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Local polarization reversal in relaxor SBN single crystals by electron and ion beam irradiation

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The local polarization reversal under the action of medium-energy electron and ion beam irradiation has been studied in barium-strontium niobate single crystals ($Sr_{0.61}Ba_{0.39}Nb_2O_6$, SBN) with free surface and surface covered by dielectric layer (resist) [1]. SBN single crystals were grown using a modified Stepanov method. The studied plates were cut perpendicular to the polar axis and polished to optical quality.

The scanning electron microscope (Auriga CrossBeam workstation, Carl Zeiss NTS) was used for irradiation with medium-energy electrons and ions [1]. Two types of exposure regimes were used: (1) dot exposure – discrete irradiation by isolated dots with the distances between the points 7 and 100 μm; (2) stripe exposure – continuous irradiation by stripes with period 7 μm. The stripe exposure was performed along Y crystallographic direction and at 45° to it. Domains were imaged on the surface by piezoelectric force microscopy. Confocal Raman microscopy [2] and Cherenkov type second harmonic generation [3] were used for domain imaging in the bulk.

The ensemble of isolated submicron-size domains appeared in the samples with free surface, whereas the isolated circular domains were revealed in the samples covered by resist. This fact can be attributed to the charge localization in the resist [1]. The circular shape of isolated domains (isotropic domain growth) is caused by step generation at the wall by merging with initial isolated residual nanodomains. It was found that the domains area linearly increases with irradiation dose for distance between dots 100 μm, while the area of domains recorded with 7-μm-distance linearly increases with saturation at dose above 15 pC. The obtained dose dependence of the switched area can be attributed to screening of the depolarization field by injected electrons. The observed domain growth retardation and saturation of the switched domain area for short period is due to the electrostatic interaction of the approaching charged domain walls.

The quasi-regular chains of isolated domains (at doses below 100 μC/cm^2) and stripe domains (at doses above 100 μC/cm^2) were formed as a result of stripe irradiation. The width of the obtained stripe domains linearly increased with irradiation dose and saturated at high doses. The width of stripe domains created by scanning along Y and 45° to Y was almost equal for doses below 250 μC/cm^2. The value of saturation the width of stripe domains oriented along 45° to Y was less than ones oriented along Y, which may be associated with more favorable growth domains along the crystallographic directions. The depth of the created domains on the radiation dose was measured for dot and stripe irradiation. The created domain structures were a stable at room temperature at least for several months. The PFM contrast of created domains decreased with heating and disappeared completely at 120 °C.

The obtained results can be used for creation of the precise domain patterns with arbitrary orientation and shape in SBN single crystals in order to produce the nonlinear optical devices.

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