

## DS 29: Focus Session: Organic Materials for Spintronics: From Spininterface to Devices (jointly with HL, MA, O)

Since the first report of an organic spin valve in 2004, novel devices such as spin-OLEDs (organic light emitting diodes) and spin-OFETs (organic field effect transistors) as well as sensors based on magnetic resonance were developed. This rapid development of the field of organic spintronics is driven by the large spin life time in organic molecules, combined with the large diversity and flexibility of molecular synthesis and technological processing. Despite the tremendous progress, there are still many challenges which must be tackled. On one hand, it is desirable to achieve a computer-aided design for novel molecules that can keep their properties at the interfaces with the spin-injecting electrodes. On the other hand, novel technologies for the fabrication of spin devices and the spin transport properties of various molecules are being tested. Last but not least, the spin injection at spininterfaces, i.e. at the interface between the organic molecules and the ferromagnetic electrodes, is a key factor that still needs to be understood and controlled. This topical session aims to give an overview of the latest developments in the dynamic field of organic spintronics. (Organizers: Martin Aeschlimann, Uni Kaiserslautern; Bernd Büchner, IFW Dresden; Dietrich R. T. Zahn, TU Chemnitz)

Time: Thursday 9:30–13:30

Location: H32

### Invited Talk

DS 29.1 Thu 9:30 H32

**Organic Magnetoresistance: The effect of excitons on charge transport in organic semiconductors** — •WILLIAM GILLIN — Queen Mary, University of London, UK

It has been known since 2003 that applying a magnetic field to an organic light emitting diode (OLED) will cause changes in both the light output (efficiency) of a device and the current through the device (organic magnetoresistance or OMR). The observation of this phenomenon has spurred a number of models to explain the observations but these can be classified in to two broad classes: excitonic and bipolaron. As the effect of the magnetic field is to apply a small perturbation to existing spin dependent processes that are affecting charge transport and recombination, the study of OMR provides an interesting new tool for understanding these processes. In this talk I will highlight the recent developments in the study of organic magnetoresistance and illustrate that the effect probably has several components which are all acting in parallel and which can have different signs and magnetic field dependencies. By developing an understanding of the different magnetic field characteristics of different processes we may open a door on to a new way of studying the interactions responsible for the fundamental operation of organic electronic devices.

### Topical Talk

DS 29.2 Thu 10:00 H32

**Metal-phthalocyanines: Materials for molecular spintronics** — •JENS KORTUS<sup>1</sup>, RICO FRIEDRICH<sup>1</sup>, TORSTEN HAHN<sup>1</sup>, CLAUDIA LOOSE<sup>1</sup>, and MARTIN KNUPFER<sup>2</sup> — <sup>1</sup>TU Bergakademie Freiberg, Germany — <sup>2</sup>IFW Dresden, Germany

Metal-phthalocyanines (MPC) are very stable and can have different spin states depending on the transition metal ion. In this contribution we will discuss electronic, (magneto)optical and transport properties of MPC in view of possible application in spintronic devices.

In particular a recently investigated layered system of MnPc and F<sub>16</sub>CoPc shows charge transfer at an interface between two metal phthalocyanines, which is investigated in detail using density functional theory. These results are of importance for the application of such interfaces in organic electronic devices because charge transfer considerably affects the energy level alignment and the transport behaviour of the respective hetero-junction. Since the transfer of charge is also connected to a transfer of spin and the hybrid system has a net spin of  $S = 2$ , such compounds could also be termed *spin-transfer materials* with future applications in the area of spintronics [1].

[1] S. Lindner, M. Knupfer, R. Friedrich, T. Hahn, J. Kortus Phys. Rev. Lett. 109 (2012) 027601-1/5

### Topical Talk

DS 29.3 Thu 10:30 H32

**Magneto-optical Kerr Effect Spectroscopy of Selected Phthalocyanines and Porphyrines** — •GEORGETA SALVAN<sup>1</sup>, PETER ROBASCHICK<sup>1</sup>, FRANK LUNGWITZ<sup>1</sup>, MICHAEL FRONK<sup>1</sup>, CAROLA MENDE<sup>1</sup>, HEINRICH LANG<sup>1</sup>, RICO FRIEDRICH<sup>2</sup>, JENS KORTUS<sup>2</sup>, and DIETRICH R. T. ZAHN<sup>1</sup> — <sup>1</sup>TU Chemnitz, 09126 Chemnitz, Germany — <sup>2</sup>TU Bergakademie Freiberg, Freiberg 09596, Germany

Phthalocyanines and porphyrines find nowadays many applications from pigments to organic electronics. Nevertheless, they still have a

special charm for fundamental investigations thanks to the large flexibility of their molecular structure. This work focuses on the influence of the molecular spin ground state on the room temperature magneto-optical activity of some phthalocyanines and porphyrins. The films in the typical thickness range between 30 nm and 100 nm were prepared by organic molecular beam deposition in high vacuum. Magneto-optical Kerr effect (MOKE), which is commonly used to study the magnetic properties of inorganic ferromagnetic layers or magnetic nanostructures, is measured here spectroscopically in the region of the Q and B absorption bands of phthalocyanines and porphyrines. From this the magneto-optical Voigt constant is calculated numerically and can be correlated to the electronic properties of the molecules. For instance, the hybridisation of Co<sub>3d</sub> states with the HOMO  $\pi$ -orbital of CoPc leads to additional features in the magneto-optical spectra compared to e.g. CuPc. The magnitude of the Voigt constant in the Q band is hardly sensitive to the molecular spin, but highly sensitive to the orientation of the molecules with respect to the substrate plane.

### Topical Talk

DS 29.4 Thu 11:00 H32

**Molecular Quantum Spintronics** — •MARIO RUBEN — Institut für Nanotechnologie (INT), Karlsruhe Institut für Technologie (KIT) — Institut de Physique et Chimie (IPCMS); Université de Strasbourg (UdS)

Molecules can be considered as physical Quantum Objects. Magnetic molecules consist of an atomic core of one-to-few open spin ions surrounded by a shell of organic material. At low temperature such molecular spin objects behave as simple, few-level systems.[1,2] Since quantum coherence and stable entanglement of electron spins are extremely difficult to achieve, alternative concepts propose the use of nuclear spins as quantum information carrier. Nuclear spins are extremely well isolated from environment and less prone to decoherence, and the coherent manipulation can be adapted by tailoring the molecular environment. However, although being well isolated from their surroundings, nuclear spins have to be addressed, ideally electronically since complementary with existing technologies. The delicate balance between decoupling of the magnetic molecule for stable coherence and connecting it for read out can be carried out by synthetic engineering of the molecular components. The first example of a completely electronic read out of a nuclear spin of a lanthanide ion (bearing electron and nuclear spins) embedded in a magnetic molecule TbPc2, was recently reported.[3] [1] M. Urdampilleta et.al. Nature Mater. 10, 502 (2011) [2] J. Schwöbel, et. al. Nature Comms. 2, 1953 (2012) [3] R. Vincent, et. al. Nature 488, 357 (2012)

### Coffee break (15 min)

### Topical Talk

DS 29.5 Thu 11:45 H32

**Nanomembrane based electrodes for contacting ultra-thin organic layers** — •CARLOS CESAR BOF BUFON<sup>1</sup>, CELINE VERVACKE<sup>2</sup>, MARIA ESPERANÇA NAVARRO FUENTE<sup>2</sup>, DOMINIC J. THURMER<sup>2</sup>, CHRISTIAN MÜLLER<sup>5</sup>, MICHAEL FRONK<sup>3</sup>, GEORGETA SALVAN<sup>3</sup>, DIETRICH R. T. ZAHN<sup>3</sup>, and OLIVER G. SCHMIDT<sup>2,4</sup> — <sup>1</sup>Brazilian Nanotechnology National Laboratory, CNPEM, PO Box 619, 13083-970, Campinas, Brazil — <sup>2</sup>Institute for Integrative Nanosciences,

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One of the main challenges for accessing the electronic properties of ultrathin organic layers (UOL), and consequently their application for future devices, consists of connecting such layers to the external word. Two main problems usually arise by trying to vertically connect UOLs: i) the interdiffusion of metallic atoms into the sub-10nm molecular layers, which leads to the damaging and/or the modification of the final device behavior; ii) the presence of pin-holes across the molecular layer, which is responsible for short circuited junctions. Here we discuss the fundamentals, potentialities and limitations of using rolled up nanomembranes as top electrodes for contacting a variety of UOLs, including self-assembled monolayer's and ultra-thin organic semiconducting layers.

### Topical Talk

DS 29.6 Thu 12:15 H32

**Spiinterfaces as microscopic spin traps** — •MIRKO CINCHETTI — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Kaiserslautern, Germany

Interfaces between ferromagnetic materials and organic semiconductors - also known as spinterfaces - constitute an incredibly rich playground in the field of spintronics. For example, spinterfaces have the potential to be implemented as tunable spin filters, which will pave the way to a whole new class of advanced, i.e., actively controlled spintronics devices. The progress in the field of spinterface science depends thus critically on elucidating the still unexplored spin-dependent carrier dynamics at such hybrid interfaces.

We use time-resolved two-photon photoemission to optically pump and probe a hybrid electronic state forming at the prototypical spinterface between cobalt and the organometallic complex tris(8-hydroxyquinolinato)aluminium (Alq3). We generate a transient spin polarization in the hybrid interface state, and follow its behavior in four dimensions: energy, time, spin and momentum. We find that electrons are confined at the Co-Alq3 interface for times in the range of 0.5-1 ps, and that the confining potential is strongly spin dependent. Such spin-dependent trapping behavior elucidates the fundamental microscopic origin of the spin-filtering properties at spinterfaces, which is important for the design of next-generation spintronics devices based on tunable organic spin filters.

DS 29.7 Thu 12:45 H32

**ESR study of the magnetic properties of the MnPc–F<sub>16</sub>CoPc dimer** — •AZAR ALIABADI, SUSI LINDER, MARTIN KNUPFER, YULIA KRUPSKAYA, VLADISLAV KATAEV, and BERND BÜCHNER — IFW Dresden, 01069 Dresden

Photoemission spectroscopy has demonstrated a charge transfer at the interface between two transition metal phtalocyanines (MnPc and F<sub>16</sub>CoPc) indicating the formation of a MnPc<sup>δ+</sup>/F<sub>16</sub>CoPc<sup>δ-</sup> heterojunction [1]. In this work, the MnPc-F<sub>16</sub>CoPc dimer system with charge transfer was investigated using ESR spectroscopy at different temperatures. Comparison between ESR spectra of the parent com-

pounds (MnPc and F<sub>16</sub>CoPc powders) and of the product of the reaction (MnPc/F<sub>16</sub>CoPc mixed powder) has revealed characteristic features due to the formation of the MnPc–F<sub>16</sub>CoPc dimer. We discuss distinct magnetic properties of the MnPc–F<sub>16</sub>CoPc dimer and their possible relation to the charge transfer in the studied complex.

[1] S. Lindner, M. Knupfer, R. Friedrich, T. Hahn, and J. Kortus, *Phys. Rev. Lett.* **109**, 027601 (2012).

DS 29.8 Thu 13:00 H32

**Influence of surface interaction on the properties of single-molecule-magnets** — •DAVID KLAR<sup>1</sup>, ANDREA CANDINI<sup>2</sup>, BERNHARD KRUMME<sup>1</sup>, LOIC JOLY<sup>3</sup>, SVETLANA KLYATSKAYA<sup>4</sup>, JEAN-PAUL KAPPLER<sup>3</sup>, MARIO RUBEN<sup>3,4</sup>, and HEIKO WENDE<sup>1</sup> — <sup>1</sup>Fakultät für Physik und CENIDE, Universität Duisburg-Essen — <sup>2</sup>Centro S3 Modena, Istituto Nanoscienze - CNR — <sup>3</sup>Institut de Physique et Chimie des Matériaux de Strasbourg, Université de Strasbourg — <sup>4</sup>Institute of Nanotechnology, Karlsruhe Institute of Technology

Due to the consecutive downsizing of devices, single-molecule-magnets as building blocks for spintronic applications are of high interest for actual research. The remanent behavior, caused by the single-ion anisotropy, of TbPc<sub>2</sub> molecules in bulk samples at less than 5 K is reported in the literature. Our goal is to investigate and to understand the influence of the surface on the properties of the TbPc<sub>2</sub> molecules deposited onto a substrate. Therefore we study submonolayer coverages of TbPc<sub>2</sub> molecules on ferromagnetic surfaces like Ni, and on a very inert surface of highly oriented pyrolytic graphite (HOPG) that should maintain the properties of isolated molecules. By XAS and XMCD we analyze the element specific magnetic and electronic properties. The low interaction with the HOPG surface hardly affects the magnetic properties of the molecules and we were able to observe a remanent magnetization, but only at very low temperatures (T < 4 K). On the Ni surface an indirect exchange leads to an antiferromagnetic coupling between the molecules and the surface. As a result, we obtained a remanent magnetization at higher temperatures (T ≈ 100 K).

DS 29.9 Thu 13:15 H32

**Paramagnetic organic radicals on rutile TiO<sub>2</sub>(110) single crystals** — •REZA KAKAVANDI, SABINE-ANTONIA SAVU, THOMAS CHASSÉ, and MARIA BENEDETTA CASU — Institute of Physical and Theoretical Chemistry, University of Tübingen, Germany

A novel class of organic compounds, namely the nitronyl nitroxide radicals, has recently gained attention because of its magnetic property. In this work a pyrene-substituted nitronyl nitroxide radical (NitPyn) deposited on well characterized rutile TiO<sub>2</sub>(110) single crystals has been investigated by using X-ray photoemission spectroscopy (XPS) and near edge X-ray absorption fine structure spectroscopy. The mechanism of molecular adsorption on the well defined surface, the chemical environment at the interface and the electronic structure of thin films are discussed by analyzing the XPS core level signals. The persistence of the paramagnetic character of the molecules is also discussed with respect to the chemisorption on the surface. Our studies clarifies the orientation of the molecule in the thin films as a function of film thickness as well as the influence of the substrate, identifying the fine balance between molecule-molecule and molecule-substrate interactions.