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Thinning technology for lithium niobate wafer by surface activated bonding and chemical mechanical polishing

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1. Introduction

Lithium niobate ($LiNbO_3$) has been widely used as material for the fabrication of modulators for optoelectronic devices due to its combination of high electro-optic coefficients and high optical transparency in the near infrared wavelengths used for telecommunications. It is known that the frequency of the electro-optical modulators made by the thin single crystal $LiNbO_3$ with few micrometers (~μm) is much higher than that of the traditional modulators made by thick substrates (~500 μm) [1].Traditionally, the thin films are obtained by chemical vapor deposition, rf sputtering, sol-gel, and crystal ion slicing [2-3]. In this study, the $LiNbO_3$/Si hybrid wafers were fabricated by using room-temperature surface activated bonding. The thermal expansion mismatch problems existing between $LiNbO_3$ and Si substrates can be overcome. After bonding, the thin the $LiNbO_3$ layer can be obtained by chemical mechanical polishing [4].

2. Experiment

The substrates used in this study are 4" $LiNbO_3$ and Si wafers. The $LiNbO_3$ wafers with 400 μm thickness were single-side polished Y-Z cut wafers, while the silicon substrates with 500 μm thickness are double-side polished wafers. The two wafers were cleaned, activated and then bonded at room temperature. To optimize the bonding parameters, the contact angles, surface free energy and adhesion strength were measured. Finally, the $LiNbO_3$/Si hybrid wafer was bonded to a flat and parallel glass support disc in order to carry out the chemical mechanical polishing (CMP) process. The thickness of $LiNbO_3$/Si hybrid wafers can be verified by using the CG10 contact gauge during lapping and polishing. The surface morphologies and roughness of $LiNbO_3$/Si hybrid wafers after CMP were observed by Wyko NT1100 optical profiling system. Finally, the thickness of thinned $LiNbO_3$ was evaluated by the scanning electron microscope (SEM).

3. Results and discussion

Figure 1 shows the contact angle and surface free energy of $LiNbO_3$ wafers treated by different gases plasma at the same treated time. It was found that the wafer treated by O_2 plasma presents lowest contact angle and highest free energy. Under the optimum oxygen plasma treated conditions, the highest bonding strength between $LiNbO_3$ and Si wafers can be obtained and as shown in Fig. 2. This is consistent with the result obtained in Fig.1. Figure 3 shows that the removal rate and surface roughness of $LiNbO_3$ increased with increasing platen velocity and down pressure during lapping 1 process. Higher platen velocity instead of increased down pressure was chosen to increase the removal rate in order to minimize the damage probabilities. The details of lapping and polishing parameters were listed in Table I. The boron carbide wheel with big abrasive size (FEPA#500) was used in lapping 1 process to reduce the thickness of the $LiNbO_3$ wafer. When the thickness of $LiNbO_3$ is around 120 μm, the aluminum oxide wheel with small abrasive size (FEPA#2400) would be used in the lapping 2 process. The thickness of the $LiNbO_3$ wafer was left about 40 μm before polishing to ensure the removing of damaging layer. Amorphous silica with an abrasive size of 32 nm and cloth polishing pad were chosen during polishing. Finally, the thickness of the 4" $LiNbO_3$ substrate can be reduced from 400 μm to 10 μm without generating serious cracks. By adjusting the slurry and pad, the surface roughness of $LiNbO_3$ wafer was reduced from 850 nm to 1.5 nm over 1.9 × 2.5 mm^2 as shown in Fig. 4. The cross-section of the $LiNbO_3$/Si hybrid wafers was examined by SEM and showed in Fig. 5. the thickness of the $LiNbO_3$ layer was very uniform and presents about 10 μm.

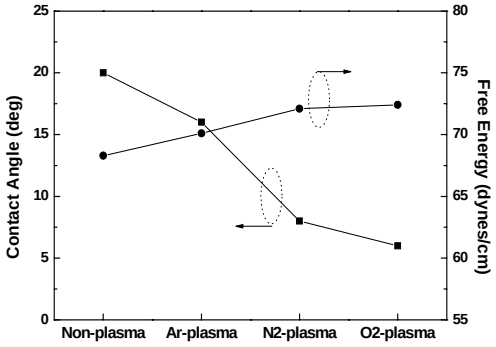

Fig. 1 Contact angle and surface free energy of the $LiNbO_3$ wafer treated by different gases plasma.

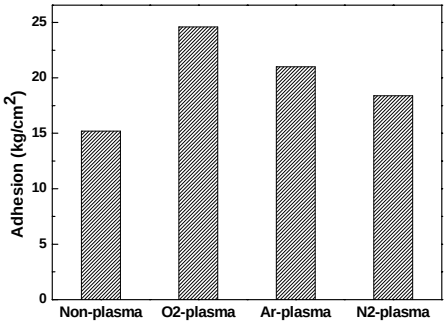

Fig. 2 Adhesion strength of Si and $LiNbO_3$ wafers treated by different gases plasma.

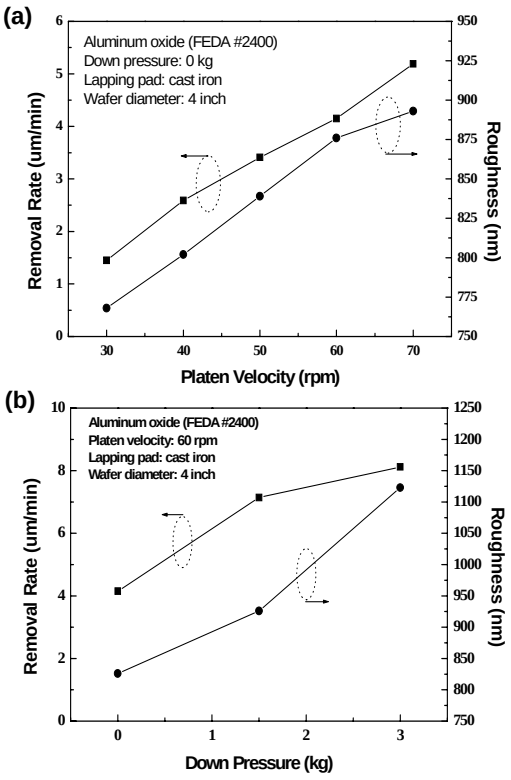

Fig. 3 Removal rate and roughness for lapping 1 varied with (a) the platen velocity and (b) down pressure.

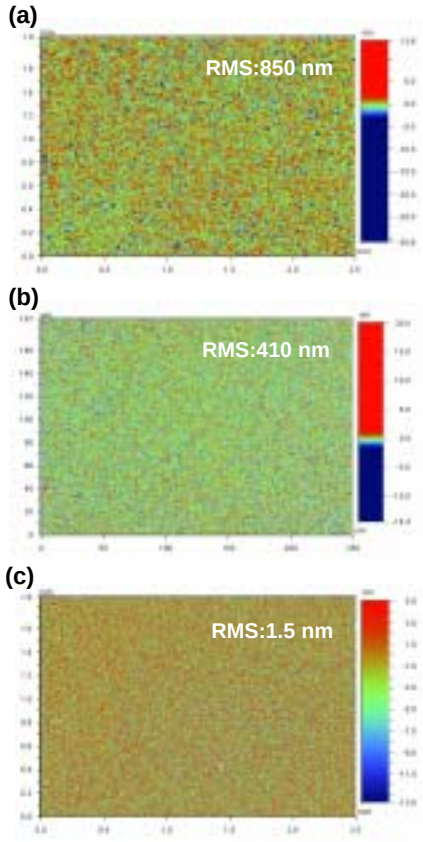

Fig. 4 Surface roughness for the $LiNbO_3$ processed under (a) lapping 1, (b) lapping 2, and (c) polishing.

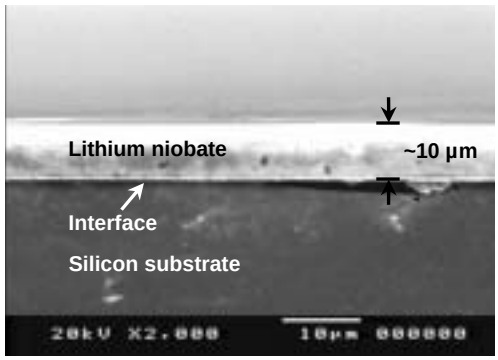

Fig. 5 SEM cross-sectional micrograph of $LiNbO_3$/Si hybrid wafer.

Table I Chemical mechanical polishing parameters

	Lapping 1	Lapping 2	Polishing
Pad	Cast iron	Glass	Cloth
Slurry	Boron carbide	Aluminum oxide	Amorphous silica
Down Pressure (Kg)	1.5	1.0	0.5
Platen velocity (rpm)	60	70	70
Removal Rate (μm/min)	4.5	2.5	0.1

4. Conclusions

In summary, $LiNbO_3$/silicon hybrid wafers were fabricated by a combination of surface activated bonding and chemical mechanical polishing techniques. In this study, oxygen plasma can effectively activate the surfaces of $LiNbO_3$ and Si wafers and result in high bonding strength at room temperature. After the bonding process, $LiNbO_3$ was lapped by boron carbide and aluminum oxide with an abrasive size of 30 μm and 10 μm, and then polished by amorphous silica with an abrasive size of 32 nm. Finally, the thickness of the 4" $LiNbO_3$ wafer can be reduced from 400 μm to 10 μm without generating serious cracks.

Acknowledgements

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