

Structuring Lithium Niobate: Collective Etching and FIB Milling for Photonics and Phononics

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Abstract: In this paper, we discuss fabrication processes implemented for the realization of micron-sized and submicron-sized patterns in lithium niobate for application to nanophotonics or phononics. FIB milling as well as collective processes based on reactive ion etching in fluorine chemistries and their use for the fabrication of photonic and phononic crystal structures is illustrated. We will discuss the limitations of both methods and see how they can affect the actual physical performance of the fabricated devices.

OCIS codes: (160.3730) Lithium niobate; (350.4238) Nanophotonics and photonic crystals; (230.1040) Acousto-optical devices.

The remarkable physical properties of lithium niobate make this material a key element in a number of applications ranging from integrated optoelectronics to radio-frequency acoustics. Its high nonlinear, electro-optical or acousto-optical coefficients, its piezoelectric properties, or the possibilities it offers in terms of waveguide fabrication allow for the realization of both active and passive devices, many of them having successfully migrated from laboratory experiments to commercial and wide-scale applications. Further development on LiNbO_3 devices has for long been hindered by the lack of truly reliable and versatile techniques allowing surface machining of this material. And although lithium niobate might be, as is however well known and widely used, it remains to date a non-conventional material from a microfabrication point of view. If a variety of wet and dry etching techniques has been reported in the literature, none of the reported processes has really set itself as a standard. In particular, the etching of deep structures at submicron scale remains a challenging and critical technological step in the realization of a number of devices, particularly in nanophotonics or phononics.

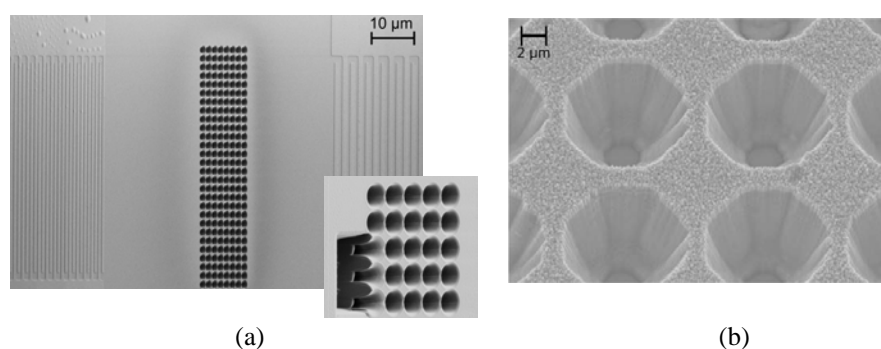


Fig. 1: Phononic crystal made of air holes etched out of lithium niobate by FIB. The hole diameter is about $2\ \mu\text{m}$ for a pitch of $2.2\ \mu\text{m}$. The hole depth is about $2.3\ \mu\text{m}$. The periodical structure is surrounded by two interdigital transducers acting as elastic wave emitters and receivers, respectively. (b) $10\ \mu\text{m}$ pitch air/ LiNbO_3 phononic crystal etched by reactive ion etching. The $9\ \mu\text{m}$ diameter holes are $10.5\ \mu\text{m}$ in depth.

In this work, we discuss fabrication processes implemented for the realization of micron-sized and submicron-sized patterns in lithium niobate for application to nanophotonics or phononics. We will show that focused ion beam (FIB) milling offers interesting possibilities for the patterning of submicron-sized structures. The limited yield of this technological solution however calls for the implementation of collective processes with comparable etching capabilities. We therefore propose some possible alternatives based on reactive ion etching (RIE) in fluorine-based chemistries. We will more precisely emphasize the current need for highly-selective etch masks with respect to LiNbO_3 and we will propose some potential solutions based on the use of electroplated nickel. We will discuss the limitations of both etching methods and see how they can affect the actual physical performance of the fabricated photonic and phononic crystal devices.