Using Time-resolved X-ray Diffraction to Reveal the Mechanisms of Piezoelectricity in Ferroelectrics

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Abstract

Ferroelectrics are the broad class of materials, which may sustain spontaneous electric polarization. The applications of ferroelectrics are numerous and go far beyond the ability of their spontaneous polarization to switch between a few equivalent states. Many ferroelectric materials are piezoelectric: they are used in sensors, actuators, frequency generators and microelectromechanical devices. The piezoelectric effect in ferroelectrics (as e.g. $PbZr_{1-x}Ti_xO_3$) may exceed such in non-ferroelectrics (as e.g. in α-quartz SiO_2) by three orders of magnitude. The connection between piezoelectricity and ferroelectricity remains to be long-standing puzzle and the subject of debates and research for many groups worldwide.

The goal of our work is to implement advanced X-ray crystallographic tools for characterization of structural and microstructural mechanisms of polarization switching in ferroelectrics. We question which of these mechanisms enhance piezoelectricity. We use stroboscopic X-ray data-acquisition to collect diffraction intensity as a function of time and alternating electric field. We measure *in-situ* X-ray diffraction signal (as e.g. single crystal rocking curves, reciprocal space maps and powder diffraction profiles) simultaneously with the macroscopic hysteresis loops. The angular positions of Bragg peaks are used to calculate the field dependence of lattice parameters, the profile shapes; the exchange of intensities between Bragg peaks components are used to follow the change of the domain microstructure. We will discuss the origin of piezoelectricity in single crystals of $Sr_{0.5}Ba_{0.5}Nb_2O_6$ and / or $Na_{0.5}Bi_{0.5}TiO_3$ and / or $PbZr_{1-x}Ti_xO_3$ especially focusing at the separation of intrinsic (crystal structure related) and extrinsic (domain wall motion related) contributions to the piezoelectricity.

Short Biography

Dr Semën Gorfman is the senior lecturer at the MSE department. He joined Tel Aviv University in October 2017. He received his MSc in Physics from Chelyabinsk State University (Russia) and obtained PhD in Solid State Physics from the University of Siegen (Germany). In 2008-2011 he worked as a postdoc in the University of Warwick (United Kingdom), in 2011-2016 / 2016-2017 was a lecturer in the Universities of Siegen / Freiburg (Germany). His research interest and expertise span fundamental and X-ray crystallography, physical properties of crystals, piezoelectrics and ferroelectrics, high-resolution X-ray diffraction and precise structure analysis, in-situ X-ray diffraction studies of crystalline materials under external perturbation, application of synchrotron radiation. The research of Dr Gorfman are frequently performed at such central synchrotron radiation facilities as ESRF, PETRA III and Diamond. As a part of his appointment in TAU, he aims to build a multi-purpose four-circle X-ray diffractometer for characterization of functional materials.