DF 9: Electric, Electromechanical and Optical Properties I

Time: Thursday 10:00–13:00 Location: H48

Invited Talk DF 9.1 Thu 10:00 H48

Electric Field Induced Critical Points and Electromechanical Response in Relaxor Ferroelectrics — •Zdravko Kutnjak[1], Robert Blinc[1], Jan Petzelt[2], and Stanislav Kamba[2] — [1]Jozef Stefan Iinstitute, Ljubljana, Slovenia — [2]Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic

The giant electromechanical response in ferroelectric relaxors such as $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) is of great importance for a number of ultrasonic and medical applications as well as in telecommunications. Despite intensive research the origin of this effect is however still not fully understood.

On the basis of dielectric, heat capacity, and piezoelectric investigations on PMN-PT crystals of various PT compositions we show the existence of a line of critical points for paraelectric to ferroelectric transformation in the composition–temperature–electric field (x-T-E) phase diagram [1]. This line effectively terminates a surface of first order transitions. Above this line supercritical evolution has been observed.

On approaching the critical point both the enthalpy cost to induce the intermediate monoclinic states decrease significantly. It is shown that the critical fluctuations in the proximity of the critical points are directly responsible of the observed enhancement of the electromechanical response in PMN-PT system [1]. Preliminary results of critical phenomena observed in other relaxor systems will be presented [2].

[1] Z. Kutnjak, R. Blinc, J. Petzelt, Nature vol. 441, 956 (2006)
[2] W. Kleemann et al., Phys. Rev. Lett. vol. 97, 065702 (2006)

DF 9.2 Thu 10:40 H48

Modifikation der Materialeigenschaften von Lithiumniobat durch Bestrahlung mit hochenergetischen ^{3}He-Ionen * — •Hilke Hattermann[1], Konrad Peithmann[1], Karl Maier[1] und Michael Kösters[2] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, Rheinische Friedrich-Wilhelms-Universität zu Bonn, Nußallee 14-16, 53115 Bonn — [2]Physikalisches Institut, Rheinische Friedrich-Wilhelms-Universität zu Bonn, Wegelerstraße 10, 53115 Bonn

Lithiumniobat ist ein ferroelektrisches Material, welches u.a. in der integrierten Optik vielseitige Verwendung findet. Durch die Bestrahlung mit hochenergetischen, leichten Ionen wie z. B. 40 MeV ^{3}He können die Eigenschaften von $LiNbO_3$ gezielt verändert werden. Zwei Beispiele werden in diesem Vortrag vorgestellt:

1.) Ein kongruent schmelzender $LiNbO_3$-Kristall wird periodisch bestrahlt, wobei sich im bestrahlten Bereich der Brechungsindex n verändert. Daher wird so eine periodische Modulation von n erzeugt, die bei einer Periode von einigen Mikrometern als Beugungsgitter für sichtbares Licht dienen kann.

2.) Wird ein mit Magnesium dotierter $LiNbO_3$- Kristall teilweise bestrahlt, so verändert sich sein Polungsverhalten und die Koerzitivfeldstärke im bestrahlten Bereich sinkt.

(*Gefördert durch DFG-FOR 557.)

DF 9.3 Thu 11:00 H48

Polaronic charge transport in reduced $LiNbO_3$ investigated by means of time-resolved ESA spectroscopy — •Christoph Merschjann, Bettina Schoke, Daniela Conradi, Mirco Imlau, and Manfred Wöhlecke — Department of Physics, University of Osnabrück, D-49069 Osnabrück

Charge-transport processes are investigated in differently reduced $LiNbO_3$ single crystals by means of time-resolved excited-state-absorption (ESA) spectroscopy. The detected transient light-induced absorption (α_{li}) upon intense pulsed laser illumination ($\lambda = 532\,nm, \tau = 8\,ns$) originates from four distinct types of metastable small polarons. From the temporal and spectral characteristics of α_{li} one is able to distinguish between bound Nb_{Li}^{4+} and free Nb_{Nb}^{4+} polarons, Nb_{Li}^{4+}:Nb_{Nb}^{4+} bipolarons, and bound O^- hole polarons. Among other results we find competing photochromic effects in the blue spectral range in reduced $LiNbO_3$. Furthermore, non-exponential relaxations of α_{li} are observed, whose time constants strongly depend on the state of reduction and purity of the samples. The excitation and recombination phenomena of photo-induced small polarons can be described by a charge transport model, based on a random-walk of excited charge carriers. The presented experimental method is an ideal complement to EPR and electrical measurements, yielding time-resolved spectra at room temperature.

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DF 9.4 Thu 11:20 H48

Extrinsic defects in high quality CaF_2 crystals for optical applications — •Stephan Hausfeld, Janis Sils, and Michael Reichling — Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49076 Osnabrück, Germany

Oxygen defects and other impurities were detected in CaF_2 single crystals by a highly sensitive method of photoluminescence under excitation by ultrashort UV laser pulses. To identify oxygen defects the luminescence was measured before and after annealing the crystal at 650°C and quenching it to room temperature. Only after this treatment luminescence of oxygen-vacancy dipoles in CaF_2 is visible. This observation can be explained by the dissociation of dipole dimers which do not contribute to the observed luminescence into simple oxygen-vacancy dipoles due to annealing and quenching. As major other impurities we identified Terbium, Cerium and Europium. Almost no luminescence of any impurity can be found in our crystals of highest quality. Only the oxygen defects remain as trace impurities in these samples.

DF 9.5 Thu 11:40 H48

Comparison of the light-induced absorption in single-domain $LiNbO_3$ and PPLN:Y after thermal reduction in vacuum — •Bettina Schoke[1], Christoph Merschjann[1], Mirco Imlau[1], and Inna Naumova[2] — [1]Department of Physics, University of Osnabrück, Germany — [2]Physics Department, Moscow State University, Russia

We study excitation and recombination processes of small polarons in nominally pure single-domain and yttrium doped periodically poled $LiNbO_3$ (PPLN:Y) after the samples were thermally reduced in vacuum. This treatment creates bipolarons (Nb_{Li}^{4+}:Nb_{Nb}^{4+}) which are stable at room temperature. They may be dissociated into small bound (Nb_{Li}^{4+}) and free (Nb_{Nb}^{4+}) polarons via light illumination ("optical gating"). The resulting light-induced absorption is measured time–resolved via excited–state–absorption (ESA) spectroscopy in the blue, red and infrared spectral range after optical excitation with intense ns laser pulses ($\lambda = 532\,nm$). In thermally reduced PPLN:Y, as in single-domain $LiNbO_3$, we observe both dissociation and recombination of bipolarons. The investigations also indicate the existence of photo-induced hole polarons (O^-) at room temperature. From the direct comparison of both samples we can deduce the influence of the periodic poling on the charge transport of the small polarons and can clarify the role of the yttrium in $LiNbO_3$ with regard to the polaronic properties. Financial support by the DFG (projects TFB 13-04, IM 37/2-2 and GRK695).

DF 9.6 Thu 12:00 H48

Comprehensive study of surface damage induced by SFG in Lithiumtriborate (LBO) — •Stefan Möller, Änne Andresen, Christoph Merschjann, Manfred Neumann, and Mirco Imlau — Department of Physics, University of Osnabrück, D-49069 Osnabrück

We have investigated the build-up of surface damages of LiB_3O_5 single crystals generated during sum-frequency generation (SFG) of UV-light ($\lambda = 355\,nm$) by a focused Q-switched Nd:YAG laser ($f = 20\,kHz$, $\tau_{1064} = 10\,ns$, $\overline{P}_{1064} = 1.5\,W$) on timescales $> 100\,h$ and intensities below the damage threshold. The comprehensive study was performed with low coherence microscopy, X-ray spectroscopy (XPS), excited-state absorption (ESA) and atomic force microscopy for optical, electrical and microscopic characterization of the damages. The aim of our work is to avoid the build-up of this damage in order to extend the lifetime of LBO in UV-laser systems. As a result we found two kinds of damages: The first is a deposition of foreign material on the surface. Here, XPS uncovers several foreign elements as Na, S, Si, Ca, C depending on the composition of the ambient atmosphere during SFG. The second kind of damage is characterized by an ablation of the surface of the crystal. Only this second kind of damage disturbs the beam quality noticeably, as a strong increase of the beam propagation factor M^2 was monitored simultaneously. With the results of the ESA studies we are able to discuss the role of polarons for the surface damage formation process as well as the cross-correlation of these two kinds of damages. Financial support by the DFG (TFB 13, project

A5/13-04).

DF 9.7 Thu 12:20 H48

High-temperature-recorded index gratings in periodically-poled lithium niobate* — •Michael Kösters, Ulrich Hartwig, Theo Woike, and Karsten Buse — Institute of Physics, University of Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Holographic index gratings based on a zero-electric-field photorefractive effect are recorded at high temperatures in copper-doped periodically-poled lithium niobate crystals. High-temperature recording causes strong absorption modulations which are linked to index gratings via the Kramers-Kronig relations as it is described in Ref. (1). The gratings do not originate from the electro-optic effect and can be read out regardless of their orientation in the crystal. Subsequently, the interplay between the periodic domain structure (grating vector $\mathbf{G}$) and the index grating (grating vector $\mathbf{K}$) is studied: The fundamental $\mathbf{K}$-grating is strongly suppressed. Pronounced sideband gratings with $\mathbf{K}_s = \mathbf{K} \pm s\mathbf{G}$ appear, where s is an integer number. The findings are of great importance for applications, where both, index gratings and ferroelectric domain gratings, are needed, e.g. for a DFB-OPO (Distributed-Feedback Optical Parametrical Oscillator).

*Financial support from the Deutsche Forschungsgemeinschaft (FOR 557) and from the Deutsche Telekom AG is gratefully acknowledged.

(1) U. Hartwig, K. Peithmann, B. Sturman, and K. Buse, Appl. Phys. B **80**, 227 (2005).

DF 9.8 Thu 12:40 H48

Reduction of optical damage in lithium niobate crystals by thermo-electric oxidization* — •Matthias Falk, Theo Woike, and Karsten Buse — Institute of Physics, University of Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Lithium niobate crystals are a promising material for nonlinear-optical applications, e.g., second harmonic generation. But the conversion efficiency is limited because of unwanted light-induced refractive index changes, the so-called "optical damage". This effect is mainly caused by iron impurities that occur in the valence states Fe^{2+} and Fe^{3+}. Electrons from Fe^{2+} are excited by light, redistributed and finally trapped, preferentially in the darker areas of the crystal. Space-charge fields build up and change the refractive index via the electro-optic effect. A method to suppress such index changes, the thermo-electic oxidization treatment, is presented: The crystals are annealed in the presence of an externally applied electrical field. By this the iron impurities are nearly completely oxidized to the Fe^{3+} state, thus there are less photoexcitable electrons in the crystal. Consequently, the optical damage is suppressed by one order of magnitude. Furthermore, it is shown, that for charge compensation of the removed electrons, lithium and hydrogen ions leave the crystal during the treatment.

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