HL 15: Organic Semiconductors: Optics and Photonics

Time: Tuesday 9:30–12:00 Location: POT/0006

HL 15.1 Tue 9:30 POT/0006

Accessing 'Slow' Dynamics in Photocatalysts with PIAS — •Maria Ferree[1], Rebecca Gröninger[2], Tianhao Xue[1], Thomas Bein[1], Bettina Lotsch[2], and Frédéric Laquai[1] — [1]Dept. Physical Chemistry, LMU München, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

Quasi-steady-state Photoinduced Absorption Spectroscopy (PIAS) is a highly sensitive tool for probing long-lived excited states and charge carriers in semiconductors. We showcase PIAS capabilities by studying diverse systems, ranging from conjugated polymers and COF-based films to nanoparticle dispersions. PIAS is often overshadowed as researchers default to sophisticated Transient Absorption (TA) Spectroscopy. However, low-frequency modulated excitation with lock-in signal detection capture extremely weak changes in transmission induced by polarons or triplet states with lifetimes ranging from nanoseconds to seconds - dynamics that remain largely inaccessible by TA, but highly relevant for diffusion-limited processes, e.g. photocatalysis. Frequency-dependent measurements provide insight into lifetimes and concentrations of long-lived species. Whilst Time-resolved Photoluminescence (TRPL) can further reinforce the conclusions obtained from PIAS by extracting exciton recombination kinetics. Our studies of organic semiconductor-based photocatalysts are a reminder that PIAS is a powerful, often more suitable method complementary to ultrafast spectroscopy and other characterisation techniques. It provides unique access to 'slow' excited-state dynamics through relatively straightforward data acquisition and processing.

HL 15.2 Tue 9:45 POT/0006

Subwavelength OLED pixels based on plasmonic electrodes — •Leo Siebigs[1], Cheng Zhang[2], Björn Ewald[1], Luca Steinbrecher[2], Maximilian Rödel[1], Thomas Fleischmann[1], Monika Emmerling[2], Bert Hecht[2], and Jens Pflaum[1] — [1]Experimental Physics 6, University of Würzburg, 97074 Würzburg — [2]Experimental Physics 5, University of Würzburg, 97074 Würzburg

Next-generation display technologies, such as augmented and virtual reality, demand the continued miniaturisation of individual pixels. A novel approach towards achieving the necessary ultra-high resolution involves subwavelength organic light-emitting diode (OLED) pixels based on plasmonic nanoelectrodes. The nanoelectrode acts as an optical antenna, ensuring efficient light-outcoupling to the far-field and control over the emission characteristics by adjusting the antenna geometry. However, upon scaling the pixel dimensions below the wavelength of light, sharp nanoelectrode contours dominate the device operation. As a result (i) filament growth leads to rapid device failure and (ii) spatially imbalanced charge-carrier transport and recombination limits the external quantum efficiency (EQE). We address these challenges by selectively passivating the nanoelectrode edges with an insulating layer and defining the active area via a nanoaperture. As proof-of-concept, efficient and stable hole-injection is shown in hole-only devices based on gold nanoelectrodes. For the first time, we demonstrate light extraction from individually addressable 300 nm x 300 nm plasmonic OLED pixels with a maximum luminance of 3000 cd m^{-2} and 1% EQE. C., Zhang et al., Sci. Adv. 2025, DOI: 10.1126/sciadv.adz8579

HL 15.3 Tue 10:00 POT/0006

Near infrared OLEDs for neuroimplants — •Sabina Hillebrandt[1], Sumit Mohapatra[1], Ahmed Gaber Abdelmagid[2], Konstantinos C. Daskalakis[2], Andreas Mischok[1], and Malte C. Gather[1,3,4] — [1]Humboldt Centre for Nano- and Biophotonics, University of Cologne, Germany — [2]Department of Mechanical and Materials Engineering, University of Turku, Finland — [3]School of Physics and Astronomy, University of St Andrews, United Kingdom — [4]CECAD, University of Cologne, Germany

OLEDs offer spectral tunability, mechanical flexibility, and compatibility with scalable thin-film fabrication, making them strong candidates for biointegrated photonic technologies. Near-infrared (NIR) OLED emission can penetrate deep into tissue and may enable neuromodulation without the need for genetic interventions.

We present the development of high-brightness, top-emitting NIR OLEDs specifically engineered for implantable neurotechnology. Using optimized emitter-host combinations, microcavity tuning, and customized charge-transport layers, these devices exhibit peak emission above 800 nm with no measurable output below 700 nm, thereby reducing off-target excitation and tissue scattering. The devices achieve power densities approaching 0.1 mW/mm^2, levels relevant for neuromodulation, while maintaining both thermal stability and robust operational performance. To further refine spectral purity and directional control, we integrate strong-coupling architectures, yielding polariton OLEDs with angular-stable NIR emission above 800 nm even on flexible, implantable polymer substrates.

HL 15.4 Tue 10:15 POT/0006

Aggregation enhanced singlet emission in a purely organic emitter with thermally activated delayed fluorescence — •Jiacheng Gong, Xin Zhou, Kaiwen Guo, Toulik Maitra, Denis Andrienko, Gert-Jan Wetzelaer, Paul W. M. Blom, and Yungui Li — Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany

Purely organic thermally activated delayed fluorescence (TADF) emitters have gained great attentions in the field of organic light-emitting devices. However, the long-lived triplet exciton contributes to efficiency roll-off and device degradation at high current densities. Great efforts have been made to accelerate reverse intersystem crossing (rISC), while there are less studies on the increase of singlet radiative transition rate (krS). Herein, based on the benchmark TADF emitter CzDBA, it is found that it exhibits a larger krS in neat film, which is ~ 4 times faster than that in toluene with similar dielectric environment. The modelling of excited-state dynamics for electrically excited TADF emitters demonstrates that the increased krS reduces triplet and singlet densities simultaneously, while retaining high charge-to-photon conversion efficiency. Furthermore, time-resolved photoluminescence and steady-state absorption spectroscopic analysis shows that the broadened absorption feature increases the oscillator strength and hence increases krS in terms of Strickler-Berg relation. Gaussian disorder model is further applied to PL excitation spectra, and a larger disorder factor from the film samples implies that the large disorder of energetic landscape may contribute to the enhanced krS.

HL 15.5 Tue 10:30 POT/0006

Spectral diffusion of charge-transfer states in organic donor:acceptor blends due to carrier relaxation — •Giacomo Cotelli[1], Anna Köhler[1], and Reinder Coehoorn[2] — [1]University of Bayreuth, Bayreuth, Germany — [2]Eindhoven University of Technology, Eindhoven, The Netherlands

Blends of small-molecule organic semiconductors may display emission from an intermolecular charge transfer (CT) excited state. An aspect that is not well understood so far is the spectral diffusion of such CT states. We present a comprehensive study of CT state spectral diffusion in two- and three-component blends, using kinetic Monte Carlo simulations. We disentangle the effects of the CT state lifetime, charge carrier energetic disorder and blend composition on the emission spectra. Furthermore, we highlight similarities and differences between the emission of photogenerated CT states in films and electrically generated CT states in OLEDs.

HL 15.6 Tue 10:45 POT/0006

Direct Prediction of Organic Light-emitting Diode Efficiency Roll-off from Photophysical Parameters of Thermally Activated Delayed Fluorescence Emitters — •Kaiwen Guo, Yungui Li, and Paul Blom — Max Planck Institute for Polymer Research, Mainz, Germany

Severe efficiency roll-off significantly limits the practical performance of organic light-emitting diodes (OLEDs) at high luminance, especially for the devices based on thermally activated delayed fluorescence (TADF) emitters. Although numerous TADF emitters have been developed and investigated over last decade, in molecular scale the intrinsic molecular-origin of roll-off still remains unclear. In this work, we establish a direct correlation between device roll-off and intrinsic photophysical properties of TADF emitter, and analytically derive the roll-off as a function of exciton generation rate.

We propose an integrated methodology to extract complete set of photophysical parameters of TADF emitter, including the rates of exciton decays, spin conversion kinetics and bimolecular annihilation coefficients. Notably, we reveal that the roll-off behavior in TADF based

OLED is not solely governed by bimolecular annihilation processes, but also influenced by the lifetime of delayed fluorescence. This knowledge enables us to predict the severity of roll-off directly from optical measurements and provides insight for further molecule designing.

15 min. break

HL 15.7 Tue 11:15 POT/0006

OLED-based implants for neurostimulation — •Sumit Mohapatra[1], Falko Fuhrmann[2], Julian F. Butscher[1,3], Sabina Hillebrandt[1,3], Martin Fuhrmann[2], and Malte C. Gather[1,3,4] — [1]Humboldt Centre for Nano- and Biophotonics, Department of Chemistry, University of Cologne, Germany — [2]Neuroimmunology and Imaging Group, DZNE, Bonn, Germany — [3]School of Physics and Astronomy, University of St Andrews, UK — [4]CECAD, University of Cologne, Germany

Light-based neurostimulation allows precise manipulation of neural circuits, yet delivering light to deep tissue remains a challenge. OLEDs combine spectral tunability, mechanical flexibility, and thin-film integration, enabling fabrication of neural probes for localized stimulation.

We advance this approach by integrating OLEDs onto magnetoelectric substrates to create fully wireless neuromodulation platforms, which are 200 μm-thick, contain 300*500 μm^2 OLEDs delivering mean power densities of 0.04 mW/mm^2. Tunable kilohertz-range resonances allow clustered multi-pixel operation, while thin-film encapsulation ensures biocompatibility and protection in a physiological environment. We also introduce a flexible OLED-based neuroprobe by integrating OLEDs onto 15 μm-thick commercial electrophysiology arrays. Using these pre-validated implantable platforms, they are transformed into μOLED arrays with 28 individually addressable μOLEDs (50 μm diameter, 300 μm pitch), achieving power density up to 0.1 mW/mm^2 at 7 V. In vivo optogenetic experiments using μ-OLEDs in mice confirm effective neuronal activation, verified by two-photon calcium imaging.

HL 15.8 Tue 11:30 POT/0006

Exploring Molecular Stability in Organic Solar Cells: A Combined DFT and ML Approach — •Muhammad Waqas and Harald Oberhofer — Chair for Theoretical Physics VII and Bavarian Center for Battery Technologies, University of Bayreuth

The stability of organic solar cells (OSCs) remains a significant challenge in the field. In this work, we present a data-driven approach that integrates density functional theory (DFT) and machine learning (ML) to identify molecular parameters that influence device stability. For this purpose, we compute different optical and electronic parameters by using DFT and time-dependent DFT and check their influence on the lifetime (T80) of OSCs. The first step is to collect lifetime data from the already published literature for different OSC materials. The second step involves DFT and TD-DFT calculations for the selected molecules, thereby generating a dataset. This dataset serves as a foundation for training the ML models. Based on the DFT-generated data, we train ML models that can help us recognise the most influential parameters that affect the stability of OSCs. Furthermore, based on the insights gained from the ML models, we can explore the chemical space to find other molecules that can be used to prepare more stable devices.

HL 15.9 Tue 11:45 POT/0006

Accurate characterization of next-generation photodiodes — Siddhartha Saggar[1,2], Giedrius Puidokas[2], and •Caroline Murawski[1,2] — [1]Institute of Solid-State Electronics, TUD Dresden University of Technology, 01062 Dresden, Germany — [2]Kurt Schwabe Institute for Sensor Technologies, 04736 Waldheim, Germany

Photodiodes based on organic and emerging semiconductor materials have demonstrated high potential for optical sensing in biomedicine, imaging applications, and light-based data transmission. During the last decade, concerns have arisen regarding the reliable reporting of the device performance, especially under low illumination conditions. This work addresses these concerns and provides a robust framework for measuring and reporting standardized photodetection metrics. We have developed a measurement setup including a highly sensitive electrometer, calibrated optical filters, and light sources with narrowband emission spectra. For operation of the setup, we provide open-source Python scripts and outline protocols suitable for accurate characterization of steady-state photodetecting metrics.