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Domain creation by electron and ion beams in lithium tantalate crystals

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We have studied the domain formation induced by electron (e-beam) and ion beam (i-beam) irradiation in congruent lithium tantalate ($LiTaO_3$, CLT) crystals. The obtained results have been explained in terms of kinetic approach based on analogy with a first order phase transition [1].

The studied samples represented the 0.5-mm-thick Z-cut wafers of CLT single crystals produced by Oxide Corporation. The irradiated polar surface was covered by artificial dielectric layer. The copper solid electrode was deposited on the opposite surface and grounded during irradiation. The irradiation experiments were performed using dual-beam Auriga Crossbeam Workstation (Carl Zeiss). The control of irradiation parameters and beam positioning was carried out by the electron-ion beam lithography system Elphy Multibeam (Raith GmbH). The domain structures were visualized by piezoresponse force microscopy and scanning electron microscopy after selective chemical etching in pure HF during 20 min at the room temperature.

The formation of arrays of circular domains and domain wall shape instability (appearance of domain fingers) [2] as a result of dot irradiation have been revealed (Fig. 1). The dependence of domain radius on dose was measured. The isotropic domain growth was attributed to stochastic nucleation due to prevailed isotropic screening mechanism. The domain wall shape instability was caused by screening retardation in highly non-equilibrium switching conditions due to presence of the artificial surface dielectric layer.

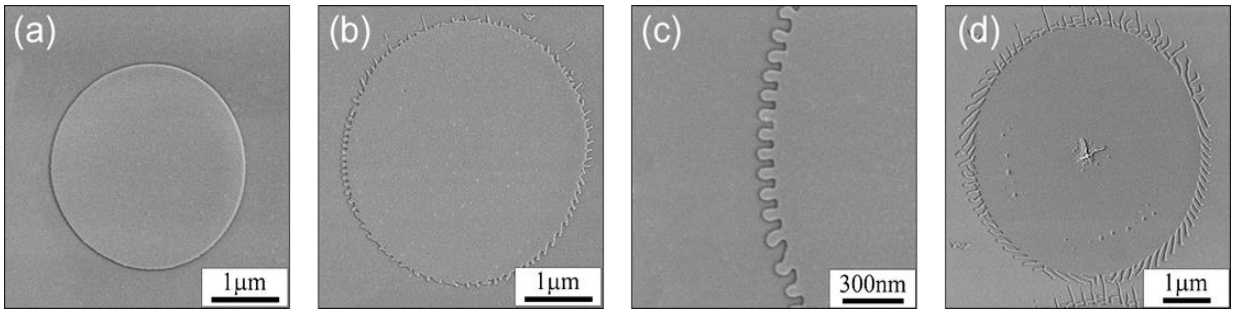

Figure 1. Scanning electron microscopy images of the etched surface topography corresponded to domains created by ion beam irradiation at the doses (pC): (a) 10, (b), (c) 60, (d) 110.

We have studied the domain formation after stripe irradiation by e-beam and i-beam. The dose dependencies of geometrical parameters of such domain structures were obtained. The main stages of domain formation such as: (1) discrete nucleation, (2) nuclei merging, and (3) continuous stripe domain formation were revealed. The appearance of domain wall instability after continuous stripe formation was found as well.

The obtained knowledge was used for optimization of periodical poling process in CLT. The periodically poled CLT with a period down to 2 μm has been created by using i-beam irradiation technique.

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2. D.S. Chezganov, L.V. Gimadeeva, E.O. Vlasov, E.M. Vaskina, V.Ya. Shur, *Ferroelectrics* **525**, 28 (2018).