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Investigation of polarization switching processes in PMN single crystal in a temperature range from 4 K to 300 K

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Relaxor ferroelectric materials have been widely studied with different techniques because of its great piezoelectric, dielectric and electromechanical properties. Where are many studies about domain structure and polarization switching processes in relaxor ferroelectric materials such as PMN, PMN-PT [1-4] but most of them were performed above the room temperature. In this work we study polarization switching processes in PMN single crystal via switching spectroscopy piezoresponse force microscopy (SS-PFM) in wide temperature range from 4 K to 300 K.

For a detailed study of polarization switching processes we simultaneously apply two different methods: switching spectroscopy piezoresponce force microscopy and modified Sawyer-Tower circuit «double wave method» [5]. We used a special electrode system consisting of two electrodes on the surface of the sample and one common electrode on bottom. Two surface electrodes have thickness 15 nm and area 400x400 μm^2. Distance between electrodes is about 20 μm. Bottom electrode covers all the sample area and its thickness is 80 nm. This scheme allows to provid measurements with Sawyer-Tower circuit, PFM through electrode and classic PFM without surface electrode. Two electrodes placed close to each other on the sample surface allows to create in-plane electrical field inside the sample. Also, presence of surface electrodes allows us to provide in-field cooling.

To test and establish PFM method with electrodes on sample surface the series of experiments have been done on $BaTiO_3$ single crystal. Thickness of BTO crystal was about 50 μm. Using switching spectroscopy PFM we have obtained piezoresponse hysteresis loops in BTO single crystal at room temperature and it was found that PFM works well with 15 nm thick of surface electrodes.

The experiment was carried out using a cryogenic atomic force microscope Attocube Systems AttoAFM I equipped with an external lock-in amplifier SR844 (Stanford Research Systems) and a functional generator Yokogawa FC120. AttoAFM I allows to perform «out of-plane» PFM measurements in temperature range from 4 to 300 K. Switching spectroscopy PFM method was created in the LabView 13, external devices were connected to PC with GPIB-USB interface. We employed the commercial platinum-iridium coated silicon cantilevers CSG30/Pt (NT-MDT). Golden electrodes was created on the sample surfaces by e-beam evaporation using a Moorfield Minilab 80 e-beam evaporator under high vacuum.

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