HL 13: Organic Electronics and Photovoltaics I: Light-Emitting Devices

Time: Monday 11:00–13:00 Location: ZEU 260

HL 13.1 Mon 11:00 ZEU 260

Two-color warm white hybrid OLEDs from thermally activated delayed fluorescence — •Ludwig Popp[1], Paul Kleine[1], Reinhard Scholz[1], Ramunas Lygaitis[1,2], Olaf Zeika[1], Axel Fischer[1], Simone Lenk[1], and Sebastian Reineke[1] — [1]Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, TU Dresden, Germany — [2]Kaunas University of Technology, Lithuania

Thermally activated delayed fluorescence (TADF) takes place in organic molecules where the energy splitting between the lowest excited singlet and triplet states (ST-splitting, ΔE_{ST}) remains sufficiently low. A newly designed sky-blue TADF emitter with an emission maximum at a wavelength of 500 nm reaches a photoluminescence quantum yield of 70% and an external quantum efficiency (EQE) of up to 14.5% in actual organic light-emitting devices (OLEDs).

In this work we use the sky-blue TADF molecule to build warm white hybrid OLEDs by combination with the red phosphorescent emitter $Ir(MDQ)_2(acac)$. Due to the very broad TADF emission, covering a majority of the high-energy visible spectrum, a dedicated deep blue emitter is becoming obsolete for reaching high color rendering indices (CRI > 80).

Furthermore, we demonstrate deeper insight into the energy transfer mechanisms in this hybrid TADF/phosphorescence approach. Time-correlated single photon counting enables to determine the actual exciton decay pathways and delivers a detailed understanding of the excitonic interplay between the particular excited states.

HL 13.2 Mon 11:15 ZEU 260

Conjugation induced thermally activated delayed fluorescence — •Paul Kleine[1], Qiang Wei[2], Yevhen Karpov[2], Xianping Qiu[2], Hartmut Komber[2], Karin Sahre[2], Anton Kiriy[2], Ramunas Lygaitis[1], Simone Lenk[1], Brigitte Voit[2], and Sebastian Reineke[1] — [1]Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, Dresden, Germany — [2]Leibniz-Institut für Polymerforschung Dresden e.V., Dresden, Germany

Thermally activated delayed fluorescence (TADF) has seen tremendous research efforts in the last years. It represents an alternative to phosphorescent emitter materials in organic light-emitting diodes, assuring 100% internal quantum efficiency via effective reverse intersystem crossing of barely radiative triplet to emissive singlet states. While many small molecules have been reported to show efficient TADF, reports on polymers sporting TADF are rare. Up to now, publications cover concepts only, where TADF chromophores are linked to polymer networks, retaining their monomeric properties. In this talk, we discuss a novel strategy that unlocks an additional molecular design rule reserved exclusively for polymeric materials. A π-conjugated cyclic polymer composed of non-TADF building blocks was developed. Conjugation induced HOMO destabilization leads to a decreased singlet-triplet splitting and efficient TADF in the polymer, while the repeating unit shows only inefficient phosphorescence. This conjugation induced TADF concept represents a novel molecular design rule particularly for solution-processable polymeric materials.

HL 13.3 Mon 11:30 ZEU 260

Investigation of organic light emitting diodes based on thermally activated delayed fluorescence via magnetic resonance methods — •Nikolai Bunzmann[1], Sebastian Weissenseel[1], Benjamin Krugmann[1], Jeannine Grüne[1], Stefan Väth[1], Andreas Sperlich[1], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Bavarian Center for Applied Energy Research (ZAE Bayern), 97074 Würzburg

Organic light emitting diodes (OLEDs) based on thermally activated delayed fluorescence (TADF) exhibit a high upconversion rate from non-emissive triplet to emissive singlet states due to a small energy splitting ΔE_{ST} between the respective states. Consequently, the internal quantum efficiency (IQE) of such devices is strongly enhanced. However, the underlying mechanism of reverse intersystem crossing (RISC) is naturally spin forbidden, wherefore spin sensitive measurement methods are desirable in order to elucidate the TADF process. Therefore, we use electrically and electroluminescence detected magnetic resonance (EDMR, ELDMR) techniques. Hereby, transitions between triplet substates, which are split in an external magnetic field, are driven by microwaves, applied via a non-resonant stripline. We evaluate the dependence of multi-frequency ELDMR and EDMR spectra on changes in experimental conditions in order to obtain detailed information about the investigated spin system. Thereby we contribute to a better understanding of the TADF mechnism, which is crucial in order to further improve the performance of OLED based light sources.

HL 13.4 Mon 11:45 ZEU 260

Orientation of Phosphorescent Dopants in Organic Vapor Phase Deposited Films — •Thomas Lampe[1], Matthew J. Jurow[3], Francisco F. Navarro[2], John Facendola[2], Tobias D. Schmidt[1], Peter I. Djurovich[2], Mark E. Thompson Thompson[2], and Wolfgang Brütting[1] — [1]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Department of Chemistry, University of Southern California, Los Angeles, California 90089, United States — [3]The Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, California 94720, United States

Organic vapor phase deposition (OVPD) is an efficient film deposition technique for the preparation of organic thin films. However, the atmospheric conditions during deposition differ from the common thermal evaporation in high vacuum. To investigate the effects of these differences on heteroleptic phosphor orientation in organic guest-host systems we deposited films via OVPD while controlling the substrate temperature during deposition. The measurement of the alignment of the emissive transition dipole moments in samples deposited at room temperature leads to results comparable to preparation via thermal evaporation. Deposition of the film on a cooled substrate reveals a thermally activated behaviour of the molecular alignment process at low temperatures. The confirm an earlier model for the molecular alignment of heteroleptic phosphopors and give further insight into the physical properties of this phenomenon.

[1] M. Jurow, et. al.: *Nature Mat.* **15** (2015), 85-91

HL 13.5 Mon 12:00 ZEU 260

Magnetic resonance at ultra-small fields in PPV-based OLEDs — •Hermann Kraus, Viola Zeller, Sebastian Bange, and John M. Lupton — Universität Regensburg, Universitätsstraße 31, 93053 Regensburg, Deutschland

Large magnetoresistance and magnetoluminescence effects which arise, for example, due to spin-dependent recombination rates are well-known for OLEDs, although models are still under debate given that they remain hard to verify from a measurement of integrated current and luminance. At very low fields a change in the sign of magnetoresistance appears: the so called ultra-small magnetic field effect for which also several models exist.

Spin resonance of paramagnetic species enables direct manipulation of charge carrier and excitonic precursor spins but most work on spin resonance in OLEDs was done at external magnetic fields on the order of several hundred millitesla. While it is also possible to perform these experiments at fields down to a few millitesla it was believed that resonance effects disappear once the external field is of the same order of magnitude as the internal hyperfine fields. We show that electron spin resonance signals are detectable through both the current and the electroluminescence at ultra-small fields corresponding to a few MHz resonance frequency. This demonstration provides insights into the ultra-small magnetic field effect in magnetoresistance as well as testing the principles of magnetic resonance for very low Zeeman splitting.

HL 13.6 Mon 12:15 ZEU 260

Ultrathin metal electrode for bottom-emitting OLEDs on buckled substrates — •Yungui Li, Toni Bärschneider, Paul-Anton Will, Yuan Liu, Simone Lenk, and Sebastian Reineke — Dresden Integrated Center for Applied Physics and Photonics Materials (IAPP) and Institute for Applied Physics, Technische Universität Dresden, 01062 Dresden, Germany

We here report our investigations on nanometer thick, composite ultrathin metal electrodes used in organic light-emitting diodes (OLEDs) comprising buckled substrates. The thin metal electrodes are made of 1 nm molybdenum trioxide (MoO3), 2 nm gold, and 3-15 nm of

silver. A composite electrode with 9 nm silver based on flat glass substrate shows a maximum transparency of about 80% at 455 nm and a sheet resistance of 10 Ω/sq. With reactive-ion etching process, a buckled surface with depths around 50 to 100 nm is designed to extract the trapped light of bottom-emitting OLEDs since total internal reflection in flat device. When the thin metal electrode is utilized for green bottom-emitting OLEDs, the devices show a maximum external quantum efficiency of 17.5% for buckled OLEDs while in contrast only 13.8% for flat devices. Compared to flat devices, buckled devices show the same level of leakage current and better color stability at different angles. The results confirm the high potential of composite thin metal systems as alternative electrode for OLEDs, with the capability of application for bottom- and top-emitting OLEDs on patterned surfaces.

HL 13.7 Mon 12:30 ZEU 260

Impact of charge carrier injection on single-chain photophysics of conjugated polymers — •Felix J. Hofmann, Jan Vogelsang, and John M. Lupton — Universität Regensburg

Charges in conjugated polymer materials have a strong impact on the photophysics and their interaction with the primary excited state species has to be taken into account in understanding device properties. Here, we employ single-molecule spectroscopy to unravel the influence of charges on several photoluminescence (PL) observables. The charges are injected either stochastically by a photochemical process, or deterministically in a hole-injection sandwich device configuration. We find that upon charge injection, besides a blue-shift of the PL emission and a shortening of the PL lifetime due to quenching and blocking of the lowest-energy chromophores, the non-classical photon arrival time distribution of the multichromophoric chain is modified towards a more classical distribution. Surprisingly, the fidelity of photon antibunching deteriorates upon charging, whereas one would actually expect the number of chromophores to be reduced. A qualitative model is presented to explain the observed PL changes. The results are of interest to developing a microscopic understanding of the intrinsic charge-exciton quenching interaction in devices.

HL 13.8 Mon 12:45 ZEU 260

Optical Detection of the Magnetic Field Effect in OLEDs with Metal-Free Dual Singlet-Triplet Emitters — •Wolfram Ratzke[1], Lisa Schmitt[2], Hideto Matsuoka[2], Christoph Bannwarth[2], Marius Retegan[3], Jonas Zipfel[1], Sebastian Bange[1], Philippe Klemm[1], Frank Neese[3], Stefan Grimme[2], Olav Schiemann[2], John Lupton[1], and Sigurd Höger[2] — [1]University of Regensburg, Germany — [2]University of Bonn, Germany — [3]MPI Mühlheim an der Ruhr, Germany

Even though the magnetic field effect of organic light emitting diodes (OLEDs) has been investigated for more than one decade it is still difficult to identify the underlying mechanisms. Furthermore, theories are discussed which are based on the magnetic field dependent formation of singlet and triplet excited states in order to explain the change in the device resistance without a simultaneous experimental access to all three observables. The spin states can be measured by detecting the fluorescence and phosphorescence but so far this was always restricted to the exclusive observation of pure singlet or triplet emission by investigating different molecular systems, and hence a coherent statement is not possible. Recently, we have developed metal-free OLED emitters which exhibit simultaneous fluorescence and phosphorescence, even at room temperature. These materials can give insight into the change of spin-state statistics when an external magnetic field is applied, and offer a new perspective to distinguish between different field regimes and spin-dependent mechanisms which lead to the magnetic field effect.