DF 10 Electric, Electromechanical and Optical Properties I

Time: Thursday 14:30–18:10 Room: MÜL Elch

Invited Talk

DF 10.1 Thu 14:30 MÜL Elch

Broadband Dielectric Spectroscopy in Functional Transition-Metal Compounds — •Joachim Hemberger, Peter Lunkenheimer, Robert Fichtl, Stefan Weber, Torsten Rudolf, Franz Mayer, Andrei Pimenov, Vladimir Tsurkan, and Alois Loidl — Center for Electronic Correlation and Magnetism, University of Augsburg, D-85135 Augsburg, Germany

Transition-metal compounds offer an exceptional variety of functional properties with a broad range of application. In addition to the canonical dielectric oxides reaching from piezo-electric or ferroelectric to high-permittivity materials, compounds with complementary magnetic and electronic properties are currently more and more under focus. An example are multiferroic compounds combining ferroelectricity and ferromagnetism. However, the coexistence of magnetic spin, orbital or charge degrees of freedom requires the consideration of systems with partially filled d-shells in contrast to the usual dielectric d^0-systems. This is accompanied by an deterioration of the insulating properties. Non-d^0 systems commonly are "bad insulators", i.e. they posses smaller, correlation induced electronic gaps instead of the large band gaps of usual optically transparent dielectric materials. This leads to finite DC- and AC-contributions to the conductivity and to a finite charge carrier density in the conduction band. The talk will outline the potential as well as the difficulties of broadband dielectric spectroscopy to study complex transition-metal compounds and illustrate them discussing various examples like titanates, manganates or Cr-based thio-spinels.

This work was supported by BMBF (VDI/EKM 13N6917-A) and DFG (SFB 484).

DF 10.2 Thu 15:10 MÜL Elch

Structuring of ferroelectric volume domains in lithium niobate crystals by space charge fields — •Felix Kalkum, Helge A. Eggert, and Karsten Buse — Institute of Physics, University of Bonn, Wegelerstr. 8, 53115 Bonn

The controlled structuring of ferroelectric domains in lithium niobate crystals promises a variety of new optical applications, e.g., electrically switchable Bragg filters. The quality of domain structures made by conventional methods is not sufficient for most of these applications. Therefore the so-called method of electrical fixing was studied: After a space charge field is written in iron doped lithium niobate crystals by means of the photorefractive effect, an external electrical field is applied. Since the resulting electrical field is above the threshold field for ferroelectric domain inversion in some regions and below in others, domains can be structured. A stochastical description of domain inversion assumes that the electrical field increases the probability for inversion, but does not imply necessarily a domain inversion if it exceeds the coercive field. The stochastical approach explains the shape and the effective modulation degree of the domain patterns. *Financial support by the DFG (BU913/11) and by the Deutsche Telekom AG is gratefully acknowledged.

DF 10.3 Thu 15:30 MÜL Elch

Fabrication of embedded waveguides in $LiNbO_3$ by radiation damage — •K. Peithmann[1], M.-R. Zamani-Meymian[1], M. Haaks[1], K. Maier[1], B. Andreas[2], K. Buse[2], and H. Modrow[2] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, — [2]Physikalisches Institut, Bonn, Germany

Irradiation of $LiNbO_3$ with low-mass, high-energy ions as 40 MeV ^3He (range in $LiNbO_3 \approx 0.6$ mm) creates strong, permanent refractive-index changes: The ordinary refractive index n_o is decreased and the extraordinary refractive index n_e is increased in the regions where the ions are transmitted through the material. Characteristic dependences of these changes on the ion dose and their thermal stability are measured, and the feasibility of fabrication of embedded waveguides (size ≈ 30 μm) using spatially modulated ion distributions is demonstrated.

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DF 10.4 Thu 15:50 MÜL Elch

Photorefraction as a general property of light-induced metastable states in nitrosyl compounds — •Dominik Schaniel[1], Thomas Weisemoeller[1], Mirco Imlau[1], Theo Woike[2], Karl Krämer[3], and Hans-Ueli Güdel[3] — [1]Fachbereich Physik, Universität Osnabrück, Barbarstrasse 7, 49069 Osnabrück — [2]Institut für Mineralogie, Universität zu Köln, Zülpicherstrasse 49b, 50674 Köln — [3]Department of Chemistry and Biochemsitry, University of Bern, Freiestrasse 3, 3000 Bern 9

Photorefractive materials have a broad range of applications in the field of nonlinear optics and need often to be tailored to meet specific demands. In oxidic electro-optic materials or photorefractive polymers tuning is achieved by additional doping of charge carriers or application of external fields. We report on another class of photosensitive compounds containing molecules of type $[ML_5NO]^{n\pm}$ with M a transition metal, L a broad range of ligands, and n the formal charge of the anion/cation. In these compounds metastable states can be generated by light irradiation and tuning of the photorefractive response is achieved by selecting different molecules $[ML_5NO]^{n\pm}$, e.g., the lifetime and spectral sensitivity of the metastable states can be varied from 10^{-8}s to10^1s and from 300-1200 nm, while the size of the effect can be adjusted up to $\Delta n \sim 10^{-2}$. We show that photorefraction is a general property of the light-induced metastable states accessible in molecules of the type $[ML_5NO]^{n\pm}$ and thereby establish a new class of photorefractive compounds.

DF 10.5 Thu 16:10 MÜL Elch

Space-charge waves in silicon carbide — •M. Lemmer[1], M. Imlau[1], M. Petrov[2], V. Bryksin[2], and A. Lebedev[2] — [1]Department of Physics, University of Osnabrück — [2]Physico-Technical Institute, Russian Academy of Sciences, St. Petersburg

The non-linear phenomenon of space-charge waves (SCW) is investigated in single crystals of 4H-SiC polytype. By excitation with an oscillating interference pattern at $\lambda = 488$ nm and an externally applied electric field of $0 < E_0 \leq 10$ kV/cm spatial rectification (SR) is found. The amplitude and the frequency of the SR-resonance signal show relevant dependences on the applied electric field and the wave number K of the interference pattern. For instance the amplitude exhibits a pronounced maximum at low values of K of approximately $2 \cdot 10^3$ cm^{-1}. All results are successfully described by the generalized SCW-model, if the effect of trap saturation, caused by a limited trap density, is considered. This allows to determine important material parameters of 4H-SiC like the product of mobility and lifetime of the charge carriers $\mu\tau = (7.4 \pm 0.8) \cdot 10^{-7}$ cm^2/V, the Maxwell relaxation time $\tau_M = (5.3 \pm 0.6) \cdot 10^{-4}$ s, and the effective trap concentration $N_{\text{eff}} = (5 \pm 1) \cdot 10^{13}$ cm^{-3}.

Supported by the Deutsche Forschungsgemeinschaft (DFG, projects GRK 695 and 436 RUS 17/16/06).

DF 10.6 Thu 16:30 MÜL Elch

Dispersion of the electrooptic properties of Cerium-doped Strontium-Barium-Niobate — •K. Bastwöste[1], M. Imlau[1], and M. Goulkov[2] — [1]Fachbereich Physik, Universität Osnabrück, Barbarastrasse 7, D-49069 Osnabrück — [2]Institute of Physics, Kiev, Ukraine

The electrooptic coefficient r and the photorefractive trap density N_{eff} are determined as a function of the wavelength in Cerium-doped Strontium-Barium-Niobate (SBN:Ce) by applying the photorefractive method of photo-induced light scattering. A pronounced increase of r is found in the blue-green spectral range, which is described by a combination of the Sellmeier formulation and the polarization tensor concept. Thus, the strength and energy of the average dipole oscillator characterizing the optical interband transfer are estimated with $f_e = (2 \pm 0.5) \cdot 10^{31}$ s^{-2} and $E_e = (3.7 \pm 0.26)$ eV. The increase of r with decreasing wavelength equals to already reported results for electrooptic crystals. Nevertheless, the strong increase by more than a factor of two is remarkable compared to an increase of 16 % in $LiNbO_3$:Fe [1] and 38 % in $BaTiO_3$ [2]. The dispersive behavior of N_{eff} is discussed in the context of the results of undoped SBN and interband photorefraction [3].

Financial support from the Deutsche Forschungsgemeinschaft (DFG, project GRK 695).

[1] S. Fries, S. Bauschulte, Phys. Stat. Sol. **125**, 369 (1991).

[2] A. R. Johnston, J. Appl. Phys. **42**, 3501 (1971).
[3] M. D. Ewbank,R. R. Neurgaonkar, W. K. Cory, J. Feinberg, J. Appl. Phys **62**, 374 (1987).

DF 10.7 Thu 16:50 MÜL Elch

Ferroelectric domain gratings contributing to photo-induced polarization-anisotropic light scattering in $LiNbO_3$:Fe — •A. Selinger, U. Voelker, and M. Imlau — Fachbereich Physik, Universität Osnabrück, Barbarastrasse 7, D-49069 Osnabrück

Only recently, the appearence of a bright polarization-anisotropic elliptical scattering pattern upon exposure to cw- and pulsed laser light has been discovered in thin Fe-doped $LiNbO_3$ crystals, i.e. in samples with thicknesses below 900 μm [1]. Our further investigations reveal that this phenomenon can be explained by the interplay of photo-induced refractive-index and ferroelectric-domain gratings. For example, the kinetics of the scattering intensity of the ellipse is found to be identical to the kinetics of the so called e-line, which is a scattering pattern originating solely from the photo-induced formation of microdomains. At the same time, the polarization-flip observed in the ellipse, comparable to that in the well-known anisotropic ring, gives rise to a contribution of photorefractive gratings via the electrooptic tensor element r_{42}. This approach is strongly supported by experimental studies of the influence of temperature towards appearence, stability and decay of the elliptical scattering pattern. An Ewald-construction, taking into account both photo-induced refractive-index and ferroelectric-domain gratings, is presented and allows to explain the specific shape of the ellipse.

Financial support by the Deutsche Forschungsgemeinschaft (DFG, project IM 37/2-1) is greatfully acknowledged.

[1] A. Selinger, U. Voelker, M. Imlau, OSA Trends in Optics and Photonics (TOPS), Vol. 99, pp. 61 -67

DF 10.8 Thu 17:10 MÜL Elch

Frequency mixing of photorefractive index gratings with ferroelectric domain gratings in lithium niobate crystals — •Ulrich Hartwig[1], Michael Kösters[1], Theo Woike[1], Karsten Buse[1], Alexander Shumelyuk[2], and Serguey Odoulov[2] — [1]Institute of Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [2]Institute of Physics, National Academy of Sciences, 252650 Kiev, Ukraine

Copper-doped lithium niobate crystals are periodically poled. Afterwards holographic gratings are recorded into this material using only diffusion for charge redistribution. Readout reveals that the principal grating with grating vector **K** is strongly suppressed. At the same time sideband gratings with grating vectors $\mathbf{K}\pm\mathbf{G}$ appear, where **G** is the grating vector of the domain pattern. From the measurements the grating vector **G** and the duty cycle DC (ratio of the width of up- and down domains) of the domain pattern can be calculated. These values are important quality criteria of the periodic structure of the sample. The findings of this work enable nondestructive quality inspection of periodically-poled lithium niobate. Furthermore, conclusions can be drawn for applications involving both holographic gratings and periodic domain structures for, e.g., hybrid distributed-feedback optical parametric oscillators.

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DF 10.9 Thu 17:30 MÜL Elch

Light-induced changes of polarization dynamics in PLZT ceramics — •T. Granzow, A. Volkenborn, and J. Rödel — FB Material- und Geowissenschaften, TU Darmstadt

Due to their excellent electrooptical properties, PLZT ceramics have been investigated since the early days of electrooptics. Most investigations have focussed on the influence of electric fields on the optical properties. The opposite effect, the influence of illumination on the ferroelectric domain structure and hysteresis is still not entirely clear. It has been shown that there is an interplay between the nucleation of ferroelectric domains, motion of domain walls and light-induced free charge carriers, but there are contradictions both in theory and in experiments if free charge carriers will help or hinder ferroelectric polarization reversal.

In this talk, we will compare the polarization behavior in PLZT 8/65/35 and PLZT 9.5/65/35 with and without illumination in the visible spectral range. We will present the ferroelectric hysteresis detected by measuring the switching current as well as the integrated polarization. To obtain the domain dynamics, the development of P on a timescale between 1 μs and 10 s under a constant electric field is examined for various field amplitudes. It will be shown that, although the difference between the illuminated and unilluminated hysteresis measurement is rather small for frequencies up to 100 Hz, there is a notable decrease of the switching time constants in the ms range. This phenomenon will be discussed within the framework of conduction band electrons facilitating domain wall movement.

DF 10.10 Thu 17:50 MÜL Elch

Theoretical modelling of optical and luminescence processes in tungstate crystals — •Yuriy Hizhnyi and Sergiy Nedilko — Faculty of Physics, Kyiv National Taras Shevchenko University, 2, block 1, Hlushkova av., 03680, Kyiv, Ukraine

Tungstate crystals AWO_4 (A = Zn, Cd, Pb) are widely used as scintillation materials in various scientific and technical applications. Despite of intensive investigations of their optical and luminescent characteristics carried out in the last decade, there is no a commonly assumed view on the origin of luminescence processes in these crystals. Profound examinations of luminescence mechanisms in tungstate crystals can be done using theoretical calculations of their electronic structures.

In our study, we use a complex approach in calculations, which combines two different methods. The electronic and optical properties of perfect AWO_4 crystals are studied by full potential Linear Augmented Plane Wave (FLAPW) method [1]. The electronic structures of the lattice defects and impurities that in general determine the luminescence properties of AWO_4 crystals are examined in the molecular cluster approach. Several types of defects are modelled in clusters constructed from 12 - 110 atoms of the crystals. The electronic structures of the clusters are calculated by the Restricted Hartree-Fock (RHF) method [2].

Results of calculations are compared with corresponding experimental data. Schemes of possible luminescence processes in AWO_4 crystals are determined on the basis of the obtained results.

[1] P. Blaha, et al., 2001, ISBN 3-9501031-1-2
[2] Schmidt M.W., et al., J.Comput.Chem., 14, 1347, (1993)