

HL 58: OFETs, OLEDs, and organic optoelectronics

Time: Wednesday 16:30–18:45

Location: EW 202

HL 58.1 Wed 16:30 EW 202

Light-matter interaction in protein microcavities — ●CHRISTOP P. DIETRICH, ANJA STEUDE, MARCEL SCHUBERT, SVEN HÖFLING, and MALTE C. GATHER — SUPA, School of Physics and Astronomy, University of St Andrews, KY16 9SS St Andrews, United Kingdom

There is an increasing interest in using biologically produced structures and materials for photonic applications. Recent research impressively illustrates the broad potential of biological materials for providing optical gain[1]. In particular, fluorescent proteins like eGFP retain a special position within the quickly growing family of biologically produced laser materials. eGFP has a barrel-like molecular structure that prevents concentration induced quenching of the fluorescence by suppressing Förster and Dexter energy transfer[2]. This allows the use of pure solid-state fluorescent protein as efficient optical gain material. We demonstrate highly efficient lasing from multiple photonic states in microcavities filled with self-assembled rings of recombinant eGFP in its solid state form. The lasing regime is achieved at very low excitation energies of 13nJ and occurs from cavity modes dispersed in both energy and momentum. The distribution of lasing states in energy is induced by the large spectral width of the gain spectrum of recombinant eGFP (FWHM = 25nm). Our results imply that there is considerable self-absorption in eGFP and that strong exciton-photon coupling may be observed in fluorescent proteins if suitably designed resonators are used.

[1] M.C. Gather and S.H. Yun, *Nat. Photon.* **5**, 406 (2011).

[2] M.C. Gather and S.H. Yun, *Nat. Comm.* (in press).

HL 58.2 Wed 16:45 EW 202

Modulating 2D material optoelectronics through photochromic self-assembled monolayers — ●JUAN LI¹, CARLOS-ANDRES PALMA¹, JAKOB WIERZBOWSKI^{1,2}, JULIAN KLEIN^{1,2}, FILIPPO NISIC³, MAHMOUD M. ASMAR⁴, SERGIO E. ULLOA⁴, CLAUDIA DRAGONETTI³, JONATHAN J. FINLEY^{1,2}, EMANUELA MARGAPOTI^{1,2}, and JOHANNES V. BARTH BARTH¹ — ¹Physik-Department, Technische Universität München, James-Frank-Str. 1, 85748 Garching, Germany — ²Walter Schottky Institut, Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany — ³Dipartimento di Chimica, Università degli Studi di Milano and UdR dell'INSTM di Milano, Via Golgi 19, I-20133 Milano, Italy — ⁴Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

The recent spotlight on highly crystalline natural-occurring and synthetic two-dimensional materials (2DMs) stands as a unique opportunity to accelerate atomically-precise technology made of complex 2DM and molecular architectures. Here we explore the modulation of the optoelectronic properties of graphene and molybdenum disulfide (MoS₂) by means of azobenzene self-assembled monolayers platforms. We present (a) the emergence of photoswitchable bound states in graphene (b) photoswitchable rectification and (c) tuning of the photoluminescence yield on MoS₂. Our results pave the way toward hybrid molecular/2DM (opto)electronic technology.

HL 58.3 Wed 17:00 EW 202

Time-resolved measurement of intramolecular photoinduced electron transfer processes in perylene diimides — ●ROBIN CARL DÖRING¹, EDUARD BAAL², JÖRG SUNDERMEYER², and SANGAM CHATTERJEE¹ — ¹Faculty of Physics and Materials Science Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — ²Faculty of Chemistry and Materials Science Center, Philipps-Universität Marburg, Hans-Meerwein-Str., D-35043 Marburg, Germany

Perylene diimides (PDI) are commonly used as dyes but are also viable candidates for devices such as organic field-effect transistors and organic photovoltaics. We study a series of PDI samples by time-resolved photoluminescence and transient absorption measurements to identify the relaxation mechanisms following fs-optical excitation. Here, photoinduced electron transfer (PET) can occur. Following a high-energy excitation, an electron from the lone pair of the diimide is transferred to the HOMO of the perylene core, hence disallowing radiative recombination. By introducing alkyl groups as spacer units the distance between electron donor and the fluorophore is increased. Therefore, the distant distance dependent PET is altered, leading to a reduced

PET efficiency and hence changed decay rates.

HL 58.4 Wed 17:15 EW 202

Pressure Dependent Electronic Properties of Organic Semiconductors from First Principles — ●FRANZ KNUTH¹, CHRISTIAN CARBOGNO¹, VOLKER BLUM^{1,2}, and MATTHIAS SCHEFFLER¹ — ¹Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — ²MEMS Department, Duke University, Durham, NC 27708, USA

The electronic properties of organic semiconductors typically exhibit a significant dependence on the strain, stress, and pressure [1]. In this contribution, we present the theoretical background, assessment of approximations, and results of electronic and transport properties in the framework of density-functional theory. Our implementation considers the analytical strain derivatives (stress tensor) including the contributions that stem from (a) van-der-Waals interactions [2] and (b) the Fock-exchange in hybrid functionals. We validate our approach by investigating the geometric and electronic changes that occur in polyacetylene and anthracene under hydrostatic pressure. We show that the fraction of exact exchange included in the calculations is critical – and non-trivial to choose – for a correct description of these systems. Furthermore, we point out trends for the electrical conductivity under pressure and identify the dominant charge carriers and transport directions.

[1] J. H. Kim, S. Seo, and H. H. Lee, *Appl. Phys. Lett.* **90**, 143521 (2007); G. Giri *et al.*, *Nature*. **480**, 504 (2011)

[2] A. Tkatchenko and M. Scheffler, *Phys. Rev. Lett.* **102**, 073005 (2009).

HL 58.5 Wed 17:30 EW 202

A Transition from Vacuum Level Alignment to Fermi Level Pinning in Organic Semiconductors — ●MAHDI SAMADI KHOSHKHOO¹, ALEXANDER ANDRE¹, THOMAS CHASSÉ^{1,2}, and MARCUS SCHEELE^{1,2} — ¹Institute of Physical and Theoretical Chemistry, Universität Tübingen, Germany. — ²Center for Light-Matter Interaction, Sensors & Analytics LISA+, Universität Tübingen, Germany

Coupled organic-inorganic nanostructures (COINs) have emerged as a promising class of materials for quantum dot-based optoelectronic devices. The architecture of these devices includes semiconductor quantum dots physically and electronically connected to each other through organic semiconductor bridges which can form a charge-transfer layer with the ability to pass only electrons or holes. In this way, the understanding of energy level alignment at 1) the organic/inorganic semiconductor or 2) the organic semiconductor/metal interface is essential in order to design charge-transfer layers with inherent rectification ability. In this presentation, we demonstrate the utilization UPS to investigate the interfaces between organic semiconductors and various metal substrates (which are chosen to span a wide range of work functions) in order to recognize the transition between two different alignment regimes. The substrates were chosen in a way that π -electronic molecular orbitals of ligands have an insignificant hybridization with substrate wave functions. This method provides valuable information for the design and fabrication of COIN optoelectronic devices, such as minimum hole and electron injection barriers, energy of polaronic states, polaronic relaxation energies, and the amount of interface dipole.

HL 58.6 Wed 17:45 EW 202

Extracting the emitter orientation in organic light-emitting diodes from external quantum efficiency measurements — ●TOBIAS D. SCHMIDT¹, LUKAS J. REICHARDT¹, ANDREAS F. RAUSCH², SEBASTIAN WEHRMEISTER¹, BERT J. SCHOLZ¹, CHRISTIAN MAYR¹, THOMAS WEHLUS², ROSSA MAC CIARNAIN³, NORBERT DANZ³, THILO C. G. REUSCH², and WOLFGANG BRÜTTING¹ — ¹Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — ²OSRAM OLED GmbH, Wernerwerkstrasse 2, 93049 Regensburg, Germany — ³Fraunhofer Institute for Applied Optics and Precision Engineering, 07745 Jena, Germany

Emitter orientation will play a major role in future applications of organic light-emitting diodes due to its strong impact on the efficiency of the devices. Up to now, determining the orientation of transition dipole moments required elaborate angular-dependent measurements of the light emission pattern. In this paper, we present a simplified and

straightforward method to extract the emitter orientation from external quantum efficiency measurements. We demonstrate the validity of the method on three different dye-doped emitting systems.

HL 58.7 Wed 18:00 EW 202

Permeable Base Transistor - an Organic Thin-Film Transistor with High On/off Ratio and HF-operation — ●MARKUS KLINGER¹, AXEL FISCHER¹, FELIX KASCHURA^{1,2}, BAHMAN KHERADMAND-BOROJENI^{2,3}, DANIEL KASEMANN¹, and KARL LEO¹ — ¹IAPP, TU Dresden, George-Bähr-Str. 1, 01069 Dresden — ²cfAED, Flügelweg 20, 01157 Dresden — ³CCN, TU Dresden, Helmholtzstraße 18, 01069 Dresden

Optimization of Organic Field-Effect Transistors (OFET) typically involves expensive structuring techniques in order to achieve small channel lengths in the micrometer range. Here, we show a Permeable Base Transistor (PBT), fabricated using thermal vapor deposition and shadow masks. These PBTs consist of a 'sandwich'-geometry with three parallel electrodes separated by two semiconducting C₆₀ layers. The current flow between the upper and lower electrode is controlled by a thin perforated electrode in the middle [1]. Since electron transport is directed vertically, channel lengths in the range of 100 nm are achieved. By using insulating layers, we realize downscaled transistors with an active area of (0,2 mm)². The PBTs reach a current density of 10 A/cm², an on/off ratio greater than 10⁶ and a gain of 1000 at a low driving voltage of 1.0 V. The transit frequency of 2.2 MHz is determined with an optimized measuring setup [2]. In comparison to aggressively scaled horizontal OFETs [3], we present a device configuration realized at low cost, allowing for applications with high current and switching speed. [1] J. Appl. Phys., **111**(4), 044507; [2] IEEE Transactions on Electron Devices, **61**(5), 1423-1430; [3] Small, **8**(1), 73-79

HL 58.8 Wed 18:15 EW 202

Anisotropic electron mobility studies on Cl₂-NDI single crystals and the role of static and dynamic lattice deformations upon temperature variation — ●N.H. HANSEN¹, F. MAY², D. KÄLBLEIN², T. SCHMEILER¹, C. LENNARTZ², A. STEEGER¹, C. BURSCHKA³, M. STOLTE³, F. WÜRTHNER³, J. BRILL², and J. PFLAUM^{1,4} — ¹Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — ²InnovationLab GmbH, Speyerer Strasse 4, 69115 Heidelberg, Germany and BASF SE, 67056 Ludwigshafen, Germany — ³Institut für Organische Chemie and Center for Nanosystems Chemistry, Universität Würzburg, 97074 Würzburg,

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Recently, high mobility air-stable electron semiconductors have been synthesized to fill one of the major technological gaps in an all-organic circuitry. One of the promising candidates with a thin-film mobility of up to 1.3 cm²/Vs at ambient conditions is Cl₂-NDI (naphthalene diimide) [Stolte et. al., Proc. of SPIE, Vol. 7778, 777804, 2010]. Yet little is known about its elementary carrier transport mechanisms on a molecular level. To address this lack of information, we performed anisotropic field effect transistor measurements on Cl₂-NDI single crystals and observe an increasing mobility at lower temperatures (1.5 cm²/Vs at 300 K, 2.8 cm²/Vs at 175 K), which hints at a band-like transport, as commonly assumed. However, as we will demonstrate the experimental data can be consistently described in the framework of a hopping-type model based on Levich-Jortner rates, which accounts for thermally induced lattice effects and electron-phonon interaction.

HL 58.9 Wed 18:30 EW 202

Ultra-high vacuum fabrication and characterization of organic thin film transistors: In-situ electrical and surface sensitive analysis on temperature effects and layer growth — ●ROMAN LASSNIG¹, MICHAEL HOLLENER¹, BERND STRIEDINGER², ALEXANDER FIAN², BARBARA STADLOBER², and ADOLF WINKLER¹ — ¹Institute of Solid State Physics, Graz University of Technology, Austria — ²Materials Division, Joanneum Research, Austria

Many of the underlying principles affecting critical organic field effect transistor (OFET) parameters such as performance and lifetime are not fully understood to the present date. We present analysis on the formation, structure and stability of the semiconducting layer in pentacene OFETs, through a unique combination of in-situ layer deposition, real-time electrical and surface analytical characterization, during and subsequent to the deposition process itself. All investigations have been performed under ultra-high vacuum conditions at temperatures ranging from 125 K up to semiconductor desorption. In-situ Auger electron spectroscopy (AES) and thermal desorption spectroscopy (TDS) were performed parallel to the electrical investigations. Ex-situ atomic force microscopy allowed direct connections to be made between growth mode, morphology and charge transport mechanisms. Of special interest was the onset of the OTFT functionality as a function of layer thickness in combination with sample pretreatment. In addition, the evaluation of, coverage and growth temperature dependent, linear and saturation charge carrier mobilities proved to be of great interest in regard to contact resistance assessments.