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Fabrication of Y128-cut and Y36-cut lithium niobate single crystalline thin films by crystal-ion-slicing technique

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Abstract

Y128-cut and Y36-cut single crystalline lithium niobate (LN) thin films are fabricated by crystal-ion-slicing (CIS) technique onto LN substrates.The conditions for the successful exfoliation of submicro-thick LN thin films are independent on the wafer cutting types used in the present work. The BCB wafer bonding is adopted instead of the mostly used hydrophilic bonding, which does need a strict surface treatment process before the bonding.

1. Introduction

Lithium Niobate ($LiNbO_3$, LN) crystal is the most important non-linear optical material, which has wide applications in various electro-optic modulator. Moreover, LN is piezoelectric material that has been extensively used as the substrate for surface acoustic wave (SAW) devices. Although the LN has intriguing optical and piezoelectrical properties, the mostly used LN-based devices are fabricated on LN single crystal wafers, and the deposition of high quality LN thin films is still a challenging task, which hampers the integration of those LN devices with other functionalities.

Theepitaxialgrowthof LN by traditional thin films deposition techniques is difficult due to the large lattice mismatch between LN and substrate, and the stoichiometry of the LN films is very sensitive to the growth conditions, which significantly influences the thin film properties. More importantly, LN is strongly anisotropic and LN crystals with special orientations are often used for different applications. For example, z-cut LN for optical devices[1, 2], y128-cut for surface acoustic wave devices[3], and y36-cut for bulk acoustic wave devices[4], etc.. However, only c-axis prefered orientation corresponding to z-cut crystal orientation can be achieved by the thin films deposition techniques, which dose not fulfill the requirements of diverse device applications.

In recently years, crystal-ion-slicing (CIS) technique has been developed to fabricate submicron-thick single crystalline thin films.The process is roughly described in Fig.1, which includes four main steps: the first is He^+implantation, and the implantation energy determines the thickness of finally obtained LN films; the second is wafer bonding between LN and substrate, which is critical for a successful integration of LN film onto a homogeneous or heterogeneous substrate; the third is exfoliation of the thin LN layer along the He^+-induced damage region by annealing the bonded wafer pairs under elevated temperature; and the fourth is polishing of LN films in order to obtain high quality thin films surface.

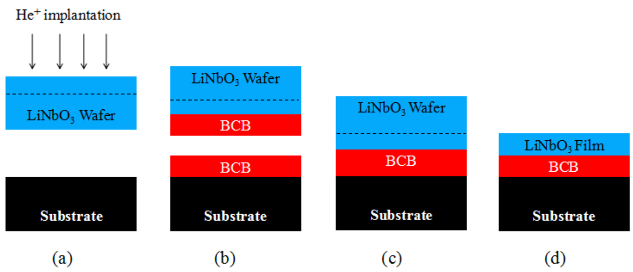


Fig. 1 Schematic process of CIS for LN films fabrication: (a) He^+ implantation on LN wafer, (b) BCB spin-coating on LN wafer and substrate, (c) wafer bonding via BCB, (d) splitting off of LNthin-film.

In the second step, most literatures adopted hydrophilic wafer bonding[18]between two SiO_2 bonding layers, which relies on a smooth SiO_2 layer with a surface roughness of less than 1 nm, thus the CVD-grown SiO_2 on LN has to be polished by CMP, which is difficult to implement since the SiO_2 layer usually has a thickess of less than 2μm. Instead, the indirect bonding via adhesive polymerdose not have strict requirementsforsurface roughness and can chieve strong bonding strength.

In the present work, y128-cut and y36-cut LN single crystalline thin films are fabricated by CIS involving BCB wafer bonding. The He^+ implantation conditions for different cuttings are invesigated, and the parameters of BCB bonding are studied.

2. Results and Discussions

4-inches y128-cut and y36-cut LN wafers are implanted with He^+ ions, the energies of He^+ ions are 150 keV and 285 keV, respectively, and the He^+ dose keeps at 2×10^{16} ions/cm^2. After implantation the LN wafers are cut into 8 mm×8 mm pieces. The implantation conditions for different wafers are summarized in Table I.

Table I He^+Implantation parameters

Cut type	He^+Energy (keV)	He^+ dose (ions/cm^2)
y128-cut	150	2×10^{16}
y128-cut	285	2×10^{16}
Y36-cut	150	2×10^{16}
Y36-cut	285	2×10^{16}

The 8 mm×8 mm implanted-LN and 10 mm×10 mm LN substrate are spin-coated with BCB, which is followed by a pre-baking process at 100 ℃ for 2 mins in order to volatilize extra organic solvent. The pre-baked LNs are bonded together and annealed in vacumm at 300℃ for 2 hours. During the annealing, the BCB is solidified and the implanted LN is exfoliated along the He+-induced damage region, which results in a LN(film)/BCB/LN (substrate) structure.

Although two types of LN orientations are chosen, both have been successfully exfoliated and transferred onto the LN substrate. The XRD patterns of the Y128-cut LN thin film is shown in Fig. 2, the FWHM of the thin film is 0.13° as indicated by the red curve, demonstrating a high cryalline quality of the LN film.

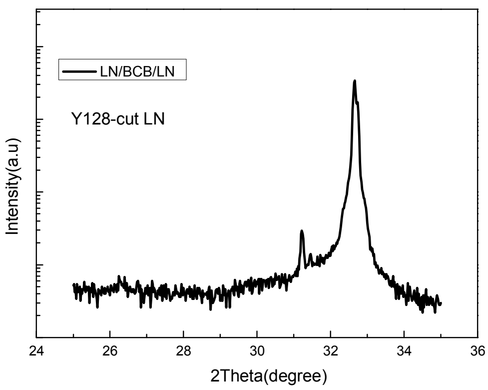
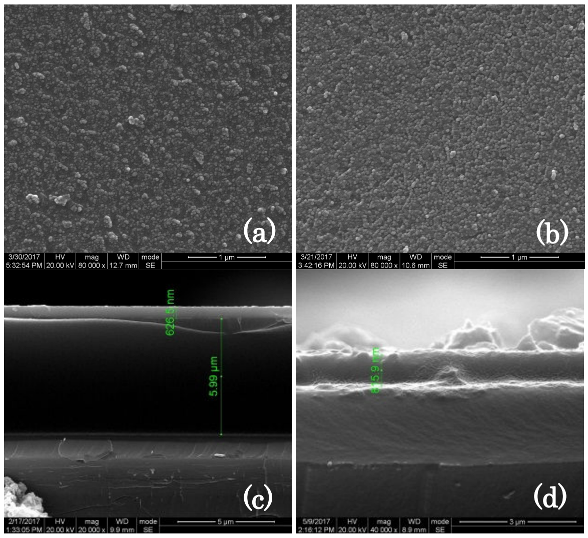


Fig. 2 XRD pattern of y128-cut LN thin film

The SEM images of the y128-cut and y36-cut LN thin films are shown in Fig. 3(a)(b), and no visible cracks can be observed on the thin film surface. The cross-sectional images of Y128-cut LN film are shown in Fig. 3(c)(d), it is observed that the thin film thickness is dependent on the He^+ energy, 150 keV and 285 keV result in 626 nm- and 859 nm-thick thin films, respectivly. Notebaly, the He^+ dose needs not change according to the He^+ energy, i.e. the dose keeps the same for the fabrication of thin films with different thicknesses.



(b)

Fig. 3 The SEM images of the y128-cut LN thin films

3. Conclusions

Single crystalline LN thin films are fabricated by CIS technique involving a BCB bonding step between the implanted LN and the substrate. The XRD results indicate the film has a high crystalline quality. The implantation and exfoliation paramaters keep the same for different crysal orientations.

Acknowledgements

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