KFM 14: Polar Oxide Crystals and Solid Solutions II

Chair: Prof. Dr. Holger Fritze (TU Clausthal)

Time: Thursday 14:00–16:35 Location: POT 106

KFM 14.1 Thu 14:00 POT 106

Domain wall current in lithium niobate single crystals at temperatures up to 370°C — •U. Yakhnevych[1], M. Kunzmer[1], I. Kiseleva[2], J. Gössel[2], J. Ratzenberger[2], M. Rüsing[2], L.M. Eng[2,3], and H. Fritze[1] — [1]Institut für Energieforschung und Physikalische Technologien, TU Clausthal, Am Stollen 19 B, Goslar, 38640, Germany — [2]Institut für Angewandte Physik, TU Dresden, Nöthnitzer Straße 61, 01187 Dresden, Germany — [3]Dresden-Würzburg Cluster of Excellence - EXC 2147, TU Dresden, 01062 Dresden, Germany

Lithium niobate (LN) ferroelectric crystals with an artificially formed domain structure are widely used in novel electronic devices. So far, a complete picture of the electrical transport mechanism at domain walls is still missing, including its high temperature behavior. This work focuses on the determination of the domain wall conductivity from room temperature up to 370 °C. Using 5%MgO:LN, conductive DWs are prepared and enhanced following the procedure by Godau et al. [1]. Direct current measurements using an electrometer amplifier and impedance spectroscopy are applied to locally map the temperature-dependent DW current. A strong dependence of the electrical conductivity on temperature is observed. The activation energy shows distinct values for low-to-medium and high temperatures, respectively, reaching values of ˜0.1 eV and ˜0.15*eV. For further analysis, the obtained samples should be measured at even higher temperatures. [1] C. Godau, T. Kämpfe, A. Thiessen at al. ACS Nano 11, 5, 4816-4824 (2017). https://doi.org/10.1021/acsnano.7b01199

KFM 14.2 Thu 14:20 POT 106

Ferroelectric domains and domain walls under uniaxial stress * A case study in lithium niobate — Ekta Singh[1], Henrik Beccard[1], Michael Lange[1], Sven Reitzig[1], Zeeshan H. Amber[1], Clifford W. Hicks[3], Julius Ratzenberger[1,2], •Michael Rüsing[1], and Lukas M. Eng[1,2] — [1]Institut für Angewandte Physik, TU Dresden, Nöthnitzer Straße 61, 01187 Dresden, Germany — [2]ct.qmat: Dresden-Würzburg Cluster of Excellence - EXC 2147, TU Dresden, 01062 Dresden, Germany — [3]School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, United Kingdom

In material science, mechanical strain has an influence on a multitude of material properties. For ferroelectrics, strain can be achieved via standard techniques, such as lattice-mismatched epitaxial growth of thin films, or hydrostatic pressure. However, these methods are either limited to specific material combinations or non-local investigation techniques. Here, we present an alternative approach [1] to study bulk crystals under the influence of uniaxial strain, using a piezo-actuator-based device that is compatible with various local probe techniques. To demonstrate the operation we present the influence of strain on the vibrational properties probed via micro-Raman spectroscopy [1], as well as the influence of strain on the local conductivity of ferroelectric domain walls probed by scanning con-ductance microscopy [2]. [1] E. Singh et.al, arXiv:2210.14120 (2022). [2] E. Singh et.al, Phys. Rev. B 106,144103 (2022).

KFM 14.3 Thu 14:40 POT 106

Hall effect in conductive ferroelectric domain walls in $BaTiO_3$ — Henrik Beccard[1], Elke Beyreuther[1], Michael Rüsing[1], Benjamin Kirbus[1], Ekta Singh[1], •Samuel Seddon[1], Petr Bednyakov[2], Jiri Hlinka[2], and Lukas M. Eng[1,3] — [1]Institut für Angewandte Physik, TU Dresden, Nöthnitzer Straße 61, 01187 Dresden, Germany — [2]Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 18221 Praha 8, CZR — [3]ct.qmat: Dresden-Würzburg Cluster of Excellence - EXC 2147, TU Dresden, 01062 Dresden, Germany

Two dimensional (2D) electronic systems are essential in cutting-edge nano- electronic research. Here, conductive ferroelectric domain walls (DWs) are experiencing a concerted research effort for the last decade. Much of the research, however, did focus onto measuring and tuning the electrical DW conductivity [1], with very little investigations reporting on the very fundamental DW properties such as charge carrier density and mobility. Here, we adapted the 4-point van der Pauw [2] geometry to probe these 2D sheets of ferroelectric DWs in $BaTiO_3$, and were able to determine the aforementioned properties. We find large electron mobilities of 400 cm^2 $(Vs)^{-1}$ and decent electron densities [3]. Not only are these results by themselves novel, but also perfectly demonstrate the power of this simple methodology to quantify the charge carrier properties in any low-dimensional system.

[1] C. Godau, et al., ACS Nano **11**, 4816 (2017)
[2] L. J. Van der Pauw, Philips Tech Rev **20**, 220-224 (1958)
[3] H. Beccard, et al., ACS Appl. Nano Mater. **7**, 8717-8722 (2022)

KFM 14.4 Thu 15:00 POT 106

Thin Patterned Lithium Niobate Metasurfaces by Parallel Additive Capillary Stamping of Aqueous Precursor Solutions — •Jan Klenen[1], Fatih Alarslan[2], Laura Vittadello[1], Martin Steinhart[2], and Mirco Imlau[1] — [1]Department of Physics, Osnabrück University, Germany — [2]Institute of Chemistry of New Materials, Osnabrück University, Germany

Optical metasurfaces are a rapidly evolving field in the aim to miniaturize optical functionalities and integrated photonics [A. Fedotova et al., *ACS Photonics* **2022**]. However, the large-scale application is still challenging as the preparation of such metasurfaces, i.e., by mechanochemical wafer thinning or lithographic pattering, is usually complex, time-consuming, and expensive. We try to address this problem and present a novel method of metasurface patterning based on parallel additive capillary stamping of $LiNbO_3$ on an ITO substrate [F. Alarslan et al., *Advanced Engineering Materials* **2021**, 24(6)]. This technique offers the advantage of rapid, easily customizable and cheap structuring of layers with thicknesses on the order of 100 nm. Nonlinear optical investigations performed with the TIGER microscope show a homogeneous second harmonic generation (SHG) of the surface coinciding with the $LiNbO_3$ film structured by hexagonally arranged macropores. The additional implementation of gold nanoparticles at the position of the macropores allows for a drastic enhancement of the SHG by exploiting plasmonic resonances. Financial support by the ERC (project 646742 INCANA) and DFG (projects IM 37/12-1, FOR 5044 and INST 190/165-1) is gratefully acknowledged.

15 min. break

KFM 14.5 Thu 15:35 POT 106

Optical nonlinearities of lithium tantalate solid solutions — •Mirco Imlau, Tobias Hehemann, Sören Domke, Niklas Dömer, Fiete Breer, Felix Kodde, Jan Kleenen, Anton Pfannstiel, and Laura Vittadello — Institute of Physics, Osnabrück University

Optical nonlinearities of optical materials, i.e. the nonlinear material response to incident electromagnetic radiation, are the fundamental physical basis for a number of components in nonlinear photonics, such as nonlinear optical Kerr lenses, saturable absorbers or frequency converters. The properties of optical nonlinearities are closely related to the electronic and atomic structure of the material systems used. Against this background, lithium niobate tantalate (LNT, $LiNb_xTa_{1-x}O_3$ with $0 \leq x \leq 1$) solid solutions are promising because the edge compounds themselves (LN, x=1 and LT, x=0) are already extensively used in photonics' components, but especially because the nonlinear optical properties of LNT may be tailored to the specific requirements of the application via composition. We here present the state-of-the-art knowledge of our studies on optical nonlinearities of LNT over the entire composition range, both, for quasi-instantaneous nonlinear responses (absorption & nonlinear index, frequency conversion) and transient responses (time-resolved transient absorption on the temporal multiscale from femtoseconds to seconds & transient index dynamics). The findings are discussed in the framework of emerging applications in (nano-)photonics, particularly for laser systems of the next generation, and will be compared with LN and LT. Financial support by the DFG (project IM 37/12-1, FOR 5044).

KFM 14.6 Thu 15:55 POT 106

Small polaron absorption centers in lithium noibate-tantalate solid solutions — •Anton Pfannstiel[1], Simone Sanna[2], Yuriy

Suhak[3], and Steffen Ganschow[4] — [1]Inst. Physics, Osnabrück University — [2]Inst. Theoretical Physics, University of Gießen — [3]Inst, Energy Research, Technical university of Clausthal — [4]Leibniz-Institut für Kristallzüchtung (IKZ), Berlin

The study of small polarons in ferroelectric lithium niobate (LN) enabled the understanding of various physical phenomena on a microscopic level, like photo-induced coloration or conductivity and led to the formulation of a robust model of polaronic localization centers and energies [O. F. Schirmer *et al* 2009 J Phys.: Condens. Matter **21** 123201]. So far, for lithium tantalate (LT) and the solid solution, lithium niobate-tantalate (LNT) a respective small polaron model is missing in literature.

For this purpose, this study provides polaron self localization energies for LN, LT and LNT crystals of various composition. Thermally reduced crystals are optically bleached at cryogenic temperatures. The resulting small polaron absorption bands are identified through transmission spectroscopy and modeled within the framework of small polaron absorption theory. The determined polaron energies are interpreted against the background of the known defect models for LN and LT but also in conjunction with ab-initio modeling results for carrier self-localization. Financial support by the DFG [projects IM 37/12-1, SA 1948/3-1, SU 1261/1-1, GA 2403/7-1, FOR5044] is gratefully acknowledged.

KFM 14.7 Thu 16:15 POT 106

Nonlinear diffuse fs-pulse reflectometry adopted to LNT solid solutions — •F. Kodde[1], L. Vittadello[1], J. Klenen[1], K. Koempe[2], V. Hreb[3], D. Sugak[3], V. Sydorchuk[4], U. Yakhnevych[5], and M. Imlau[1] — [1]Institute of Physics, Barbarastr. 7, Osnabrück University — [2]Department of Biology and Chemistry, Barbarastr. 11, Osnabrück University — [3]Department of Semiconductor Electronics, Bandery Str. 12, Lviv Polytechnic National University, 79013 Lviv, Ukraine — [4]Institute for Sorption and Problems of Endoecology, NASU, 13 Gen. Naumov St., 03164 Kyiv, Ukraine — [5]Institute of Energy Research and Physical Technologies, Am Stollen 19B, TU Clausthal

Nonlinear diffuse fs-pulse reflectometry is a powerful tool to analyze the spontaneous polarization of polar oxide nano-crystals [Kijatkin *et al.*, Photonics **4**, 11 (2017)]. It profits from the absence of a phase-matching condition for frequency conversion. We present our systematic investigations at the example of nanocrystals of $LiNb_{1-x}Ta_xO_3$ (LNT) solid solutions [Vasylechko *et al.*, Crystals **11**, 755 (2021)], that show a disappearance of the birefringence if the temperature is precisely adjusted [Wood *et al.*, J. Phys.: Condens. Mat. **20**, 235237 (2008)]. Accordingly, we have extended the experimental setup by a temperature controlled pellet holder and determined the harmonic ratio as a function of composition, i.e. Li/Ta-ratio. We find both, a characteristic maximum of the harmonic ratio, and a dependence of the maximum on the composition. Financially supported by the DFG and BMBF [project IM 37/12-1, FOR5044, BMBF, FKZ: 01DK20009].