Improvement on the Optical Damage resistance of the $LiNbO_3$ Single Crystals by the ZnO doping

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1. Introduction

Lithium Niobate($LiNbO_3$) single crystal is used widely for many opto-electronic devices due to its excellent piezoelectric and optical properties[1-6], however, it is restricted to device applications for higher performances because of the photorefractive effect(optical damage).

Many researchers have explained that the photorefractive effect is induced by the space charge field, between the negative charged regions, trapped electrons excited by the laser beam, and the remaining cation centers, which causes the variation of refractive index[7]. Chen[8] et al. explained this effect could be induced by the presence of inherent internal field and Amodei[9] et al. thought to be due to the diffusion of the photo-excited carriers. In 1974, Glass[10] et al. proposed photovoltaic effect. They investigated that the probabilities of charge transfer by the optical transition from Fe^{2+} to Nb^{5+} in the +c and -c directions differ from each other because of difference in the distance between Fe atoms and Nb atoms, therefore photorefractive effect appears.

It is well-known that the resistance of the optical damage is improved by MgO doping. Bryan[11] et al. suggested that the reduction of photorefraction in MgO doped $LiNbO_3$ results from the increase in photoconductivity and Sommerfeldt[12] et al. has found that the photoconductivity of the $LiNbO_3$:Mg:Fe increases with the amount of MgO doping. All of these experimental results can be explained by the model of substitution Mg^{2+} for Nb_{Li}^{4+} in nonstoichiometric $LiNbO_3$($[Li_{1-5X}Nb_{5X}]Nb_{1-4X}O_3$)[13]. However, even in MgO doped $LiNbO_3$, the darkening induced by the two-photon absorption appears under the intensive laser radiation[14]. Volk[15] et al. proposed the ZnO doping to $LiNbO_3$ in order to reduce this effect.

This paper presents the variation of the properties with the different amounts of ZnO doping(3, 5, 7, 9mol%) to find the improvement on the photorefractive effect.

2. Experiment

Undoped and ZnO doped $LiNbO_3$ single crystals were grown by the Czochralski mothod.

The lattice parameter, refractive index and transmittance of the single crystals grown were measured by least square method of the XRD, SD 2000 automatic Ellipsometer produced by PLAS MOS Co. and UV/VIS/NIR Spectrophotometer by PERKIN ELMER Co..

3. Results

The $LiNbO_3$ single crystals grown is typically 35~40㎜ in diameter and 60~80㎜ in length.

Table 1 The calculated values of lattice parameters of $LiNbO_3$ single crystals grown.

		a_H(Å)	$\triangle a_H$(%)	c_H(Å)	$\triangle c_H$(%)	c_H/a_H
Undoped		5.1492	-	13.8046	-	2.6809
ZnO doped	3mol%	5.1417	-0.0015	13.9167	0.8120	2.6848
	5mol%	5.1520	0.0544	13.8177	0.0949	2.6820
	7mol%	5.1513	0.0408	13.8266	0.1594	2.6841
	9mol%	5.3316	3.5423	13.5887	-1.5639	2.5487

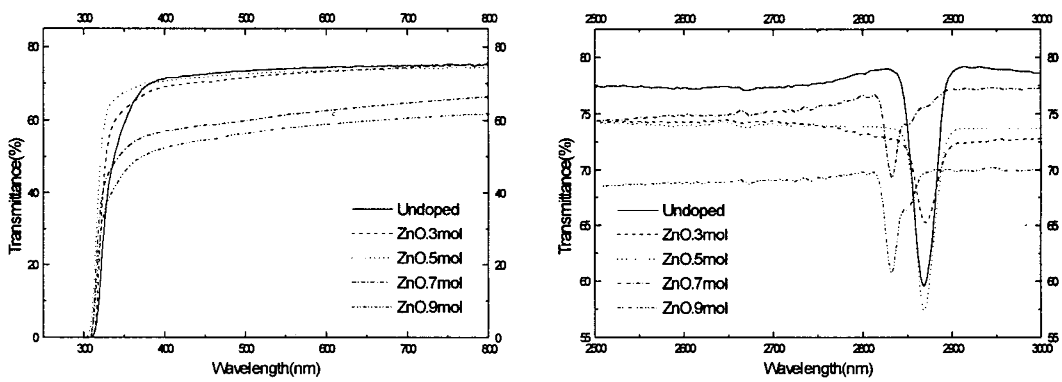
Table 1 shows the calculated values of the lattice parameters. The lattice parameters increase with the amounts of ZnO doping up to about 0.05% in a-axis and 0.1 to 0.8% in c-axis. Extra X-ray diffraction peaks were observed in 9mol% ZnO doped $LiNbO_3$ and it is thought that beyond the limit of solubility of ZnO, the second phase were formed.

Table 2 Refractive index of $LiNbO_3$ single crystals grown with the variations of ZnO doping.

Wavelength : 632.8nm
Angle : 70.00°

		Average	Stdev.	Max.	Min.
Undoped		2.304	0.0041	2.306	2.285
ZnO doped	3mol%	2.253	0.0038	2.259	2.241
	5mol%	2.309	0.0026	2.315	2.306
	7mol%	2.235	0.0073	2.245	2.222
	9mol%	2.255	0.0070	2.264	2.235

ZnO doped $LiNbO_3$ single crystals have the lower refractive index than that of undoped crystal, relatively, and this result is appeared in Table 2. The fluctuation of refractive index shows very small value in the range of the 10^{-3} order.



(a) (b)

Fig. 1 Transmittance of $LiNbO_3$ single crystals grown with the different amounts of ZnO doping.
(a) absorption edge in the visible range
(b) OH^- absorption band in the near IR range

According to the transmittance of the crystals, as shown in Fig. 1, the doping of ZnO has an effect on the shift of the absorption edge and OH^- absorption band to the shorter wavelength range by 5~10nm and 40nm, respectively. This result gives the proof that Zn_{Nb}^{3-} is formed in $LiNbO_3$ lattice and means indirectly that ZnO doping reduces the photorefractive effect of the $LiNbO_3$.

Reference

1. T. Y. Fan, A. Cordova-Plaza, M. J. F. Digonnet, R. L. Byer and H. J. Shaw, J. Opt. Soc. Am. B3 (1986) 140.
2. W. J. Kozlovsky, C. D. Nabors and R. L. Byer, Opt. Lett. 12 (1987) 1014.
3. A. Cordova-Plaza, T. Y. Fan, M. J. F. Digonnet, R. L. Byer and H. J. Shaw, Opt. Lett. 13 (1988) 209.
4. M. M. Abouelleil and J. J. Leonberger, J. Am. Ceram. Soc. 72 (1989) 1311.
5. E. Lollier, J. P. Pocholle, M. Papuchon, M. de Mecheli, M. J. Li, Q. He and D. B. Ostrowsky, Opt. Lett. 15 (1990) 996.
6. D. C. Gerstenberg, G. E. Tye and R. W. Wallace, Opt. Lett. 16 (1991) 992.
7. Y. Ohmori, M. Yamaguchi, K. Yoshino and Y. Inuishi, Japanese J. Appl. Phys. 18 (1979) 79.
8. F. S. Chen, J. Appl. Phys. 40 (1969) 3389.
9. J. J. Amodei, RCA Rev. 32 (1971) 185.
10. A. M. Glass, D. von der Linde and T. J. Negran, Appl. Phys. Lett. 25 (1974) 233.
11. D. A. Bryan, R. Gerson and H. E. Tomaschke, Appl. Phys. Lett. 44 (1984) 847..
12. R. Sommerfeldt, L. Holtmann, E. Krätzig and B. C. Grabmaier, Phys. Status Solidi A106 (1988) 89.
13. S. C. Abrahams and P. Marsh, Acta Cryst. B42 (1986) 61.
14. A. M. Glass, Opt. Eng. 17 (1987) 470.
15. T. R. Volk, V. I. Pryalkin and N. M. Rubinina, Opt. Lett. 15 (1990) 996.