The doping effects of MgO and ZnO on the $LiNbO_3$ single crystals grown by a floating zone technique

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1. Introduction

The $LiNbO_3$ single crystals are used for second harmonic generation(SHG) waveguide device, optical modulator, optical memory device, etc. because of their nonlinear optical characteristics. However, the application for these optical devices are limited mainly because of the optical damage which are attributed to the variation in refractive indices of $LiNbO_3$ single crystal with the strength of the incident beam. MgO is a well known dopant for improving the optical damage resistance of $LiNbO_3$ single crystals. The ionic size of Mg^{2+} is similar to that of Li^{+} and the difference in the ionic sizes between Mg^{2+} and Zn^{2+} is very small. Furthermore, magnesium and zinc have same valence value. $LiNbO_3$ single crystals(undoped, 5mol% MgO-doped, and 5mol% ZnO-doped) of congruently melting composition(48.6mol% Li_2O) were grown by a floating zone(FZ) technique. As-grown crystals were annealed at 1000℃ for 24 hours in air. This study presents the doping effects of MgO and ZnO on the electrical and optical properties of the FZ-grown $LiNbO_3$ crystals.

2. Experimental procedure

The optimum conditions for the fabrication of the sintered $LiNbO_3$ feed-rods were established.

The optimum condition of powder synthesis

-Solid-state reaction temperature : 950℃

-Soaking time : 12 hours

-The average particle size : ≈ 1㎛

-The particle shape : octahedron

The optimum sintering condition of the feed-rods

-The sintering temperature : 1100℃

-Soaking time : 2 hours

-The relative density of sintered feed-rods : ≈ 80%

-The average grain size : ≈ 3㎛

The optimum growth condition of $LiNbO_3$ single crystals using a floating zone(FZ) technique are as follows;

-The growth rate : 3~5 mm/hr

-The rotation speed : 8~10 rpm(feed-rod)

10~15 rpm(grown crystal)

-Atmosphere : N_2 flowing gas(↑), 0.5~1.0 ℓ/min

3. Experimental results

3.1 Lattice parameter

The lattice parameters(a_H and c_H) of $LiNbO_3$ crystal doped with 5mol% MgO or ZnO were increased slightly compared with those of the undoped $LiNbO_3$ single crystal.

	a_H(Å)	c_H(Å)	c_H/a_H	Δa_H(%)	Δc_H(%)
undoped LN	5.1419	13.8467	2.693	-	-
MgO doped LN	5.1461	14.1069	2.724	0.0817	1.879
ZnO doped LN	5.1456	14.2543	2.770	0.072	2.994

3.2 Curie temperature

Curie temperatures of $LiNbO_3$ crystals doped with 5mol% MgO or ZnO were higher than that of the undoped $LiNbO_3$ crystals. This is thought to be

attributed to the decrease in the Li/Nb ratio. Curie temperature of the undoped $LiNbO_3$ was about 1140℃ while those of $LiNbO_3$ crystals doped with 5mol% MgO or 5mol% ZnO were about 1220℃ and 1230℃, respectively.

3.3 Electrical conductivity

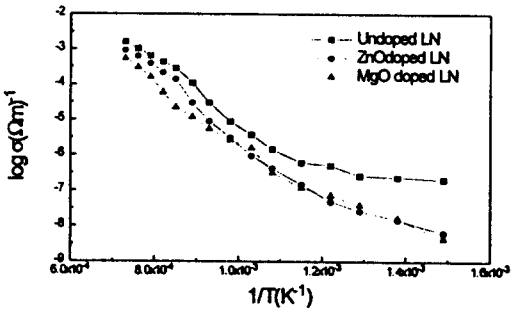

Fig.1 Variation of electrical conductivities of undoped , 5mol% MgO-doped and 5mol% ZnO doped $LiNbO_3$ wafers with the temperature.

3.4 Absorption edge and OH^- band

Absorption edge and OH^- band of $LiNbO_3$ crystals doped with 5mol% MgO or ZnO shifted slightly to the peak position with the shorter wavelength compared with the undoped $LiNbO_3$ crystal. This phenomena is thought to be due to the substitution of Mg^{2+} or Zn^{2+} to the Nb-sites and a good proof for the increase in the optical damage resistance of $LiNbO_3$ single crystal by the doping of 5mol% MgO or ZnO.

	absorption edge	OH^- band
undoped LN	325nm	2867nm
MgO doped LN	317nm	2830nm
ZnO doped LN	312nm	2852nm

3.6 Nonlinear rafractive index

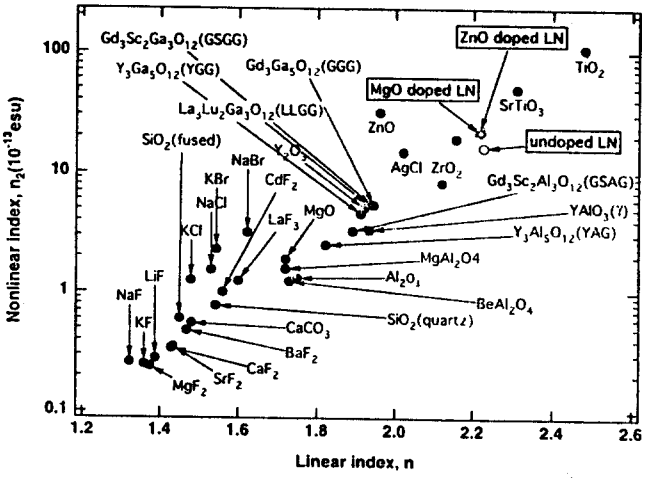

Fig.2 Relationship between the linear refractive index and nonlinear refractive index of undoped, 5mol% MgO-doped and 5mol% ZnO-doped $LiNbO_3$ wafers(at 1064nm).