# DF 3 FV-internes Symposium Polare Polymere und Ferroelektrete

Zeit: Samstag 08:30–12:00 Raum: TU C130

## Hauptvortrag

DF 3.1 Sa 08:30 TU C130

**Polymer ferroelectrics and ferroelectrets** — •Reimund Gerhard-Multhaupt — Department of Physics, University of Potsdam, Am Neuen Palais 10, D-14469 Potsdam

The orientation of molecular dipoles in the polymer chains and their stabilisation within crystalline domains by means of structural features and/or electrical charges render several semicrystalline polymers ferroelectric. Recent research shed new light on copolymers of polyvinylidene fluoride (PVDF), on odd-numbered polyamides and on polymeric relaxor ferroelectrics obtained through irradiation or copolymerisation. In addition, voided space-charge electret polymers have been shown to exhibit ferroelectric-like behavior and are thus often called “ferroelectrets” [1]. In this review, some recent developments will be reported and discussed with respect to fundamental mechanisms of ferroic behavior in polar or voided polymer electrets and to applications-relevant properties such as pyro- and piezoelectricity. It will be emphasized that polymer ferroelectrics and ferroelectrets usually contain at least two phases and are thus closely related to the well-known ferroelectric oxide-polymer micro- or nanocomposites.

[1] S. Bauer, R. Gerhard-Multhaupt, G. M. Sessler, “Ferroelectrets: Soft Electroactive Foams for Transducers”, *Physics Today* **57**(2), 37–43 (February 2004).

DF 3.2 Sa 09:10 TU C130

**Charged polymer foams as piezoelectric transducer materials: Enhancement of piezoelectric properties by optimisation of the elastic properties, the internal charging and the stacking of ferroelectret films** — •Michael Wegener — Department of Physics, University of Potsdam, Am Neuen Palais 10, 14469 Potsdam, Germany, mwegener@rz.uni-potsdam.de

Ferroelectrets are foams of electret polymers with an anisotropic cellular structure. In ferroelectrets, an internal void charging leads to charge layers of opposite polarity at opposite void surfaces. The charged voids represent large macroscopic dipoles which can be deformed by application of mechanical stresses or electric fields yielding a direct or inverse piezoelectric response of the polymer foam. During the last five years, the preparation, the structural modification and the electric charging of ferroelectrets have been investigated in detail. Here, several approaches to the optimisation of polymer-foam ferroelectrets are described and discussed, such as (i) the variation of elastic properties by structural modification with suitable inflation procedures, (ii) the optimised electric charging, taking into account the electric field threshold for micro-discharges within the voids, and (iii) the enhancement of the piezoelectric activity by stacking two or more foamed polymer-film ferroelectrets.

DF 3.3 Sa 09:30 TU C130

**Three-dimensional mapping of polarization profiles in ferroelectric polymers with thermal pulses** — •Axel Mellinger[1], Rajeev Singh[1,2], Michael Wegener[1], Werner Wirges[1], Reimund Gerhard-Multhaupt[1], and Sidney B. Lang[3] — [1]Department of Physics, University of Potsdam, Am Neuen Palais 10, 14469 Potsdam, Germany — [2]Department of Electronics & Communication, University of Allahabad, Allahabad, (U.P.)-211002, India — [3]Department of Chemical Engineering, Ben-Gurion University of the Negev, P.O.B. 653, 84105 Beer Sheva, Israel

The probing of polarization and space-charge depth profiles via thermal methods has been an area of ongoing research for nearly 30 years. Recent thermal-pulse measurements with state-of-the-art equipment have demonstrated that individual data points can be acquired on a timescale of seconds [1]. Using a focused laser beam as excitation source thus opens up the possibility of obtaining high-resolution, large-area three-dimensional polarization maps. This technique was tested on films of ferroelectric polyvinylidene fluoride poled with patterned electrodes, yielding a lateral resolution of 38 $\mu$m and a near-surface depth resolution of less than 0.5 $\mu$m. At larger depths, the lateral resolution is limited by fast thermal diffusion in the metal electrode rather than the laser spot size. Finite-element solutions of the heat-conduction equation show a transient temperature distribution differing significantly from the one-dimensional case, with potential impacts on the data-analysis procedure.

[1] A. Mellinger, R. Singh and R. Gerhard-Multhaupt, Rev. Sci. Instr. **76** *(in press)*, 2005.

DF 3.4 Sa 10:20 TU C130

**Charging and Switching of Ferroelectrets: How Much Can Ferroelectrets Behave Like Ferroelectrics?** — •Reinhard Schwödiauer, Ingrid Graz, Mario Dansachmüller, and Siegfried Bauer — Johannes Kepler Universität, Altenbergerstr. 69, A-4040 Linz

Nonpolar porous charge electrets with internally charged surfaces can exhibit pronounced piezoelectricity and have been termed ”Ferroelectrets”. Their puzzling and unexpected features resemble those normally known from traditional ferroelectrics: Ferroelectrets are piezo- and pyroelectric, their polarization can be reversed by means of an external field and electrical as well as mechanical hysteresis loops were observed. Here we report about the very different charging and switching mechanism in ferroelectrets, both in simple model-systems and in less simple foam structures. We also want to address some of the specific peculiarities and pitfalls related to present ferroelectrets and their characterization. Interfacial charge injection at high electric fields and anelastic non-linearities, for instance, can be the cause for false ferroelectric-like hysteresis effects which do not reflect any polarization reversal. Our contribution is an attempt towards a more comprehensive picture of how much ferroelectrets behave like ferroelectrics.

DF 3.5 Sa 10:40 TU C130

**Pyroelektrische Composites mit leitfähiger Matrix** — •Sabine Kopf und Bernd Ploss — FB Physikalische Technik, Fachhochschule Jena, Carl-Zeiss-Promenade 2, 07745 Jena

Composites aus ferroelektrischen Keramikpartikeln in einer Polymermatrix sind hochinteressante Materialien für pyroelektrische Sensoren, speziell wegen ihrer Prozesskompatibilität mit der Fertigung integrierter Schaltungen. Im Gegensatz zu homogenen Ferroelektrika können solche pyroelektrischen Composites auch so präpariert werden, daß die sonst störende piezoelektrische Aktivität vollständig kompensiert wird.

Die schlechte Anpassung zwischen der hohen Dielektrizitätszahl der Keramikpartikel und der substantiell kleineren Dielektrizitätszahl der Polymermatrix begrenzt allerdings den pyroelektrischen Koeffizienten dieser 0-3 Composites. Um die Auskopplung der pyroelektrischen Aktivität zu verbessern, wurde Polyurethan (PU) als Matrixmaterial mit Alkalihalogeniden dotiert. Eine drastische Erhöhung des pyroelektrischen Koeffizienten wurde mit leifähigem PU erreicht.

Untersucht wurden Dielektrizitätszahl und Gleichstromleitfähigkeit sowie der pyroelektrische Koeffizient von Composites mit Blei-Zirkonat/Titanat (PZT). Die empirischen Ergebnisse werden mit theoretischen Simulationen nach dem Maxwell-Wagner- und dem Bruggeman-Modell verglichen.

DF 3.6 Sa 11:00 TU C130

**Time-domain electrostatic force spectroscopy (EFS) on Solid Electrolytes using an AFM** — •Ahmet Taskiran, Andre Schirmeisen, Harald Fuchs, Bernhard Roling, Sevi Murugavel, Hartmut Bracht, and Frank Natrup — Physikalisches Institut and CeNTech, University of Muenster, Wilhelm-Klemm-Str.10, 48149 Münster, Germany

Ion conducting solid materials are widely used as solid electrolytes in batteries, etc. An important prerequisite for further progress in this field is a better understanding of ion transport mechanisms on nanoscopic length scales. We are using an AFM for EFS to measure the ionic conductivity in nanoscale volumes of homogeneous and heterogeneous solid electrolytes. The AFM is operated in the non-contact mode under ultra-high-vacuum conditions. After a change of the tip voltage the relaxation of the electrostatic force between tip and sample is measured as a function of time. The measurements are carried out at different temperatures ranging from 200 K to 675 K and at different places on the sample. The relaxation times at different temperatures can be fitted with an Arrhenius function. From the Arrhenius plot we obtain the activation energy of the ion hopping processes in the sample. In our work we focus on nanostructured solid electrolytes, where dramatic changes in the ion conductivity are caused by incorporated nanocrystallites. We find that the activation energies for the ions in the nanocrystallites and in the glass regions are different, in agreement with macroscopic results. Our measurements show that EFS is capable of probing the ion dynamics and transport in nanoscopic subvolumes of the samples.

DF 3.7 Sa 11:20 TU C130

**Stacks of piezoelectric cellular polypropylene films: Characterisation of audio and ultrasound transducer properties** — •Michael Wegener, Steffen Bergweiler, Olena Voronina, Werner Wirges, and Reimund Gerhard-Multhaupt — Department of Physics, University of Potsdam, Am Neuen Palais 10, 14469-Potsdam, Germany

Transducer films of cellular polypropylene typically show high piezoelectric activity with piezoelectric coefficients of several hundred pC/N or pm/V. Their piezoelectric activity can be adjusted and enhanced by suitably modifying preparation, inflation and electric charging. However, a further enhancement of the piezoelectric activity is also possible by stacking two or more transducer films. Here, we describe the piezoelectric responses that are possible with a two-layer stack of cellular polypropylene films. Piezoelectric thickness-extension resonances as well as the emitted sound-pressure levels were measured as a function of frequency and electric field in order to determine the frequency spectrum of the piezoelectric activity and to evaluate the amplification that is possible with stacking. A significant decrease of the thickness-extension resonance of the clamped transducer film within the stack was found. However, at lower frequencies in the range between 1 and around 40 kHz, a doubling of the piezoelectric response was achieved, which makes such stacks attractive for transducers operating in the audible and lower ultrasonic frequency range.

DF 3.8 Sa 11:40 TU C130

**Influence of the amorphous phase on piezoelectricity in polyamide 11** — •Peter Fruebing, Alexander Kremmer, and Reimund Gerhard-Multhaupt — Department of Physics, University of Potsdam, Am Neuen Palais 10, 14469 Potsdam

Odd-numbered polyamides can form ferroelectric domains, in which the polymer chains are aligned in parallel and all amide-group dipoles are oriented perpendicular to the chains and parallel to each other. The domain structure is thermally stable up to the melting region (170 °C) because the amide groups are linked by hydrogen bonds. However, the piezoelectric $d_{33}$ coefficient of 4 pC/N that can be achieved on extruded polyamide-11 films after uniaxial stretching at room temperature and electrical poling above the coercive field (75 MV/m) is relatively small. This is probably a consequence of the existence of a rigid amorphous phase where dipole orientation is sterically hindered. Furthermore, there are also relaxation contributions to the polarisation which may arise from a glass-forming amorphous phase.

Dielectric relaxation spectroscopy, dynamic mechanical analysis, differential scanning calorimetry and infrared spectroscopy are employed after various preparation steps (stretching, poling and annealing) in order to understand in particular the role of different amorphous phases for dipole orientation and dipole libration and thus possible restrictions for the piezoelectric response.