2057

Fabrication of surface relief gratings on lithium niobate by combined UV laser and wet etching

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Abstract

Surface relief gratings have been fabricated on pure and Ti indiffused lithium niobate samples of x-cut and z-cut crystallographic orientations by a simple two-step process, which combines optical (pulsed ultra-violet laser) and chemical etching.

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Introduction

The variety of optical properties of lithium niobate crystals make this material attractive for many applications such as electro-optic modulators and switches, nonlinear optical frequency converters, optical waveguide amplifiers, lasers and so forth. It is a very good host material for optical integrated circuits since both passive and active components can be combined on the same chip [1].

For these reasons, surface patterning of lithium niobate crystals can be very useful for many applications such as Bragg reflectors and gain flattening filters. Several techniques have been proposed for the fabrication of such structures but they are either very complicated [2] or of limited quality and not easily controllable since they are based on direct laser ablation alone [3].

The method described here combines surface damage produced by a pulsed ultra-violet laser followed by wet etching. The acid preferentially attacks the laser-modified areas and the depth of the pattern is controllable subsequently via the etching time.

Description of the method.

An interference pattern is produced on the surface of the material by interfering two beams emerging from an injection locked excimer laser (operating with a KrF gas mixture emitting at 248 nm). The laser fluence is kept below the ablation threshold for this material, which is 80 mJ/cm^2 for this wavelength and pulse width (20 nsec), and so only minor damage is produced on the surface. Since there is no ablation involved the illumination of the samples can also be performed by using a phase mask. The illuminated surface is subsequently treated with a mixture of HF and HNO_3 acids. The wet etching step selectively etches or frustrates the etching of the illuminated areas depending on the crystal cut and face chosen for irradiation.

Results

After illumination of the surface of a lithium niobate sample with pulsed ultra-violet radiation minor damage occurs due to the strong interaction of the light with the material. The result of the illumination is shown in figure 1(a) where the Atomic Force Microscope (AFM) surface topography of the illuminated +z face of a 300 μm thick sample is shown. The surface looks damaged and a periodic relief pattern corresponding to the fringe spacing of the recording interference pattern is just discernable. This relief pattern is attributed to expansion of the material due to the interaction with the radiation [4]. After wet etching for 5 minutes in the mixture of acids at room temperature the projected interference pattern is revealed. AFM scan of the exposed surface after wet etching is shown in figure 1(b). The period of the recorded grating is ~360 nm.

Similar results have been obtained by using a phase mask optimised for 248 nm illumination. The +z face of a lithium niobate sample has been exposed to the periodic near-field intensity distribution produced near the surface of the phase mask and the surface morphology is shown in figures 2(a) and 2(b) before and after the acid treatment respectively. Irregularities of the printed pattern are attributed to imperfection of the phase mask.

Surface relief gratings can be fabricated in both z-cut and x-cut materials showing that the method is crystal-cut insensitive. X-cut and z-cut titanium indiffused lithium niobate channel waveguides are most commonly used for optical modulators and other applications in optoelectronics so the method can be applied in all lithium niobate based devices, which incorporates a grating or requires surface patterning.

Surface relief gratings were applied using this method onto x-cut titanium indiffused lithium niobate channel waveguides. The surface morphology of the waveguide with the superimposed grating is depicted in figure 3(a) for a 20μm x20μm section of the channel while a 10μm x10μm detail is depicted on figure 3(b) proving the high quality of the printed grating.

Conclusions

A simple two-step method for grating fabrication on lithium niobate has been demonstrated. The method consists of a combination of optical (laser) surface treatment followed by wet etching, using a combination of acids. The method is insensitive to the crystallographic orientation of the lithium niobate wafer and it can be applied in doped material such as Ti indiffused lithium niobate waveguides. Further work is under way for the better understanding of the process and its application for useful devices.

Acknowledgements

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Figure captions:

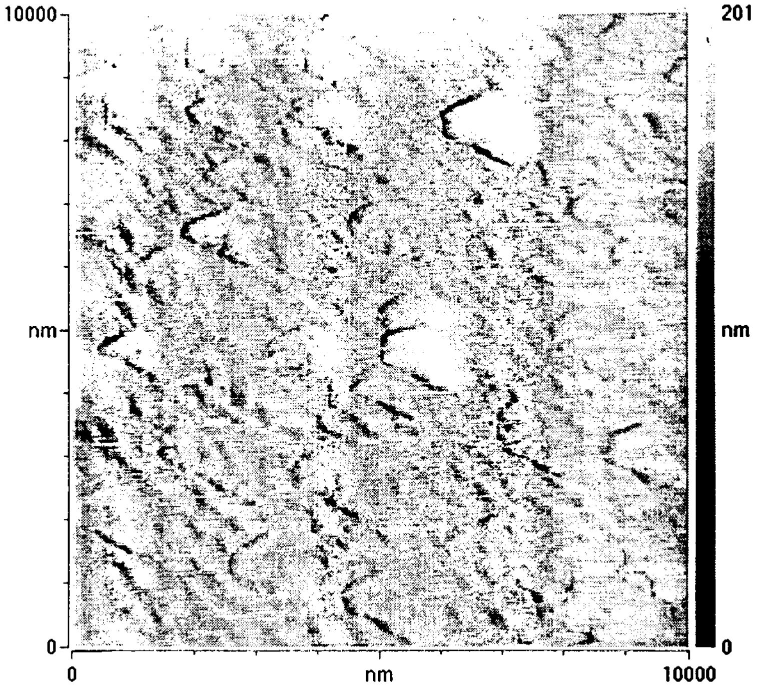
Fig 1. a) Surface damage caused by excimer laser irradiation of a +z face of a 300μm thick z-cut lithium niobate sample using interferometric exposure. b) The same area after wet etching. The fringe spacing of the recorded grating is ~360nm

Fig 2. Grating fabrication on the +z face of a lithium niobate sample. AFM pictures of the surface morphology a) before and b) after wet etching.

Fig 3. a) 20μm x20μm AFM scan of a surface relief grating applied on an x-cut Ti indiffused lithium niobate channel waveguide and b) 10μm x10μm detail of the structure.

Figure 1

a)



b)

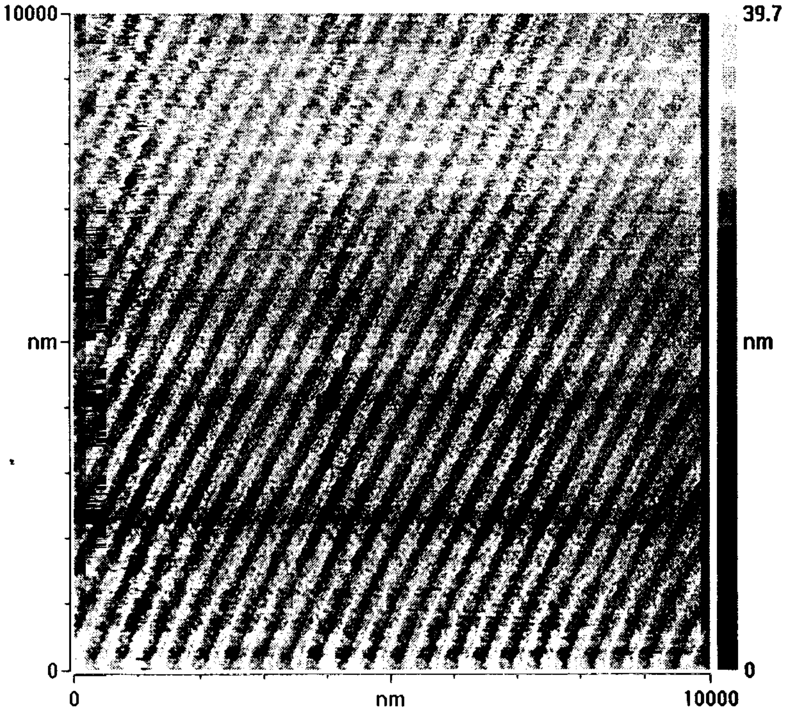
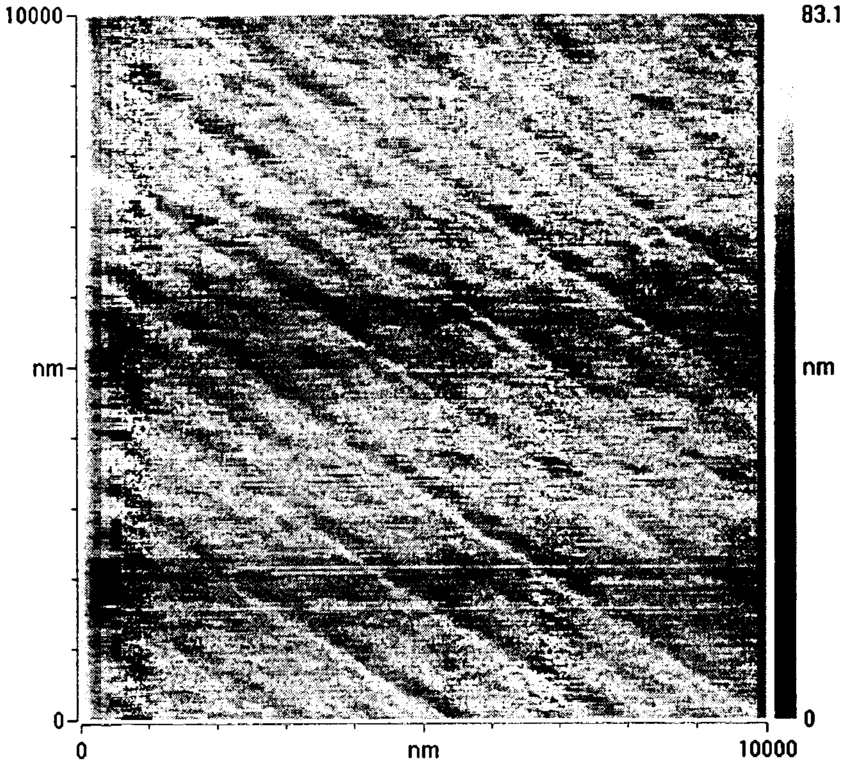


Figure 2

a)



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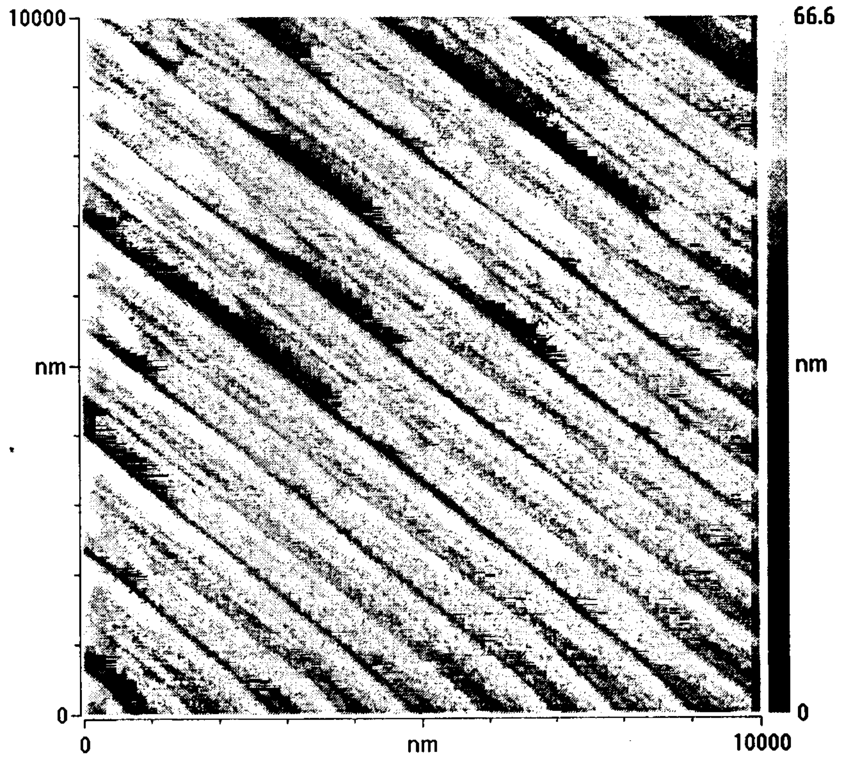
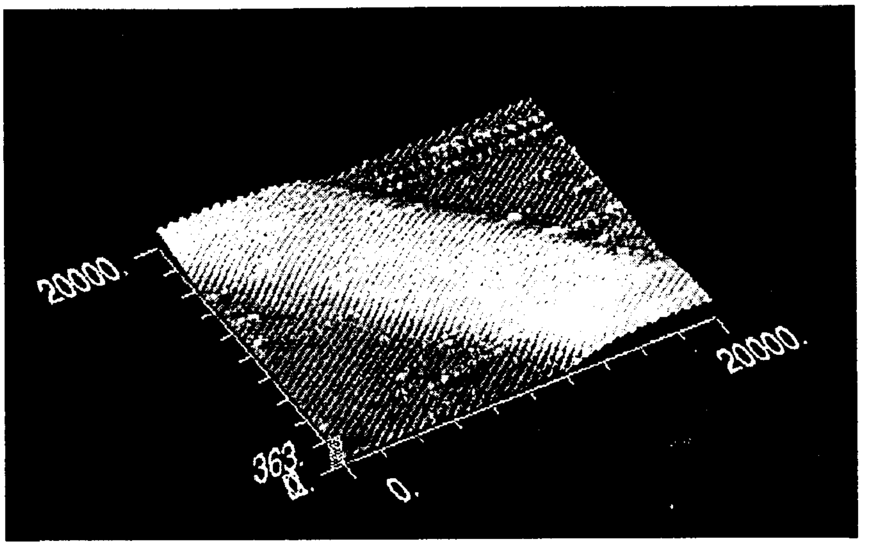


Figure 3

a)



b)