DF 4 Internal Symposium "Ferroelectric Materials for Smart Structures"

Time: Tuesday 09:30–12:50 Room: KÖN Farb

Invited Talk

DF 4.1 Tue 09:30 KÖN Farb

Piezoelectric composite materials for smart structures applications — •Andreas Schönecker — Fraunhofer IKTS, Winterbergstr. 28 , 01277 Dresden

Lightweight design in various industrial branches, like for example traffic technology and mechanical engineering, has become very important, mainly to reduce the effects of accelerated mass. However lightweight structures often suffer from vibrational sensitivity, tendency to buckling, and low damage tolerance, which desires active control of structural dynamics, as well as health monitoring and diagnostics to assure safety and reliability. A promising way to solve these problems is expected by using smart materials. Critical deformations, accelerations or other physical quantities can be detected by integrated sensors and in combination with suitable real-time controllers these impacts can be eliminated by driving structural conformable embedded or applied actuators. This paper will discuss the relevance of ferroelectric materials for smart structures, the issues of integration and the expectations on the progress in material science, system design and technology. For example, composite materials based on PZT fibres, thick and thin films are considered.

DF 4.2 Tue 10:10 KÖN Farb

Using ferro-electrical material for biometrical application — •Rainer Schmitt — 86 Ironwood Way, Palm Beach Gardens, FL 33418, USA

The matrix structure of 1-3 piezo composite consisting ferro-electrical pzt-pillars, spaced 120 microns apart in a polymer matrix has successfully been utilized for fingerprinting. For this application the pillars are driven in serial resonance mode exhibiting a different electrical impedance when exposed to the very different acoustic load of a finger tip structure, which is 1.5 Mrayls for a ridge and only 350 rayls for a valley. Individual pillars are addressed by a cross-hatched electrode structure on the top and the bottom of the sensor. Under typical material choices (pzt, polymer, electrodes and low acoustical impedance substrate as well as pillar pitches ranging from 50 - 150 microns the variation in the electrical pillar impedances is approx. 1: 4 for the ridge and valley, providing sufficient discrimination for fingerprinting. Since the sensor can be produced inexpensively using soft mold technology, developed by Fraunhofer IKTS large scale application for cell phone, car, computer access are expected. This principle of acoustical impediography, verified at a resolution of 250 dpi is now being expanded to a resolution of 500 dpi by developing the appropriate 1-3 composite with a pillar pitch of 50 microns.

DF 4.3 Tue 10:30 KÖN Farb

Nonlinear constitutive modeling of ferroelectric ceramics: the role of thermally activated processes — •A.Yu. Belov and W.S. Kreher — Institut für Werkstoffwissenschaft, TU Dresden, Hallwachsstr. 3, 01062 Dresden, Germany

The microscopic parameters characterising the interaction between domain walls and short-range obstacles in ferroelectric ceramics are assessed from the experimental data on the temperature dependence of the polarization hysteresis. The approach used is based on a nonlinear constitutive model, which accounts for thermally activated processes assisting the domain walls to overcome the energy barriers of the obstacles. Within the framework of the model the microstructure of ceramics is described effectively, employing the volume fractions of ferroelectric domains with different polarization orientations as structural variables, and its evolution is given in terms of rate equations for these variables. The average polycrystal properties are computed using a discrete orientations approximation (a set of representative orientations) for the distribution function of grain orientations. Assuming that the domain wall mobility depends on temperature according to the Arrhenius law, the microscopic parameters of the model, including the obstacle strength and activation energy, are extracted from the temperature dependence of the coercive field. The analysis of the experimental data for doped lead zirconate titanate (PZT) ceramics shows that for both soft and hard PZT compositions the domain wall motion near the coercive field is essentially thermally activated.

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DF 4.4 Tue 10:50 KÖN Farb

Templated grain growth of lead zirconate titanate — •Thomas Richter[1], Morgane Radanielina[1], Carsten Schuh[1], Reinhard Krüger[2], Dieter Sporn[2], Christoph Pientschke[3], Horst Beige[3], Gennadij Lissatschenko[4], and Hugo Schlich[4] — [1]Siemens AG; Corporate Technology, Ceramics Department; Otto-Hahn-Ring 6; 81739 Munich, Germany — [2]Fraunhofer Institut Silicatforschung — [3]Universität Halle-Wittenberg — [4]MaTecK GmbH

For maximising the piezoelectric performance of lead zirconate titanate (PZT) textured polycrystalline ceramics or even single crystals would be advantageous. However, PZT single-crystal growth from melt is impossible due to the incongruent melting behaviour. So, the PZT is to be texturised by secondary recrystallisation of introduced seeds in a fine-grained matrix. By the texturising of electrical ceramics the dielectric and the piezoelectric characteristics can be increased up to 80% of those of single crystals. In the present work growth ability was first studied by very coarse-grained PZT fibres in a fine-grained PZT matrix. The sintering took place both statically in a chamber furnace and dynamically in a temperature gradient furnace. The aim of these results is to develop an understanding for the growth of those seeds. The maximum in growth distance between the original fibre boundary and the boundary between the grown region and the matrix (average grain size about 6 micrometer) was measured at 45 micrometer. The most important parameters for recrystallisation were the temperature gradient of the temperature gradient furnace and the PbO excess of the samples.

DF 4.5 Tue 11:10 KÖN Farb

Point defects and pinning centres in acceptor- and donor-doped ferroelectrics — •Rüdiger-A. Eichel — TU Darmstadt, Eduard-Zintl Inst., Petersenstr. 20, 64287 Darmstadt

Point defects in ferroelectric oxides play an important role for tailoring device properties. In particular, if the pinning of mobile oxygen vacancies is considered that drastically may influence the ability of ionic conductivity in such compounds. On the other hand, quasi-immobile lead vacancies promote domain switching.

High-frequency and multi-pulse electron paramagnetic resonance (EPR) is used in order to study the role of aliovalent functional centres and their impact on lattice vacancies in $PbZr_xTi_{1-x}O_3$.

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DF 4.6 Tue 11:30 KÖN Farb

Pore network analysis of ceramic foams by means of synchrotron tomography — •A. Haibel[1], H. Freidank[1], and A. Berthold[2] — [1]Hahn-Meitner Institute Berlin — [2]Technical University Berlin

Due to their interconnected pore structure ceramic foams emulate well the natural configuration of human bones. In this talk we present protein based prepared ceramic foams. Biopolymers and ceramic powder mixed to a ceramic foam suspension generate a foam structure in a microwave reactor. Subsequent to the microwave coagulation the foams sinter at 1600°C. These foams act as substrates for the cultivation of stem cells. By means of high resolved synchrotron tomography experiments we investigated the effect of the different preparation techniques on the pore accruement and growth of such ceramic foams. By 3D image analysis of the tomographic images we analyzed the influence of coagulation and sintering on the pore size and shape, e. g. the influence of the different dispersing agents on the pores, the diameters of interconnections, and the wall and vessel thicknesses. The knowledge of this parameters allows the realization of ideal cell growth conditions at the artificial environment.

DF 4.7 Tue 11:50 KÖN Farb

Micro-mechanics of multi-variant and multi-phase ferroelectric domain structures — •Johannes Rödel — TU Dresden, Institut für Werkstoffwissenschaft

High-strain piezoelectric materials are often ceramics with a complicated constitution. In particular, PZT, but also PMN-PT and PZN-PT, are used with compositions near to a so-called morphotropic phase boundary, where not only different variants of the same phase (domains), but different phases may coexist. Micro-mechanical models for ferroelectric ceramics would be much more realistic, if these effects could be incorporated.

We consider the conditions of mechanical and electrical compatibility of ferroelectric domain structures. One result are the well known crystallographic relationships between domains of the same phase for various phases. Furthermore we are able to address the question of coexistence of different crystallographic phases within the very same crystallite. In general, the spontaneous strain and spontaneous polarization of a tetragonal and a rhombohedral ferroelecctric domain are not compatible. The internal fields which are caused by this incompatibility, and the associated energy contributions, can be calculated using distributed crystal defects and charge models. We can also show that this internal fields and energies can be decreased by an intermediate, e.g. monoclinic, phase.

The outlined approach can be used to model the overall behavior of multi-variant and multi-phase crystallites with certain, simplified geometrical arrangements of the constituents.

DF 4.8 Tue 12:10 KÖN Farb

Fullerene-based hypothetical ultra-low k dielectrics for microelectronic application — •Kostyantyn Zagorodniy, Manfred Taut, Helmut Hermann, and Klaus Wetzig — Institute for Solid State and Materials Research, IFW Dresden, PF 270116, D-01171 Dresden

Fullerene-based structures are shown to be good candidates for materials with very low dielectric constant. It is our idea to use the C60 fullerene as structural unit and to connect neighbouring C60 molecules by other molecules which have approximately linear shape (for example CnH2n). Such units are the base for the generation of a 3D network with low density and high mechanical stability. The introduction of bridge molecules can be understood as the creation of pores in the fullerene lattice on the 1nm scale. This results in a considerable decrease of the macroscopic polarizability of the material. In this study we analyze the influence of the length of the CnH2n bridge molecules on the properties of the material and the influence of adding fluorine to the C60 molecules. The electronic properties and the local polarizability of the structural units is expected to be changed by fluorination of the fullerenes. Quantum chemical methods are applied to calculate the local polarizability of fluorinated fullerenes. Possible improvements and the limitations are discussed.

DF 4.9 Tue 12:30 KÖN Farb

Electron Holography for ferroelectric characterization — •Hannes Lichte, Marianne Reibold, Karin Vogel, Christopher Matzeck, and Michael Lehmann — Institute for Structure Physics, Technische Universität Dresden, Dresden, Germany

Electron holography in a Transmission Electron Microscope gives quantitative access to magnetic and electric fields by evaluating their phase shifting effect on the electron wave. Electric fields stemming from the ferroelectric polarisation have been identified and analyzed by means of electron holography showing domain structures in sub-micron dimensions. Furthermore, at atomic dimensions, dipole-like structures are found in the holographic phase images of unit cells of BaTiO3, which strongly resemble the assumed atomic dipoles. The found ordering of these dipoles suggests that nano-domains exist which are only several unit cells wide.