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Formation of dendrite domain structures in single crystals of lithium niobate

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The surface shape instability leading to self-organized formation of complicated patterns under homogenous external conditions being the attribute property of nonequilibrium systems has been spotlighted as a potential bottom-up technology for fast and parallel creation of useful nanoscale patterns [1]. It has been shown previously that the realization of domain wall shape instability effect in uniaxial ferroelectrics leading to dendrite domain growth requires two conditions: strong input of the stochastic nucleation and the bulk screening retardation [2-4]. These conditions can be realized in lithium niobate single crystals with artificial dielectric layer during polarization reversal at high temperature.

In the present work, the formation of the dendrite domain structures was studied in congruent lithium niobate single crystalline Z-cut plates covered by silicon dioxide film with thickness from 150 to 900 nm. The transparent indium tin oxide (ITO) electrodes were used for polarization reversal with simultaneous *in situ* visualization and recording of the switching current. The ITO electrodes were circular at Z+ polar surface and completely covered Z- polar surface. The sample was placed in the temperature-controlled microscope stage THMS600 (Linkam, UK) at 250 °C.

The main stages of domain structure evolution for polarization reversal in the "middle" field range (7-9 kV/mm) were revealed: (1) the appearance of domain nuclei, (2) the growth of the six main branches, (3) growth, splitting and branching of the main and secondary branches. In the "low" fields range (5-7 kV/mm) the growth of only three main branches along Y+ crystallographic directions with following splitting and branching was observed. The individual domain shape followed C_{3v} crystal symmetry. The growth velocity of main branches remained constant through the most part of switching process with some deceleration at the very beginning.

The imaging of the static domain structures by scanning electron and optical microscopies allowed to reveal that they consist of three (for low fields) or six (for high fields) main branches oriented close to Y crystallographic directions. The structure of secondary branches is discussed.

The phase-field simulation was used to verify the analogy between self-organized growth of the domains and new phase during the first order phase transition [5]. The similarity of the simulated and experimentally observed shapes of isolated domains confirmed the proposed model.

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