorescent lifetime of our new blue and green TADF emitters were very short as 1.88 and 1.37 μs, respectivlely. Also, photoluminescence quantum yields are nealy 100%. Device performances of blue and green TADF show high maximum external quantum efficiency (EQE) of 24.8 and 28.8%, respectively. Especially, efficiency roll-off was drastically reduced in green TADF device, EQE at 1,000 cd/m2 and 10,000 cd/m2 were 28.6 and 24.9%, respectively. Additionally, maximum luminance was very high as 120,000 cd/m2, It means that our green TADF material must have good stability. Color characteristic of blue TADF device demonstrated deep blue of (0.14, 0.15) CIE color coordinates, and green TADF devices has (0.33, 0.58) CIE color coordinates.Detaied material and device results will be discussed in the presentation.

Presentation	Lamport, Zachary	Fluorinated benzalkylsilane molecular rectifiers	The relationship between the molecular structure and electrical characteristics of molecular rectifiers is a subject of much debate. To elucidate this relationship we examined seven alkylated silane self-assembled monolayers (SAMs) with varied lengths and polar fluorine-containing terminal groups. The electrical properties were determined using a metal/SAM/metal structure where the bottom contact was highly doped silicon and the top contact was eutectic gallium indium (EGaIn). The use of a silicon bottom contact enabled the formation of highly stable SAMs on the native oxide present on the surface without costly and time consuming procedures necessary to create extremely flat metallic surfaces. The molecular rectifiers showed a high uniformity and yield, as well as a good resistance to bias stress. We measured current rectification ratios between 20 and 200 depending on the structure, degree of order, and internal dipole of each molecule. The largest obtained value is on par with the best reported on molecular diodes. In addition, we found that the rectification ratio correlates positively with the strength of the molecular dipole moment, while an increase in molecular length results in a decreased rectification. We relate the observed dependence to the changes in the net electric field experienced by the molecules due to the local electric field generated by, and directly proportional to, the molecular dipole moment, which modifies the shape of the tunneling barrier and thus the magnitude of the current.
Presentation	Lee, Dong Ryun	Highly efficient blue and green thermally activated delayed fluorescent devices with external quantum efficiencies of 25%	Development of emitting materials with high external quantum efficiency (EQE) is one of the most important issue to commercialize organic light-emitting diodes (OLEDs). It is necessary to use all generated excitons to enhance quantum efficiency of OLEDs. Thermally activated delayed fluorescence (TADF) has been spotlighted as a way to utilize 100% generated excitons. However, EQEs of OLEDs using TADF emitters are inferior to that of phosphorescent OLEDs, especially in blue devices. Therefore, design strategies for highly efficient TADF emitter should be developed.In this work, we study design strategy in depth and provide an approach to develop efficient TADF emitting materials. Triazine derivatives with three donor moieties, 9,9',9?-(5-(4,6-diphenyl-1,3,5-triazin-2-yl)benzene-1,2,3-triyl)tris(9H-carbazole) (TCzTrz) and 9,9',9?-(5-(4,6-diphenyl-1,3,5-triazin-2-yl)benzene-1,2,3-triyl)tris(3,6-dimethyl-9H-carbazole) (TmCzTrz), were synthesized to improve the material with two donor moieties, 9,9'-(5-(4,6-diphenyl-1,3,5-triazin-2-yl)-1,3-phenylene)bis(9H-carbazole) (DCzTrz), which reported in previous paper. Additionally, 9,9'-(2-(3,6-dimethyl-9H-carbazol-9-yl)-5-(4,6-diphenyl-1,3,5-triazin-2-yl)-1,3-phenylene)bis(9H-carbazole) (DCzmCzTrz) with one 3,6-dimethylcarbzole and two carbazoles was prepared to investigate the influence of uniformity of the HOMO distribution. As a result, TADF devices with TCzTrz and TmCzTrz which have three donor moieties and uniform HOMO distribution showed high EQE of 25.0 and 25.5% , respectively.
Presentation	Lee, Jiun-Haw	Blue electroluminescence by triplet-triplet annihilation upconversion	Triplet-triplet annihilation upconversion (TTAUC) is a process involving two molecules: a low bandgap sensitizer and a wide bandgap material exhibiting triplet-triplet fluorescence (TTF) characteristics. Sensitizer is excited (optically or electrically) and generates triplet excitons through intersystem crossing. Then, the triplets of the sensitizer transfer the energy to the triplets of the TTF material and give delayed fluorescence.Here, we demonstrate a blue electroluminescence by TTAUC process. In our device, the turn-on voltage value (in terms of V) of the blue emission was lower than the bandgap value (in terms of eV) of the TTF material. Such “sub-bandgap” blue electroluminescence was observed because the carrier recombined at the low bandgap sensitizer, which is an important characteristic of TTAUC process. Yellow exciplex, coming from the interface of the electron donor and acceptor material, served as the sensitizer for TTAUC process. The electron acceptor material was also a TTF material with blue emission. Only delayed fluorescence emission (without prompt fluorescence) from the transient electroluminescence measurement was observed, which meant no direct recombination happened on the TTF material. All emission came from the triplet exciton generated from the exciplex transferred the energy to the TTF material, which provided the direct evidence of TTAUC process accounting for this blue emission.

Presentation	Lenze, Martin R.	The Influence of Impurities on Merocyanine based Organic Solar Cell Performance	The influence of impurities, which are accidentally formed during synthesis and purification of a merocyanine dye, on the performance of bulk heterojunction (BHJ) solar cells is investigated. By stepwise purification of the synthesis' crude product, several byproducts are isolated and characterized by NMR spectroscopy, mass spectrometry as well as cyclic voltammetry (CV). The impact of the main impurity – a hydroxylated species of the donor – on solar cell characteristics is analyzed in photovoltaic devices by intentional addition to the mixture of the donor and acceptor of the BHJ system. All measurements on solar cells indicate that the impurity acts as a trap for charge carriers in the donor/acceptor blend, which is in accordance with its redox properties. A sudden drop in photocurrent – and consequently power conversion efficiency – with a threshold impurity level of 0.1mol% emphasizes the demand on high purity materials to achieve highly efficient and reproducible organic solar cells. The experimental results are additionally supported by numerical simulations of the photovoltaic device, which yield further information on the distribution of traps within the BHJ network. Our results allow to predict – to some degree – the influence of traps on device performance in dependence of both trap depth as well as concentration.
Presentation	Lin, YunHui L.	Enhanced sub-bandgap efficiency of a solid-state organic intermediate band solar cell using triplet-triplet annihilation	Conventional solar cells capture photons with energy above the bandgap of the active layer while losing lower energy photons. A molecular intermediate band solar cell (IBSC) overcomes this loss by capturing the energy of sub-bandgap photons in the triplet exciton state of a molecule capable of undergoing triplet-triplet annihilation (TTA). The TTA process pools the energy of two triplet states into a high energy singlet state that is then collected as charge, essentially allowing the triplet state to serve as a stepping stone for the absorption of low energy photons that would have otherwise been wasted. Such a device has a high limiting power conversion efficiency—essentially equal to that of the singlet fission solar cell—but has not received much research attention.Here, we report a solid-state IBSC that uses TTA for enhanced photocurrent response to sub-bandgap light. In this system based on platinum(II) tetraphenyltetrabenzoporphyrin (PtTPBP), a-sexithiophene (a-6T), and diindenoperylene (DIP), the triplet state of a-6T is populated by a phosphorescent sensitization process using PtTPBP and, following TTA, the a-6T singlet excitons are dissociated at the a-6T/DIP donor/acceptor interface. In this system, TTA is found to contribute up to 12% enhancement in photocurrent generation at the peak of PtTPBP absorption under background light intensities less than 0.1 mW/cm2. Femtosecond resolution transient absorption spectroscopy measurements provide evidence for the sensitization mechanism, while external quantum efficiency measurements of devices demonstrate the effectiveness of the upconversion process.
Presentation	Lo, Chi Kin	WHY EVERY ATOM COUNTS: FUNDAMENTAL IMPACT OF A MINIMAL STRUCTURAL CHANGE IN CONJUGATED POLYMERS FOR ORGANIC PHOTOVOLTAICS	As many p-conjugated polymers provide high solar power conversion efficiencies (6-10%) in bulk-heterojunction (BHJ) organic photovoltaics (OPVs), it is important to develop an understanding of how the primary repeat unit structures can ultimately impact device performance. In this work, we have changed the Group 14 atom (C, Si, Ge) at the center of a bithiophene fused ring. Three donor-acceptor conjugated alternating copolymers with a minimal "one-atom" structural change were obtained with similar number average molecular weights ranging from 21 to 27 kDa (ÐM: 1.4-1.7). Solution 1H nuclear magnetic resonance results indicated that poly(dithienosilole-alt-thienopyrrolodione), P(DTS-TPD), and poly(dithienogermole-alt-thienopyrrolodione), P(DTG-TPD), possessed multiple backbone conformations at room temperature and reorganized at elevated temperature. In a grazing incidence wide angle x-ray scattering (GIWAXS) study, we observed that P(DTC-TPD) forms an edge-on configuration with respect to the silicon substrate, while P(DTS-TPD) and P(DTG-TPD) form a face-on configuration, which is favorable for vertical charge transport in OPV devices. Utilizing transient absorption spectroscopy (TAS), we found that P(DTC-TPD):PC71BM has a stronger bimolecular recombination leading to the formation of triplet exciton than P(DTS-TPD):PC71BM and P(DTG-TPD):PC71BM. As a result, the power conversion efficiencies (PCEs) of P(DTS-TPD):PC71BM and P(DTG-TPD):PC71BM were 7.0% and 7.7%, respectively, which were higher than PCE of 5.70% generated by P(DTC-TPD):PC71BM.

Presentation	Ohisa, Satoru	A Solution-Processed Heteropoly Acid Containing MoO3 Units as a Hole-Injection Material for Highly Stable Organic Light-Emitting Devices	We report hole-injection layers (HILs) comprising a heteropoly acid containing MoOx units, phosphomolybdic acid (PMA), in organic light-emitting devices (OLEDs). PMA possesses outstanding properties, such as high solubility in organic solvents, very low surface roughness in the film state, high transparency in the visible region, and an appropriate work function (WF), that make it suitable for HILs. We also found that these properties were dependent on the post-baking atmosphere and temperature after film formation. When the PMA film was baked in N2, the Mo in the PMA was reduced to Mo(V), whereas baking in air had no influence on the Mo valence state. Consequently, different baking atmospheres yielded different WF values. OLEDs with PMA HILs were fabricated and evaluated. OLEDs with PMA baked under appropriate conditions exhibited comparably low driving voltages and higher driving stability compared with OLEDs employing conventional hole-injection materials (HIMs), poly(3,4-ethylenedioxythiophene):poly(4-styrenesulfonate), and evaporated MoO3, which clearly shows the high suitability of PMA HILs for OLEDs. PMA is also a commercially available and very cheap material, leading to the widespread use of PMA as a standard HIM.
Presentation	Osiak, Jaroslaw G.	Isomerization of Iridium(III)complexes: An approach towards isomerically pure high performance materials	The increasing use of organic thin-film electronics keeps challenging scientists and companies to develop new and highly pure materials for reliable high performance devices. Well established materials in thin film devices like organic light emitting diodes (OLEDs) are iridium based organometallcomplexes. Those materials are used for instance as holetransporting-, matrix- or emittingmaterials. When it comes to terms of purity an often neglected aspect is the isomerical pureness of the used materials within devices. Homoleptic iridium(III) complexes used in OLEDs usually consist of two different isomers (meridional and facial) which feature different physical and photophysical properties. For some materials even traces of the undesired isomer might change the operation properties of a thin film device.In this study we present a reliable acid mediated isomerization procedure for the conversion of iridium(III) complexes into their most thermodynamically stable form. The presented procedure is scalable up to large amounts of the desired compounds and additionally features under optimized an in situ purification from other impurities. The materials used for the investigation are primarily iridium(III) complexes used for blue and deep blue OLEDsThe practical application of the isomerization procedure is discussed in the background of chromatographic and theoretical investigations. Furthermore the structures of the obtained materials are investigated and discussed regarding their photophysical properties like quantum efficiencies, decay times and their influence on processed OLEDs.
Presentation	Park, Yongsup	Manipulation of Carrier Injection Barriers of Multilayer Graphene Electrode for OLED	As the flexible OLED display technology will rapidly become commonplace, the development of flexible electrode becomes ever more important. Multilayer graphene (MLG) is one of the most promising candidates for such application.In this paper, we demonstrate that the MLG surface can be modified to accommodate the roles of both anode and cathode in a high efficiency OLED. We employed ultraviolet photoemission spectroscopy (UPS) to determine the charge carrier injection barriers. We show that the barriers can be minimized for electron injecting cathodes by, first, depositing thin layer of Cs2CO3 before depositing electron transporting layer (ETL) materials such as 1,3-Bis(3,5-di-pyrid-3-yl-phenyl)benzene (BMPYPB). We also explore the possibility of doping other ETL materials including 1,3,5-Tri[(3-pyridyl)-phen-3-yl]benzene (TMPYPB) and Tris(2,4,6-trimethyl-3-(pyridin-3-yl)phenyl) borane) (3TPYMB) with Li metals. Both methods resulted in a very small barrier height of less than 0.2 eV as revealed by the UPS.We further studied the possibility of gentle O2 plasma treatment to increase the work function (WF) of the MLG surface and to use them as anode. We show that MLG WF can be made as high as 6.5 eV and the hole injection barriers can also be minimized down to about 0.3 eV when hole transporting layer (HTL) materials like 4,4'-Cyclohexylidenebis[N,N-bis(4-methylphenyl)benzenamine] (TAPC) was deposited on the plasma treated surfaces. The X-ray photoemission spectroscopy data shows that the MLG surface remained largely intact after the O2 plasma treatment exhibiting only slight oxidation.

Presentation	Pflumm, Christof	Influence of auxiliary layers on OLED performance	It is a well known fact that the performance of OLED devices is strongly influenced by the properties of charge transport and blocking layers, even if they are not in direct contact with the emission layer. This means that the various trade-offs which exist, e.g. voltage vs. lifetime, can be tuned by a variation of these layers and fitted to the application at hand. To elucidate this, we will present different case studies and show how systematic variations of the auxiliary layers influence the performance of OLED devices. The focus will lie on changing the charge balance of the devices by introducing additional layers to hinder electron or hole flow into the emission layer. We will show how various device parameters like efficiency roll-off, maximum efficiency, voltage etc. are influenced and also elucidate the dependence on the properties of the emission layer. For this, mixed host emission layers will be used which can be tuned from electron dominated to hole dominated by varying the ratio between the electron and hole conducting material.
Presentation	Pu, Yong-Jin	Fluorescent molecules having spatially orthogonal two anthracenes for organic light emitting devices	In order to convert the non-emissive triplet excitons to the emissive singlet excitons in OLEDs, two approaches have been reported: triplet-triplet annihilation (TTA) and thermally activated delayed fluorescence (TADF). In addition to these two approaches, reverse intersystem crossing (RISC) at electron-hole pair, charge transfer complex (CT), or higher excited state (Tn = 2) have been proposed.[1,2]We compared the compound having a single anthracene unit, 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN) and the compound having spatially orthogonal two anthracenes, 10,10'-diphenyl-9,9'-bianthracene (PPBA), in terms of RISC process in OLED devices. The OLEDs with PPBA showed absence of delayed electroluminescence, while the OLEDs with MADN showed large delayed electroluminescence component derived from reproduced singlet excitons through TTA process. Magnetic field dependence of the devices with MADN was negative due to suppression of TTA process, whereas the devices with PPBA showed small positive dependence on the magnetic field, also supporting the absence of TTA process. TD-DFT calculation revealed that PPBA has two degenerated lowest triplet states (T1 and T2) with much lower energy than S1, and near-zero ?EST between Sn = 1 and Tn = 2. Small vibronic coupling constants between Tn and T1 supported the forbidden transition from Tn to T1.[1] M. Segal et al., Nature Mater. 6, 374 (2007); S. Difley et al., JACS 130, 3420 (2008); L. Yao et al., Angew. Chem. Int. Ed. 126, 2151 (2014); T. Sato et al., J. Mater. Chem. C 3, 870 (2015).[2] J.-Y. Hu et al., Adv. Funct. Mater. 24, 2064 (2013).
Presentation	Ratcliff, Erin L.	Influence of Microstructure on the Kinetics of Charge Transfer and Ion Migration at Polymer/Liquid Interfaces for Applications in Bio-electrochemical Devices	Semiconducting polymers present a low cost and flexible alternative to inorganic semiconductors for applications ranging from environmental and biomedical sensors to electrochromic windows and photoelectrochemical devices. In bioelectronics, the ability for chemical species and ions to readily intercalate through the nonporous structure has enabled high signal amplifications. However, technological implementation has thus far been hindered by the inability to control polymer microstructure, and as a result, the inability to truly control electronic and ionic charge carrier flow. Improving the understanding of the inter-connected processing, structural properties and functionality is therefore crucial to promoting further advancement of next-generation polymeric electronics. In this present work, the effects of varying morphology and molecular order in thin polymeric films are probed. Preparation of thiophene-based films via i.) spin casting or by electrochemical deposition using ii.) potentiostatic or iii.) pulsed-potential methodologies yielded varied crystallinity, electronic structure, and adhesion properties, as demonstrated using spectroelectrochemical measurements, grazing incidence wide angle X-ray scattering (GIWAXS), and photoelectron spectroscopies (UPS, XPS, NEXAFS). Electrochemical impedance spectroscopy (EIS) at varied bias potentials reveals a comprehensive picture of mass transport and interface charge transfer at the nano-porous polymer/liquid interfaces, which is shown to vary with doping levels within the polymer. Finally, scanning electrochemical microscopy (SECM) is utilized under several operation modes to validate how processing conditions impact the voltage-dependent kinetics to a well-characterized redox probe as a model system for biological sensing. Limitations of existing SECM approaches and the need for new characterization techniques will also be discussed.

Presentation	Ratzke, Wolfram	Novel dual singlet-triplet OLED emitters as local probes of spin correlations	In recent years, OLEDs have been shown to be an excellent choice to probe miniscule changes in magnetic fields[1] owing to the long lifetime of spin-spin correlations of weakly bound carrier pairs, the precursors to emissive excitons. Being sensitive to dipole-dipole[2], hyperfine[3], and spin-orbit interactions, the correlations manifest as singlet-triplet interconversion. To date, direct observation of these interconversions by doping with appropriate emitter moieties has not succeeded conclusively, since this requires detection of both singlet and triplet excitonic states through the emitted fluorescence and phosphorescence. We recently described metal-free dual emitters based on localized spin-orbit interactions and succeeded in observing simultaneous distinct electrofluorescence and -phosphorescence at room temperature.[4] Now, a range of related molecular structures with thiophene-based sidechains have been investigated in terms of their dual emission characteristics. While the local spin-orbit coupling due to the mixing of np* and pp* states fundamentally enables the radiative transition from the triplet state, the availability of nonradiative decay channels eventually determines the phosphorescence yield. Minor modifications to the molecular structure changes the conjugation pattern and access of the excited state to nonradiative relaxation channels. Remarkably, dual singlet-triplet emission with triplet lifetimes of over 150ms at room temperature can now be achieved in OLEDs by controlling the molecular rigidity.[1] W. J. Baker et al., Nature Commun. 3, 898 (2012)[2] K. J. van Schooten et al., Nature Commun. 6, 6688 (2015)[3] H. Malissa et al., Science 345, 1487 (2014)[4] D. Chaudhuri et al., Angew. Chem. Int. Ed. 49, 7714 (2010)
Presentation	Ro, Hyun	Morphology-insensitive Performance Facilitates Transition from Spin- to Roll-to-Roll-Coating For Solution-Processed Solar Cells	Solution processing via roll-to-roll (R2R) coating promises a low cost, low thermal budget, sustainable revolution for the production of solar cells. Yet virtually all high performance solution processed research cells have been demonstrated by spin-coating, a low-volume manufacturing process. We shall present device and morphology studies of an efficient organic photovoltaic system [1] (PffBT4T-2OD:PC71BM) deposited by blade-coating – a high volume manufacturing compatible technique. Significant aspects of the film morphology, average crystal domain orientation and characteristic phase separation length distribution, are markedly different when deposited by blade-coating compared to spin-coating. Interestingly device performance similar to spin-coating could be achieved when coated as greater than ?250 nm thick films. Our studies [2] suggest that high performance systems that are manufacturable characteristically support diversity in the morphology while maintaining similar performance. We further confirm that blade-coating is a valuable prototyping technique for R2R coating by demonstrating nominally identical morphologies for both piece blade-coating and continuous-web, slot- die coating.References:[1] Y. Liu, J. Zhao, Z. Li, C. Mu, W. Ma, H. Hu, K. Jiang, H. Lin, H. Ade, H. Yan, Nat Commun 2014, 5, 5293.[2] H. W. Ro, J. Downing, S. Engmann, A. A. Herzing, S. Mukherjee, M. Abdelsamie, L. K. Jagadamma, Y. Liu, A. Amassian, D. M. DeLongchamp, H. Ade, H. Yan, L. Richter, (communicated).
Presentation	Roland, Steffen	The loss mechanism in FTAZ:ICBA bulk heterojunction solar cell with open circuit voltage larger than 1 V	The active layer of polymer solar cells has long been a blend of a donor polymer and a fullerene derivative, in particular, PCBM (phenyl-C61-butyric acid methyl ester). To further improve one of the key device characteristics, open circuit voltage (Voc), indene-C60 bisadduct (ICBA), having a higher LUMO (lowest unoccupied molecular orbital) than that of the PCBM, has been actively explored. Poly(3-hexylthiophene) (P3HT):ICBA is the most successful example where the Voc of the P3HT:ICBA device was significantly improved compared with that of the P3HT:PCBM device, while the short circuit current (Jsc) and fill factor (FF) remained almost unchanged. In this study, ICBA was blended with a high-performing polymer, fluorinated poly(benzodithiophene-benzotriazole) (FTAZ), which has a similar band gap as that of P3HT. The FTAZ:ICBA device indeed shows a much higher Voc (up to 1V), however, it suffers from lower Jsc and FF, compared with these of the FTAZ:PCBM device. Transient and steady state methods were performed to carefully determine recombination losses and mobilities in these systems. It was found that an insufficient driving force for exciton separation, a much low electron mobility and a fast, first order recombination process, all lead to the poor Jsc and FF in the FTAZ:ICBA device.

Presentation	Rumbles, Garry	Role of Carrier Delocalization on Long-lived Free Carriers in Conjugated Polymers and Single-Walled Carbon Nanotubes	We will report on two studies in media of low dielectric constant, where the production of high yields of long-lived photogenerated carriers can be attributed to the delocalization of at least one of the charges. To make these investigations we use a variety of spectroscopic techniques that includes flash photolysis, time-resolved microwave conductivity (fp-TRMC), ultra-fast transient absorption spectroscopy (fTA), and time-resolved photoluminescence spectroscopy (TRPL).First, a study of charge carrier generation in a number of polymer systems where the solid-state microstructure (SSM) of the thin films can be controlled using both molecular structure and processing conditions will be discussed. By incorporating a low concentration of molecular acceptors, such as metallo-phthalocyanines and substituted fullerenes, the driving force for photoinduced electron transfer can be controlled through the excited state energy and the reduction potential. We will also include a discussion of the recombination process through an emissive exciplex state.In a second, but related, study we will report on the high yields of long-lived carriers in dilute toluene solutions of chiral-pure, polymer-wrapped single-walled carbon nanotubes (SWCNTs). We will explain how these charges are generated by direct excitation of the carbon nanotubes, and the importance of the excitation wavelength on the yield of charges.
Presentation	Salvador, Michael	Antioxidants enhance the Photooxidation Stability of Semiconducting Polymers and Blends	Organic semiconductors have been envisioned and reported for many disruptive technologies but tend to suffer from electro-optic performance roll-off, mainly due to reduced photofastness. This translates into the need for careful encapsulation strategies, compromising both applicability and cost benefits. Conceptually new strategies are necessary to suppress degradation reactions.In the plastic and rubber industry, stabilizing additives are an integer part of the final formulation, preventing photooxidation induced photobleaching and radical reactions. A wide catalog of stabilizing additives exists with typically very specific function and compatibility. These antioxidants represent an exciting opportunity for enhancing the life span of organic photovoltaics but remain mostly unexplored in the case of organic semiconducting polymers. Here, we report stabilizing additives that successfully delay the photooxidation kinetics of a wide range of organic semiconducting polymers. We report a quantitative assessment of the degradation kinetics in the absence and presence of antioxidants for pristine polymers and for polymer-fullerene blends. We elucidate the most prominent reactive species and the working mechanism of successful stabilizing additives. We further present the interference of the antioxidant with respect to the morphology of the active layer and the functionality of full devices. Our results suggest that stabilizing additives could represent a universal toolbox for stabilizing organic electronic devices, thus alleviating the requirement and cost for barrier materials.

Presentation	Schwenke, Tasja	Tuning Photophysical Properties and Solvent Behaviour of Printable Small Molecule Cationic Iridium Complexes for the Electrooptical Application	Vapor deposition and solution processing of materials are two established techniques for fabricating organic light emitting diodes (OLEDs). High vacuum vapor deposition is the tool of choice to produce OLEDs with excellent purity and quality and allows the deposition of complex device structures. However one of the major drawbacks of this process are the high production costs. A promising alternative for the low-cost mass production of devices like flexible large area displays and lighting elements is the solution processing of OLED materials. But this method is associated with several disadvantages. Avoiding the partial dissolving of neighbouring layers in the devices is still a great challenge because orthogonal solvent systems are necessary. Therefore cationic small molecule iridium (III) complexes are interesting due to their good solubility in polar solvents and even in aqueous media. Small molecules tend to crystallise in layers which results in an insufficient device performance. With structure variation of ligands and counter ions, for example through sterical demanding groups, emission wavelength, solubility and degree of crystallinity of cationic iridium (III) complexes can be influenced.In our investigation a series of cationic heteroleptic iridium (III) complexes based on pyridines, benzimidazoles and pyrazoles was synthesized and combined with different counter ions (PF6, SbF6, ClO4, BPh4, BF4, OTf4). Moreover the common matrix materials triphenylamine and a-NPB were modified for usage as counter ions. The absorption, photoluminescence, cyclic voltammetry and quantum efficiency of all complexes were investigated. In first experiments OLED devices, which were partially produced from solution, were shown.
Presentation	Stiff-Roberts, Adrienne D.	Solar Cell Materials Deposited using Emulsion-based, Resonant Infrared, Matrix-Assisted Pulsed Laser Evaporation	Resonant infrared MAPLE (RIR-MAPLE) uses infrared laser radiation that is resonant with solvent-specific bond energies to minimize degradation of organic materials during thin-film deposition. The emulsion-based approach (i.e., frozen host matrix comprises uniformly mixed solvent and water) takes advantage of hydroxyl bond vibrational modes in water to resonantly absorb 2.94 μm radiation from an Er:YAG laser. The typical emulsion target comprises the guest material, primary solvent, secondary solvent, deionized (DI) water, and surfactant. Proper selection of the emulsion components has the most significant and direct impact on film properties. Emulsion-based RIR-MAPLE is versatile because the organic material and compatible solvent are completely decoupled from the absorption of laser energy. As such, the technique is appropriate for many polymers, small molecules, nanoparticles, and hybrid nanocomposites.In this work, we report RIR-MAPLE deposition of different material systems for solar energy conversion, including polymer-small molecule bulk heterojunctions and hybrid organic-inorganic nanocomposites. Due to the close relationships among nanoscale morphology, charge transport, and organic solar cell device performance, we investigate the effects of the emulsion target recipe on nanoscale morphology and electrical characteristics of organic and hybrid solar cells. In addition, different solar cell active region structures have been deposited by RIR-MAPLE, including bulk heterojunction, bilayer, and gradient compositions. The impact of such active region structures on device performance has also been investigated.

Presentation	Suh, Min Chul	Enhancement of external quantum efficiency in organic light emitting diodes using randomly distributed nano-lens array	There has been a lot of study associated with an enhancement in light extraction efficiency of organic light emitting diodes (OLEDs) to reduce a power consumption of display devices.The representative way to obtain such effect is to introduce a specifically patterned substrate such as micro lens array (MLA). However, there are some limits for applying MLA technology to OLEDs, especially, for display applications due to a pixel blurring effect originated from such periodic patterns.In this study, we simulated optical characteristics including pixel blur effect of OLEDs to obtain optimal pattern size, shape, density, etc. As a result, we found that the randomly distributed nano-lens arrays (RDNLAs) could enhance the light extraction efficiency by ray tracing simulation by~ 29%. Very interestingly, we found that the light extraction effect (e.g. enhancement ratio) is all about the same for the RDNLA with 400 ~ 4000 nm wide nano-lens patterns. To prove such effect, we precisely controlled the diameters of nano-lens hemisphere by using 2D (dimensional) nanoporous polymer films as a template layer for nano-imprinting process. As a result, we found that our RDNLAs could enhance the light by 37.4% when the diameter of the RDNLA was 400 nm.Especially, we didn't observe any serious pixel blur effect when we introduced nano-imprinted RDNLAs while we couldn't exclude pixel blur effect when we attach MLA film on the OLEDs.
Presentation	Suh, Min Chul	New Host Materials with high Triplet Energy for Highly Efficient Blue Phosphorescent OLEDs	A series of new carbazole derivatives with different numbers of pyridine moieties for use as host materials for blue phosphorescent organic light-emitting diodes is reported. Especially, we could obtain those molecules by very simple procedure. A benzene moiety at the center of the host materials was applied to limit the molecular conjugation to increase in triplet energies (T1). And, we applied pyridine moieties to increase the polarity as well as electron affinity of the molecules. In addition, we introduced carbazole moiety to induce a hole transport characteristic, too. Hence all the molecules showed fairly large triplet energy up to 3.07 eV with bipolar character. Finally, we prepared blue phosphorescent devices employing bis(4,6-difluorophenylpyridinato-N,C2)picolinato iridium (III) (FIrpic) as a guest material and the three new carbazole derivatives with numbers of pyridine moieties as host materials exhibited moderately high efficiencies, up to 34.8 cd/A and 17.7 % as a maximum current efficiency and external quantum efficiency, respectively.AcknowledgmentsThis work was supported by the National Research Foundation of Korea (NRF) funded by the Korea government (MSIP) (NRF-2014R1A2A2A01002417) and we was supported by the BK21 Plus Program(Future-oriented innovative brain raising type, 21A20130000018,) funded by the Ministry of Education(MOE, Korea) and National Research Foundation of Korea(NRF).
Presentation	Sun, Jon-Paul	Nano-Embossed Heterojunction Non-Fullerene Acceptor Organic Solar Cells	The bulk heterojunction has been instrumental in accelerating the performance of solution-processed organic solar cells. When optimal film morphology is achieved, power conversion efficiencies in excess of 10% have been demonstrated. However, the combinatorial optimization space required to overcome morphology-limited performance is staggering, with many donor:acceptor pairs failing to reach full potential due to morphological incompatibility. This issue is especially present in the realm of non-fullerene acceptors, where many novel acceptor molecules only find success with a single donor.[1] Sequential spin coating has recently been demonstrated in polymer:fullerene systems, allowing intercalation of the fullerene between polymer chains. Since non-fullerene acceptors are too bulky to intercalate,[2] alternative strategies must be employed. Our approach is to decouple morphology from the film-casting process by utilizing a large-scale and economical nanoimprint lithography technique. Non-fullerene acceptors are used in conjunction with nanoimprinting to form engineered heterojunctions with length scales determined by the mesoporous anodized Al2O3 stamp. This talk will highlight recent results and point to unique processing opportunities and device designs enabled by this new approach.[1] S. M. McAfee, J. M. Topple, I. G. Hill, and G. C. Welch, J Mater Chem A 3, 16393 (2015).[2] N. C. Miller, E. Cho, R. Gysel, C. Risko, V. Coropceanu, C. E. Miller, S. Sweetnam, A. Sellinger, M. Heeney, I. McCulloch, J.-L. Brédas, M. F. Toney, and M. D. McGehee, Adv. Energy Mater. 2, 1208 (2012).

Presentation	SUN, TIANLEI	Polymer semiconductor blends for stretchable organic field-effect transistors	Stretchable electronics have the potential to enable integration of electronics into systems in ways that have not been previously possible, with applications ranging from bio-integration to robotics. Achieving a highly stretchable semiconductor layer without impairing its electrical properties remains one of the greatest challenges to realize these devices. In this study, we introduce an approach to achieve stretchable organic semiconductors by blending polymer semiconductors that exploit reversible plastic deformation of the semiconductor film to achieve high performance charge transport under reversible strains of over 75%.In this study, we focus on blending a rigid high-performance donor-acceptor polymer PCDTPT with the ductile polymer P3HT. We show that the mobility value is stable for films strained up to 75%, and that the films can be stretched up to 100 times from 10% to 75% strain while showing stable performance. Morphologically we characterize the films with optical spectroscopy, X-ray diffraction, and atomic force microscopy. We find that both polymers in the blend film orient in the direction of strain and return to an in-plane isotropic distribution upon strain release. The ductility is attributed to the intermixing ductile P3HT throughout the film thickness, while transistor performance of the high mobility materials is maintained due to vertical segregation of the components in the blend film. Ultimately, the polymer blend process introduced here results in an excellent combination of device performance and plasticity providing a facile approach to achieve highly stretchable electronics.
Presentation	Volz, Daniel	Design rules for the combination of stability and efficiency in blue TADF OLEDs	The lack of stable and efficient deep blue OLED materials remains a big technical issue: Rather inefficient, fluorescent OLEDs yield a satisfactory level of stability, while instable phosphorescent OLED approach the theoretical maximum efficiency. However, the combination of both features in one technical solution is yet to be realized.Materials with thermally activated delayed fluorescence (TADF) promise to cut this Gordian knot. Material with efficiency values of more than 20% EQE and CIE y coordinates in the order of 0.1 have already been shown, while promising progress has been made on the device stability in the last two years. We summarize the status quo and report own, new results. The major factors and design rules on a material and device level have been identified and will be discussed. We will emphasize the TADF-specific factors that need to be taken care when designing stable and efficient stack architectures. With these strategies, it was possible to increase the device lifetime by three orders of magnitude to reach values of more than 1000 hours at relevant starting luminances.
Presentation	Xiao, Zhengguo	Stable and Efficient Perovskite Light Emitting Diodes via Self-assembled Nanometer-sized Crystallites	Organic-inorganic hybrid perovskite materials are emerging as semiconductors with potential application in solar cells, transistors and LEDs. In particular, perovskites are very promising for LEDs due to their high color purity, low non-radiative recombination rates, and tunable emission wavelength. Nevertheless, the small electron-hole binding energy in three-dimensional (3D) perovskite materials result in small electron-hole capture rates for radiative recombination. Ultrathin perovskite emission layers, and/or small perovskite grain size have been employed to spatially confine the electrons and holes to best enable bimolecular radiative recombination. However, due to the rapid crystallization speed of the 3D perovskite materials, the grain sizes are generally around hundreds of nanometers from both one-step and two-step solution processes, with a resulting large surface roughness.In this talk, we will report highly efficient perovskite LEDs enabled through the formation of self-assembled, nanometer-sized crystallites. The addition of large-group ammonium halides such as n-butylammonium halides to the stoichiometric three-dimensional perovskite precursor solution act as a surfactant that dramatically constrains the growth of three-dimensional perovskite grains during film forming, producing crystallites with dimensions as low as 10 nm, and decreasing film roughness to less than 1 nm. These nanometer-sized perovskite grains coated with longer-chain organic cations allow for significant gains in emissivity. Incorporating such films within LEDs allow us to demonstrate external quantum efficiency of 10.4% for CH3NH3PbI3 and 9.3% for CH3NH3PbBr3 as emitters. Additionally, the n-butylammonium halide-incorporated perovskite LEDs exhibit significantly improved shelf stability with no degradation after storage in the glove box for more than four months.

Presentation	Yersin, Hartmut	Highly efficient TADF materials for OLED applications based on Cu(I) and Ag(I) compounds	Highly efficient TADF materials for OLED applications based on Cu(I) and Ag(I) compoundsHartmut Yersin, Rafal Czerwieniec, Alfiya Suleymanova, Marsel ShafikovUniversitaet Regensburg, Germanyhartmut.yersin@ur.deEmitters that show thermally activated delayed fluorescence (TADF) can harvest all singlet and triplet excitons for light generation in an electroluminescent device according to the singlet harvesting mechanism. [1] Important requirements for such materials are short emission decay times at high quantum yields to optimize efficiency, materials' stability and to minimize saturation effects at high device brightness. It has already been demonstrated that Cu(I) complexes are highly attractive for OLED applications. [1-3] In particular, new materials showing combined phosphorescence and TADF decay paths open obvious improvements. [4] Moreover, it is less known that Ag(I) complexes also represent attractive candidates for TADF materials. As an example, we highlight a new Ag(I) complex that shows 100 % emission quantum yield at an extraordinarily short TADF decay time of t(TADF) = 1.4 µs.[1] R. Czerwieniec, J. Yu, H. Yersin; Inorg. Chem. 2011, 50, 8293 H. Yersin, U. Monkowius; DE 10 2008 033563[2] R. Czerwieniec, M. J. Leitl, H. H. H. Homeier, H. Yersin; Coord. Chem. Rev. 2016, in press [3] M. J. Leitl, D. M. Zink, A. Schinabeck, T. Baumann, D. Volz, H. Yersin; Top. Curr. Chem. (Springer) 2016, 374, DOI 10.1007/s41061-016-0019-1[4] T. Hofbeck, U. Monkowius, H. Yersin, J. Am. Chem. Soc. 2015, 137, 399