Low Temperature Surface Piezoelectricity in $SrTiO_3$ using an attoAFM I for Piezo-Response Force Microscopy

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$SrTiO_3$ (STO) is one of the most investigated materials from the ferroelectric perovskite titanates family due to the variety of physical phenomena ranging from incipient ferroelectricity to superconductivity. Nowadays, considerable interest to STO is conditioned by the observations of additional anomalies in the quantum paraelectric regime of STO, which could be described in terms of a coherent quantum state occurring below $T \approx 37$ K [1]. It is supposed that these anomalies are related to the existence of large polarization clusters. Visualizing the dynamic of ferroelectric nanoscale structure at low temperatures may shed light on the mechanisms of the $T \approx 37$ K anomaly.

To observe the ferroelectric structure at nanoscale, a sample of STO ceramics was scanned in vertical piezo-response force microscopy (PFM) mode with an attocube systems attoAFM I microscope. The purpose of the experiment was to find out the dynamic of piezo-response from STO with changing temperatures from 8 K to ambient. It should be noted here that the effective vertical piezoelectric coefficient for STO ceramics never exceeded 1 pm/V, making PFM measurements quite challenging.

At room temperature, a good contrast on STO sample in PFM mode was obtained. Then the system was cooled down and the PFM data were taken from 8 K to ambient temperature with steps of 10 K. A slight enhancement of the piezo-response signal from STO at 8 K was observed. Further on, the PFM contrast remained on the same level up to 130 K. At $T \approx 130$ K though, a sharp enhancement on both PFM amplitude and phase signals was recorded (see Figure 2 and 3). This point in temperature can be associated with an antiferro-distortive phase transition (cubic --> tetragonal) in STO.

All measurements have been done by N. Andreeva and S. Plyastsov from the Research and Educational Center "Physics of Nanocomposite Materials" of the Saint Petersburg State Polytechnical University. The sample is courtesy of A. Kholkine, University of Aveiro, Portugal.

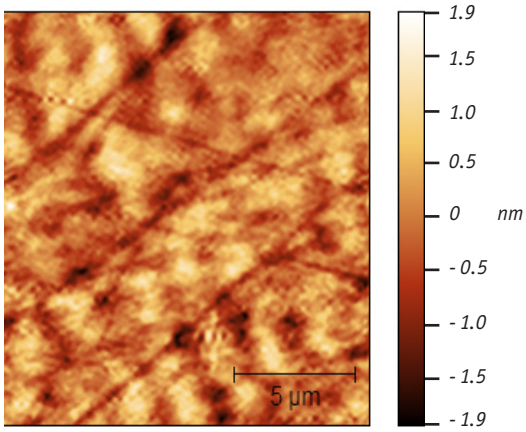

Figure 1: *Topography of STO ceramics at 130 K. Scan size is 15 x15 µm.*

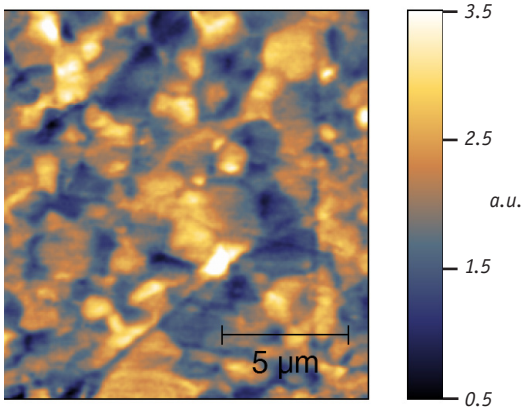

Figure 2: *Out-of-plane PFM amplitude of STO ceramics at 130 K. The PFM amplitude never exceeded 1 pm/V.*

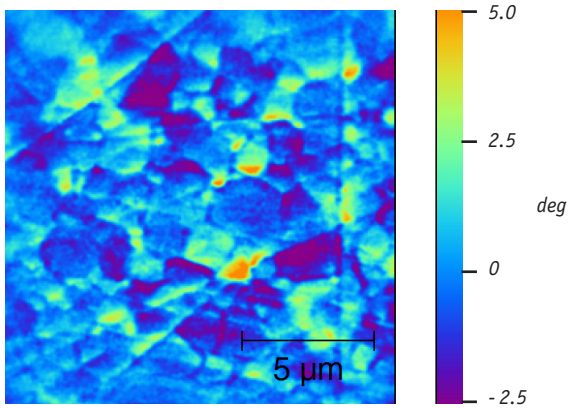

Figure 3: *Out-of-plane PFM phase of STO ceramics at 130 K.*