

## MS81.P15

*Acta Cryst.* (2011) A67, C706**Fatigue mechanisms on the atomic scale in high performance Lead Zirconate Titanate (PZT)**

Manuel Hinterstein,<sup>a</sup> Jérôme Rouquette,<sup>b</sup> Michael Knapp,<sup>c</sup> Helmut Ehrenberg,<sup>d</sup> <sup>a</sup>*Institut für Werkstoffwissenschaften Dresden, TU Dresden (Germany)*. <sup>b</sup>*Institut Charles Gerhardt, Université Montpellier II (France)*. <sup>c</sup>*CELLS-ALBA, Cerdanyola (Spain)*, <sup>d</sup>*Institute for Complex Materials, IFW Dresden (Germany)*. E-mail: manuel.hinterstein@desy.de

In materials science studies focus on the structure of matter and its applications. The investigation of the correlation between macroscopic properties and structural characteristics is crucial for the development of high performance materials. With *in situ* X-ray diffraction we were able to give an atomic scale description of the macroscopic physical properties of commercial ferroelectric material, lead zirconate titanate (PZT) [1].

These materials are intensively used for technological applications (sensors and actuators, MEMS systems and high frequency devices). One of the factors limiting the applicability of PZT, as well as other ferroelectric materials, is the phenomenon of ferroelectric fatigue. This is mostly manifested by a decrease in the polarization amplitude observed in the ferroelectric polarization hysteresis loop and a change in the temporal response after prolonged bipolar electric field cycling.

In this contribution we present a structural characterization of the fatigue mechanisms on the atomic scale. A specially developed sample environment for *in situ* X-ray diffraction with applied electric fields allowed us to study the effect of fatigue on the poling response. The decrease of polarization amplitude could be related to a change in phase composition. The change in switching kinetics could be attributed to an alteration of the field induced structural response dependent on the cycling frequency. The analysis of the disorder of lead and a microstructural characterization provided detailed structural information.

[1] M. Hinterstein, J. Rouquette, J. Haines, Ph. Papet, M. Knapp, J. Glaum, H. Fuess, *Phys. Rev. Lett* **2011**, submitted.

**Keywords:** ferroelectric, in-situ, fatigue

## MS81.P16

*Acta Cryst.* (2011) A67, C706**Phase transitions in modulated fresnoite phases for piezoelectric applications**

Siegbert Schmid, Patryck Allen, *School of Chemistry, The University of Sydney, Sydney NSW 2006 (Australia)*. E-mail: siegbert.schmid@sydney.edu.au

Materials with the fresnoite  $A_2TiM_2O_8$  ( $A = Ba, Sr; M = Si, Ge$ ) structure type are amongst several possible alternatives currently being investigated to replace PZT and other lead-based piezoelectric materials because of their potential to exhibit excellent piezoelectric response coefficients [1, 2]. Critically important to developing new materials with optimised physical properties, which are comparable to or better than those of the current lead-based piezoelectrics, is a good understanding of the underlying structural chemistry of these materials.

We have carefully investigated the composition range of  $Ba_{2-2x}Sr_{2x}TiSi_2O_8$  ( $x = 0.0 - 1.0$ ), with particular emphasis on temperature dependent phase transitions that might impact on practical applications. Variable temperature synchrotron powder X-ray and electron diffraction data, e.g., from  $Sr_2TiSi_2O_8$  have provided previously unreported

evidence of unusual phase behaviour between 125 - 1273 K. Electron diffraction data have confirmed that two incommensurately modulated  $Sr_2TiSi_2O_8$  phases, with tetragonal and orthorhombic symmetry, coexist at room temperature, although the phase appears metrically tetragonal from X-ray powder diffraction data. Observed changes of the position of the satellite reflections in  $Sr_2TiSi_2O_8$  electron diffraction patterns at elevated temperatures suggests that a symmetry-lowering transition occurs on heating, whereby the tetragonal  $P4bm$  phase transforms into the orthorhombic  $Cmm2$  phase at approximately 480 K. This is confirmed for the bulk phase from X-ray diffraction data.

Our investigation was extended to include substitutions both on the fresnoite  $A$ -site (Ba/Sr) as well as the  $M$ -site (Si/Ge). Similar behaviour as above has been observed in the closely related  $Sr_2TiGe_{0.1}Si_{1.9}O_8$  compound. However, the two phase region for the first order transition from the tetragonal  $P4bm$  to the orthorhombic  $Cmm2$  phase is unusually wide, demonstrating the extremely similar energies of formation for the two phases. A combination of variable temperature electron diffraction, synchrotron X-ray powder diffraction, neutron diffraction and resonant ultrasound spectroscopy have been used to further determine the interesting and unusual phase behaviour in this family of compounds.

[1] A. Halliyal, A. S. Bhalla, S. A. Markgraf, L. E. Cross, *Ferroelectrics*, **62** 1985, 27-38. [2] T. Asahi, T. Osaka, J. Kobayashi, S. C. Abrahams, S. Nanamatsu, M. Kimura, *Phys. Rev. B*, **2001** 63, 1-13.

**Keywords:** fresnoite, modulated structure, piezoelectric

## MS81.P17

*Acta Cryst.* (2011) A67, C706-C707**Magnetism in defect-induced SiC single crystals**

Yu Liu,<sup>a</sup> Gang Wang,<sup>a</sup> Shunchong Wang,<sup>a</sup> Wei Sun,<sup>a</sup> Xiubo Qin,<sup>b</sup> Bo Song,<sup>c</sup> Baoyi Wang,<sup>b</sup> Xiaolong Chen,<sup>a</sup> <sup>a</sup>*Research & Development Center for Functional Crystals, Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing, (China)*. <sup>b</sup>*Key Laboratory of Nuclear Analysis Technique, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, (China)*. <sup>c</sup>*Academy of Fundamental and Interdisciplinary Sciences, Harbin Institute of Technology, Harbin, (China)*. E-mail: stevenheroiclew@hotmail.com

SiC is considered to be one of the most important semiconductors with great applications for high temperature, high frequency, high power and optoelectronic devices due to its wide band-gap, high thermal conductivity, high breakdown voltage, and so on. Over the past years, the SiC based diluted magnetic semiconductors (DMSs) have attracted much attention as promising material for spintronics. Many efforts have been devoted to investigate SiC DMSs prepared by  $3d$  transition metals doping. Limited solubility of  $3d$  metals in wide band-gap (WBG) semiconductors, however, often leads to the precipitation of second phases, thwarting the attempts to get the unambiguous experimental results and leaving the origin of magnetism an open question [1], [2]. Recently, there has been increasing evidence that traditional magnetic elements are not the sole source in inducing intrinsic magnetism. RT FMs were observed in highly oriented pyrolytic graphite (HOPG) [3], [5], in Al doped SiC [6], and in Li doped ZnO [7]. Inspired by all these results defect-induced magnetism was observed in neutron irradiated  $6H$ -SiC single crystals recently [8].

Here, magnetism is further investigated in defect-induced SiC single crystals. Neutron irradiation and heavy doping of non-magnetic elements: B, Al and N were employed to induce defects in  $4H$ -SiC and  $6H$ -SiC. It is found that magnetism was observed in undoped, B doped and Al doped  $6H$ -SiC single crystals after neutron irradiation and in heavy B and Al doped ones. However, although neutron irradiation and heavy doping induced masses of defects in N doped