Domain formation by ion beam in lithium niobate crystal with suppression of surface charging by electron and UV-flood guns

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The lithium niobate ($LiNbO_3$, LN) is one of the most popular ferroelectric crystals for domain engineering due to its outstanding piezoelectric, nonlinear-optical and electro-optical properties. The charged particles beams are utilized for studying and modification of various properties of such crystals. However, the accumulation of injected charge leading to the surface charging limits the using of these techniques.

In this study, we have used the methods of a surface charge control upon focused ion beam (i-beam) irradiation and investigated its influence on ferroelectric domain formation by i-beam in LN crystals [1].

The samples were represented by 0.5-mm-thick Z-cut LN wafers. The irradiated Z^+ polar surfaces were prepared by two different methods: (1) spin coating of 500-nm-thick layer of positive photoresist AZ nLOF 1505 (MicroChemicals GmbH) and (2) careful cleaning in acetone and isopropanol using ultrasonic bath. The opposite Z^- polar surface was covered by solid 100-nm-thick copper electrode. The irradiations by electrons and Ga^+ ions were performed by dual-beam workstation Auriga Crossbeam (Carl Zeiss) attached with i-beam lithography system Elphy Multibeam (Raith). The created domain structures were visualized at the polar surfaces by optical and scanning electron microscopies after selective chemical etching in pure HF and by confocal Raman microscopy in the crystal bulk.

The method for charging control using simultaneous i-beam irradiation and defocused electron (e-beam) proposed in Ref. [2] has been used for domain patterning. The optimal ratio of the e- and i-beam currents for domain patterning has been obtained. It was demonstrated that irradiation by e-beam changed the domain shape due to partial backswitching.

We have used also the method of surface charge control during i-beam irradiation by simultaneous UV illumination (wavelengths 275 and 310 nm) by means of light-emitting diodes (LED) [3]. It was shown that the method allowed to improve the period and uniformity of created periodical 1D and 2D structures. The method efficiency can be adaptively controlled by the change of the UV LED intensity. It was shown that method efficiency depends on LED wavelength. UV LED illumination decreases the domain depth and changes of the shape of isolated domains. The UV LED illumination during 1D periodical poling resulted in uniform nucleation of domains within the irradiated area and increase of the switched area. The role of photo-domain effect due to effective bulk screening induced by photoconductivity has been discussed [4, 5].

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