Large Piezoelectricity in Electric-field Modified Single Crystals of $SrTiO_3$

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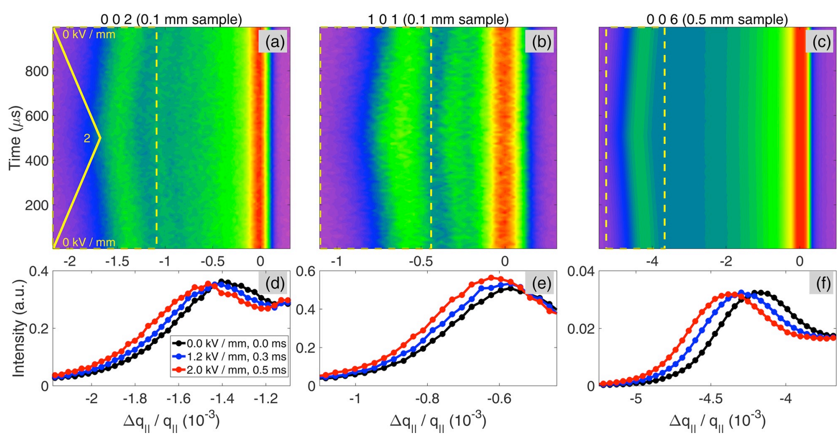
$SrTiO_3$ (STO) is a host of many application-relevant electrical and chemical properties. Being one of a few room-temperature cubic and centrosymmetric "perovskites", it offers unique opportunity to investigate the properties of a paraelectric phase. It is known, for example, ([1]) that prolonged (~a few hours) application of a static electric field to a single crystal of STO gradually forms a strained near-surface (a few μm) layer of the so-called migration-induced field-stabilized polar (MFP) phase. This phase can be observed in the static electric field and disappears instantly (within a few seconds) otherwise. Oxygen vacancies - the most prominent and most mobile defect species in STO - are likely to play a crucial role in the formation of the MFP phase [1].

The properties of the MFP phase turn out to be different from the properties of the bulk: it was previously shown ([1]) that MFP phase hosts e.g. pyroelectricity, which is symmetry-forbidden in centrosymmetric bulk of STO. **The aim of this work** was to measure the electromechanical activity (piezoelectricity / electrostriction) of the MFP phase by using stroboscopic X-ray diffraction under AC electric field. To do this, we I) formed the MFP phase by applying static electric field ($E_0 = 1$ kV / mm) to STO single crystal for ~12 hours; II) added triangular shaped AC (10 Hz - 5 kHz) component with the amplitude of $\Delta E = 1$ kV/mm, leading to the field variation between e.g. 0 and 2 kV/mm but maintaining the average field at 1 kV/mm and thus keeping the MFP phase undestroyed; III) measured the profiles of Bragg peaks, in which the contributions of bulk STO and the formed MFP phase are separated; IV) followed the time-dependence of the MFP-phase Bragg peak (as shown in the figure below) / and evaluated the corresponding MFP lattice parameter (Δc/c.



Using this technique, we demonstrated that effective piezoelectric coefficient d_{33} of the MFP phase ranges between 60 and 100 pC / N [2]. This large value of piezoelectric coefficients motivates for further studies with the ultimate goal of shifting the effect from the near-surface layer to the bulk.
Following this way, we will discuss the possible atomistic origins of the piezoelectric activity in terms of the coupling between the electrostrictive effect and spontaneous polarization (the direct structural evidence of the polar character of the MFP was obtained using a new technique of x-ray crystal structure analysis). Furthermore, we will report on the first experiments for testing the ferroelectricity of the MFP phase and the frequency dependence of the electromechanical response.

[1] J. Hanzig, M. Zschornak, F. Hanzig, E. Mehner, H. Stöcker, B. Abendroth, C. Röder, A. Talkenberger, G. Schreiber, D. Rafaja, S. Gemming, and D. C. Meyer, Phys. Rev. B 88, 24104 (2013)

[2] B. Khanbabaee, E. Mehner, C. Richter, J. Hanzig, M. Zschornak, U. Pietsch, H. Stöcker, T. Leisegang, D. C. Meyer, S. Gorfman. Appl Phys Lett **109**, 222901, (2016)