UV LASER ASSISTED DOMAIN ENGINEERING OF LITHIUM NIOBATE

Y. J. Ying[1], C. L. Sones[1], R. W. Eason[1], H. Steigerwald[2], E. Soergel[2], P. G. Lagoudakis[3]

and S. Mailis[1]¤

[1]*Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, U.K.*
[2]*Institute of Physics, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany*
[3]*Dept. of Physics and astronomy, University of Southampton, Southampton, SO17 1BJ, U.K.*

Abstract

Lithium niobate is an important optical ferroelectric crystal which is used widely by the photonics industry mainly due to its electro-optic and non-linear optical properties. High quality crystal wafers are readily available commercially in different stoichiometries and with various dopands as required by the relevant applications.

Many of the nonlinear processes which are performed in lithium niobate crystals require quasi-phase-matching which is achieved by spatially selective (in most cases periodic) ferroelectric domain inversion usually achieved by applying an external electric field through micro-structured electrodes in order to create the spatially selective electric field contrast which is required for spatially selective domain inversion. Furthermore, the differential etching between opposite domain surfaces has been recently utilized to fabricate surface micro-structures which correspond to a pre-defined inverted domain pattern. This development has further expanded the application range for this very important ferroelectric crystal.

This contribution will discuss the impact of exposing lithium niobate crystals to intense, highly absorbed, UV laser radiation. It will be shown that UV laser irradiation can change the refractive index of the material enabling the direct writing of ***optical channel waveguides***, modify the coercive field in the irradiated area thus providing a tool for spatially selective domain inversion without the use of micro-structured electrodes (***inhibition of poling***) and finally, under specific conditions, induce direct domain inversion without the application of any external electric field (***all optical poling***).

Figure 1a shows a scanning electron microscopy image a set of pole inhibited ferroelectric domain tracks on congruent lithium niobate. The domain structure is made visible by brief HF acid etching. Wedge polishing of the edge of the sample also shows the depth profile of these domains.

Figure 1b shows an optical microscopy image of etched *all optically poled* domains forming the initials “ORC”

The fortunate coexistence of UV laser-induced effects allows the combination of refractive structures with domain engineering which leads to flexible micro-structuring.

The UV laser induced and assisted ferroelectric domain inversion methods will be outlined here along with the properties of UV laser written optical waveguides including ridges. A set of waveguide ridges which are fabricated using UV laser induced poling inhibition is shown in the optical microscopy image of figure 2a. The vertical (in depth) confinement of light in these ridge structures is obtained by the refractive index change caused by the UV irradiation which is also essential for the poling inhibition step. A near field mode profile obtained from such a waveguide is shown in figure 2b.

Finally, differential etching of UV laser-assisted domains have been used for the fabrication of a variety of interesting surface micro-structures. Figure 3 shows examples of (a) single crystal micro-tip arrays used for surface enhanced Raman scattering (SERS) as well as for biological cell positioning and scaffolding applications and (b) a whispering gallery mode micro-resonator produced by surface tension reshaping.

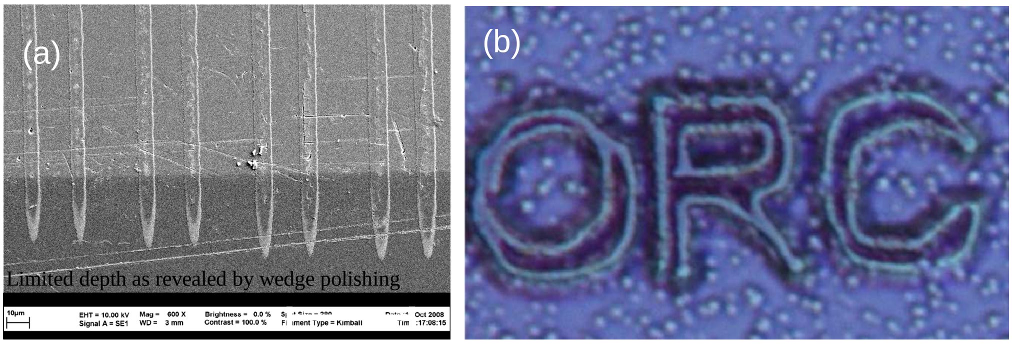

Figure 1. a) SEM image of wedge-polished ferroelectric domain tracks (revealed by brief HF acid etching) produced by UV laser-induced poling inhibition, b) Optical microscopy image of directly laser-poled domains. The width of these domains is ~ 2µm.

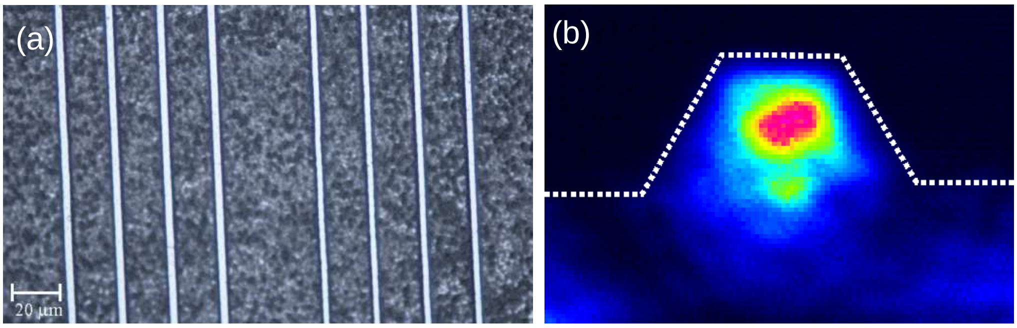

Figure 2. a) Optical microscopy image of $LiNbO_3$ waveguide ridges originated by pole inhibited domain tracks, b) near field mode intensity distribution obtained for a ridge waveguide. The dash line indicates the physical shape of the ridge structure.

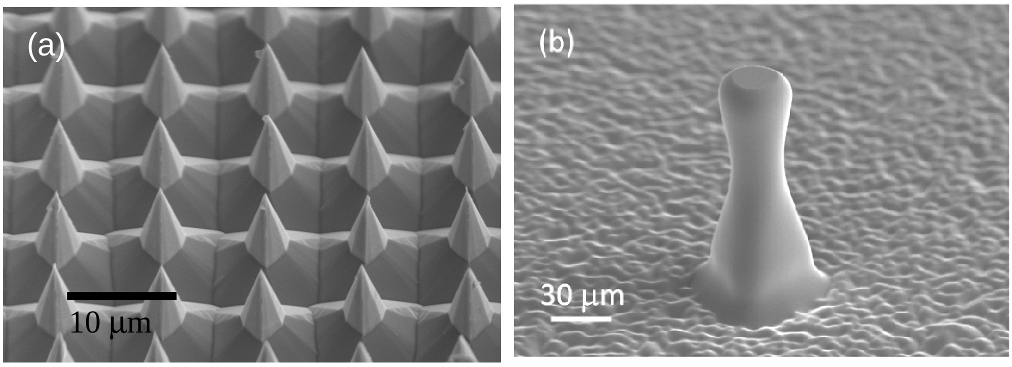

Figure 3. SEM images of a) lithium niobate surface micro-structured tip array, b) a surface tension reshaped structure forming a WGM resonator.