DF 14: Various Topics II

Nano- and microstructured dielectrics / thin films
Optical and nonlinear optical properties, photonic
High- and low-k-dielectrics
Dielectric surfaces and interfaces

Chair: Leonore Wiehl

Time: Wednesday 15:00–18:00 Location: GER 37

DF 14.1 Wed 15:00 GER 37

Applying of UV and IR nanosecond laser radiation for the nanostructuring of dielectric surfaces — •Pierre Lorenz, Igor Zagoranskiy, Lukas Bayer, Joachim Zajadacz, and Klaus Zimmer — Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstr. 15, 04318 Leipzig, Germany

Dielectric nanostructures have a widespread field of applications. However, a fast and cost-effective production is still a challenge. Laser structuring methods using self-organized processes can solve the technological difficulties. The so-called ISPM-LIFE (laser-induced front side etching using in-situ pre-structured metal layer) method allows the nanostructuring of dielectric surfaces assisted by a laser-induced nanostructured metal film. The IPSM-LIFE can be separated into two steps: First, a low laser fluence treatment results in a nanopattern formation of the metal film, caused by instabilities of a thin molten metal. Second, a high-fluence treatment of the pre-structured metal film results in nanostructuring of the dielectric surface. Different metal layer (Cr, Mo, Ti) / dielectric substrate (fused silica, sapphire, BK7) systems were tested with UV laser (KrF excimer laser $\lambda = 248\,\mathrm{nm}$, $\Delta t_p = 25\,\mathrm{ns}$, $f = 1 - 200\,\mathrm{Hz}$) and IR laser (fiber laser $\lambda = 1064\,\mathrm{nm}$, $\Delta t_p = 1 - 600\,\mathrm{ns}$ with a time resolution of $1\,\mathrm{ns}$, $f = 2 - 100\,\mathrm{kHz}$). The resultant structures were investigated by atomic force (AFM) and scanning electron microscopy (SEM). The structuring process was simulated using a heat equation to describe the laser-heating of the solid and a kind of Navier-Stokes equation to describe the mass transport in the liquid.

DF 14.2 Wed 15:20 GER 37

Local charge injection and extraction on surface-modified Al_2O_3 nanoparticles in LDPE — •Riccardo Borgani[1], Love K. H. Pallon[2], Mikael S. Hedenqvist[2], Ulf W. Gedde[2], and David B. Haviland[1] — [1]Nanostructure Physics, KTH Royal Institute of Technology, Stockholm, Sweden — [2]Fibre and Polymer Technology, KTH Royal Institute of Technology, Stockholm, Sweden

Nanocomposite polymer insulators are promising materials for high voltage direct current power transmission, due to their very low leakage current. We image the injection of charges around surface-modified aluminum oxide nanoparticles in a low-density polyethylene (LDPE) matrix[1] using a recently developed atomic force microscopy technique. Intermodulation Electrostatic Force Microscopy[2] allows us to image the surface potential around the individual nanoparticles under different bias conditions. The experimental results are consistent with the presence of shallow trap states (localized electronic states) in the LDPE near the nanoparticles, providing experimental evidence for a previously proposed explanation of the enhanced insulating properties of nanocomposite LDPE.

[1] R. Borgani, L.K.H. Pallon, M.S. Hedenqvist, U.W. Gedde, and D.B. Haviland, Nano Lett. 16, 5934 (2016).

[2] R. Borgani, D. Forchheimer, J. Bergqvist, P.-A. Thorén, O. Inganäs, and D. B. Haviland, Appl. Phys. Lett. 105, 143113 (2014).

DF 14.3 Wed 15:40 GER 37

In situ hard x-ray photoemission spectroscopy of barrier-height control at metal/PMN-PT interfaces — Erik Kröger[1], Adrian Petraru[2], Arndt Quer[2], Rohit Soni[2], Matthias Kalläne[1,3], Nikolay Pertsev[4], •Hermann Kohlstedt[2], and Kai Rossnagel[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, D-24098 Kiel, Germany — [2]Nanoelektronik, Technische Fakultät, Christian-Albrechts-Universität zu Kiel, D-24143 Kiel, Germany — [3]Ruprecht-Haensel-Labor, Christian-Albrechts-Universität zu Kiel, D-24098 Kiel, Germany — [4]Ioffe Institute, St. Petersburg, Russia

Metal-ferroelectric interfaces form the basis of novel electronic devices. A key effect determining the device functionality is the bias-dependent change of the electronic energy-level alignment at the interface. Here, hard x-ray photoelectron spectroscopy (HAXPES) is used to determine the energy-level alignment at two metalferroelectric interfaces Au versus SrRuO3 on the relaxor ferroelectric Pb(Mg1/3Nb2/3)0.72Ti0.28O3 (PMN-PT) directly in situ as a function of electrical bias. The bias-dependent average shifts of the PMN-PT core levels are found to have two dominant contributions on the 0.1 to 1 eV energy scale: one depending on the metal electrode and the remanent electric polarization and the other correlated with electric-field-induced strain. The results suggest electric-field-induced modifications of the polarization distribution as a novel way to control the barrier height at such interfaces.

E. Kröger et al., Phys. Rev. B 93, 235415 (2016).

DF 14.4 Wed 16:00 GER 37

The work function for Li^+-Ion Emission from Spodumene - a complete characterization of thermionic emission — •Martin Schäfer, Stephan Schuld, Mira Diekmann, and Karl-Michael Weitzel — Philipps-Universität Marburg

Experiments with ion beams have manifold applications, e.g. in surface structuring, in focused ion beam microscopy and micromachining, in micro-propulsion for space vehicles and for depth profiling in secondary ion mass spectrometry. Most of these applications rely on a strong and stable ion source. A classical means for generating strong ion beams is thermionic emission. In the current work [1], thermionic emission of Li+ from synthetic spodumene ($LiAlSi_2O_6$) has been investigated as a function of temperature and electric field. The data presented cover the entire range from space charge limited Child-Langmuir regime, to the Richardson-Dushman regime and finally the field assisted Schottky regime. From a self-consistent analysis of all data measured the work function for Li+ emission from synthetic spodumene is determined as (2.47 ± 0.015),eV. The thermionic currents exhibit a voltage offset of $(1.7 \pm 0.1)\,\mathrm{eV}$, which can be traced to a combination of the ionic work function of the emitter, the recombination energy Li^{++} electron, the electronic work function of the detector and the contact potential between detector and filament. Fundamental differences between ion emission and electron emission and their relevance for properties of Li-electrolytes in battery materials are discussed. [1] S. Schuld, M. Diekmann, M. Schäfer, and K. M. Weitzel, J. Appl. Phys. 120, (2016) 185102

20 min. break

DF 14.5 Wed 16:40 GER 37

Luminescent glasses for LED lighting — •Juliane Schuppich[1], Peter W. Nolte[2], Franziska Steudel[2], and Stefan Schweizer[1,2] — [1]South Westphalia University of Applied Sciences, Luebecker Ring 2, 59494 Soest — [2]Fraunhofer Application Center for Inorganic Phosphors, Branch Lab of Fraunhofer Institute for Microstructure of Materials and Systems IMWS, Luebecker Ring 2, 59494 Soest

Light emitting diodes (LEDs) are currently revolutionizing the lighting market. White LEDs are commonly realized by a blue emitting LED chip combined with a yellow emitting phosphor powder embedded in an organic polymer on top of the chip. However, the polymers are prone to aging due to high temperatures and high light intensities. This work describes an approach to replace the powder/polymer composite by a luminescent glass which offers a significantly higher thermal and chemical stability. Luminescent glasses have attracted much attention in the last decades, in particular for applications such as lasers, optical fibres, and optical amplifiers. Glass is very versatile and a good host for luminescent lanthanide ions; it provides high optical transparency, good lanthanide ion solubility, and it can be cast in almost any shape or size. Here, investigations performed on a blue LED covered with luminescent borate glass are presented. The glasses are analyzed for their optical parameters such as transmittance, reflectance, and quantum efficiency to provide a basis for subsequent optical simulations. The simulations are compared to photometric far-field measurements of the luminous intensity distributions and discussed in detail.

DF 14.6 Wed 17:00 GER 37

Tailoring metal-organic frameworks for enhanced two-photon absorption — •Lydia Nemec, Raghavender Medishetty, Roland A. Fischer, and Karsten Reuter — Technische Universität München

Two-photon absorption (2PA) is exploited in a wide range of applications such as photonics, three-dimensional data storage or fluorescence microscopy. The performance of typical molecular 2PA materials is often hindered by low molecular stability and concentration. A promising new material class to overcome these limitations are metal-organic frameworks (MOFs). In a joined experimental and theoretical venture, we demonstrate how MOFs can be tuned for enhanced 2PA properties, outperforming any currently known solid-state material with 2PA values of up to 3600 GM. We investigate the origin of the enhanced 2PA cross section through time-dependent density-functional theory calculations on the level of van der Waals corrected hybrid exchange-correlation functionals. Systematically exploring the influence of charge transfer, molecular strain and constraints, as well as structural arrangement, we identify five design criteria to enhance 2PA in MOFs.

DF 14.7 Wed 17:20 GER 37

Mid-infrared optical and plasmonic devices enabled by area-selective ion beam doping of silicon — •Martin Hafermann[1], Jad Salman[2], Raymond Wambold[2], Chenghao Wan[2], Jura Rensberg[1], Mikhail A. Kats[2], and Carsten Ronning[1] — [1]Institute of Solid State Physics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Department of Electrical and Computer Engineering, University of Wisconsin - Madison, 1415 Engineering Drive, Madison, WI 53706, USA

The free charge carrier concentration of semiconductors is tunable over several orders of magnitude by impurity doping. Comparable to noble metals in the ultraviolet-visible spectral region, highly doped semiconductors possess "metal-like" optical properties but in the mid-infrared regime. Thus, the plasma frequency of these materials can be adjusted over a wide range by controlling the doping concentration. In this work, we fabricated optical and plasmonic devices in the mid-infrared using area-selective ion implantation of phosphorous through lithographically defined masks into silicon and subsequent annealing. Reaching doping concentrations on the order of 10^{21} cm^{-3} resulted in cross-over frequencies (where $\varepsilon_{\mathrm{real}} = 0$) in the range of 4 μm. Thus, we demonstrate diffractive optical elements such as Fresnel zone plates and diffraction gratings, as well as plasmonic devices like frequency selective surfaces. Our process results in optical devices that are CMOS compatible, completely planar and monolithic, thus stackable, as well as robust against high temperatures and physical erosion.

DF 14.8 Wed 17:40 GER 37

Self-consistent theory of Anderson localization for vector waves in disordered photonic media — •Zhong Yuan Lai, Michael Golor, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

Anderson localization of light in a random dielectric system is still a controversial issue due to the vector nature of light. We investigate the effects of the vector nature of light on propagation properties in photonic crystals with binary disorder. Due to the transverse nature of light ($\nabla \cdot \vec{D} = 0$), the three vector components reduce to the well-known, two-fold polarization degrees of freedom, that is, in two orthogonal polarization modes on each lattice site in a three-dimensional lattice. It can be described as a pseudospin-$\frac{1}{2}$ degree of freedom. Hopping in the random lattice induces flipping of the pseudospin (mixing of the polarization modes) in analogy to random spin-orbit scattering in electronic systems. We generalize the photonic Coherent Potential Approximation (CPA) to this pseudospin system in order to calculate single-photon properties like the self-energy and density of states (DOS). To calculate transport properties, we generalize the Vollhardt-Wölfle theory of Anderson localization to the case of vector waves, using the pseudospin representation. We find localizing and antilocalizing contributions to the diffusion coefficient $D(\Omega)$ in the pseudospin singlet and triplet channels, analogous to random spin orbit scattering. We calculate the corresponding phase diagram of Anderson localization. Our results may provide a systematic way of analyzing the difficulties in achieving light localization in experiments.