EFFECT OF POLING ON THE PHYSICAL, PIEZOELECTRIC PROPERTIES OF $LiNbO_3$

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ABSTRACT

Undoped and 5mol%MgO doped $LiNbO_3$ were grown by floating zone method. The grown crystals were poled to c-axis in different electric field conditions. Ferroelectric domain patterns related to the poling conditions were investigated by chemical etching and the poling effects on the piezoelectric properties in the undoped and MgO doped crystals were studied.

INTRODUCTION

$LiNbO_3$ is a well known ferroelectric material which in single crystal form has found uses in various applications such as nonlinear optical devices, wave guide devices and surface acoustic wave devices.[1] Usually, a pulled $LiNbO_3$ single crystal has a polydomain structure, and the crystal does not consequently exhibit any piezoelectric or elecrrooptical properties. In order to make crystals with single domain structures, a poling process is needed.[2]

In this present paper, we describe the single crystal growth of undoped and MgO doped $LiNbO_3$ by floating zone method. and further experiments and results are presented concerning the ferroelectric domain patterns under the different electric field conditions and the poling effects on the piezoelectric properties in the undoped and MgO doped crystals

EXPERIMENTAL PROCEDURES

The anisotropy of thermal expansion along the c-axis and a-axis in $LiNbO_3$[3] making the crystal easy to be cracked during cooling, was stabilized by a heat reservoir using alumina tube.[4] The starting materials were high purity (99.99wt%)Li_2CO_3, Nb_2O_5, MgO. The growth rate was 3mm/hr and the rotation rate for both the c-axis seed and the feed rod was 30rpm in opposite directions. Growth was accomplished in argon and annealing treatment was done in air at 1000℃ for 20h after growth. A pulled crystal boule with both ends cut off is put between a pair of platinum electrodes, and then a d.c electric fields of 1, 3, 6V/cm was applied on the crystal column at 1210℃ for 10min.

Etching was done with a mixture(HF : HNO_3 = 1 : 2) at 110℃ for 4min and domain structures were observed by optical microscope. The value of dielectric constant was measured in a frequency range of 100kHz at room temperature by HP 4284 LCR meter and a HP 4194A impedance/gain-phase analyser was used to obtain electromechanical coupling factor by measuring the resonant and antiresonant frequencies of the thin disc radial mode of plates.

RESULTS AND DISCUSSIONS

The resulting crystals were 27mm in length and 6-7mm in diameter. Undoped crystal was colorless, clear and transparent, while 5mol%MgO doped crystal was slightly milky color.(Fig. 1)

Fig. 2 shows etched wafers before poling. Undoped wafers mostly formed single domain structures. but multidomains were observed in near outer edges. In case of MgO doped crystals. wafers showed typical patterns like annual-rings of a tree. Fig. 3 shows etched patterns of poled wafers. As the applied fields increase, the multiplicity of domains decreased. The resulting poling conditions for undoped and MgO doped crystals are shown in table I. It was more difficult to obtain single domain structure for MgO doped crystals. It is considered that domain mobilities of MgO doped crystals are lower than undoped crystals due to the trapping of domain walls by Mg and the decrease of effective applied field as the conductivity increased.[5]

Fig. 4 are impedance(|Z|)-frequency curves of poled crystals. The frequency range of resonance(fr) and antiresonance(fa) were observed in around 700kHz. As increased applied electric field, the maximum and minimum value of impedance were observed clearly and the frequency width in between resonance and antiresonance was increased. while in case of poor poled samples, impedance was gradually decreased as increasing frequency. From these graphs electromechanical coupling factor(Kp) can be calculated using the following equation. and the resulting values are as follows.(table II)

$$\frac{1}{{K_p}^2} = 0.395\frac{f_r}{f_a - f_r} + 0.574$$

The value of Kp in the poled crystals increased with applied field. and It was thought that the low values of MgO doped crystals were probably originated in the multiplicity of domains which makes multi-oscillation

CONCLUSION

By reducing temperature distribution with heat reservoir, high quality undoped and MgO doped $LiNbO_3$ single crystals were grown by the floating zone method. We were able to obtain single domain structure in undoped crystals at over 3V/cm. Partially poor poled regions were found in 5mol% MgO doped crystals even at and above 6V/cm. Chemical etching patterns and electromechanical coupling factor(Kp) revealed the poling conditions of crystals under different electric fields. The resulting values of Kp increased linearlly with increasing electric fields.

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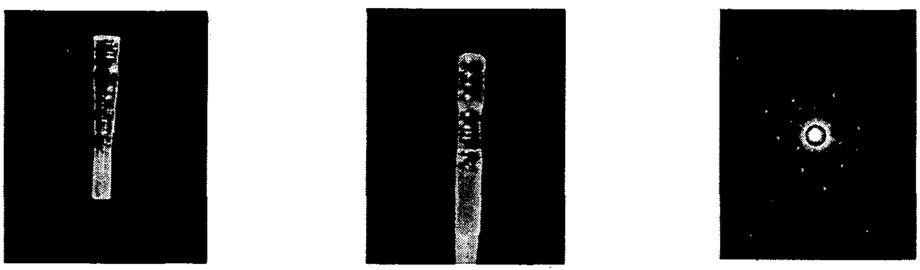
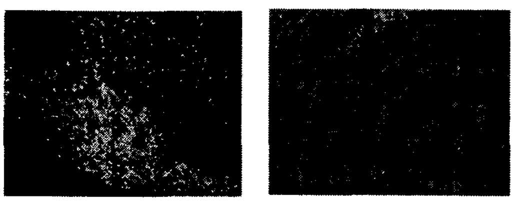


(a) (b) (c)

Fig. 1. Grown crystals of undoped(a), MgO doped(b), and c-axis Laue pattern(c)



[undoped] [MgO doped]

Fig 2. Etched patterns of undoped and MgO doped crystals before poling

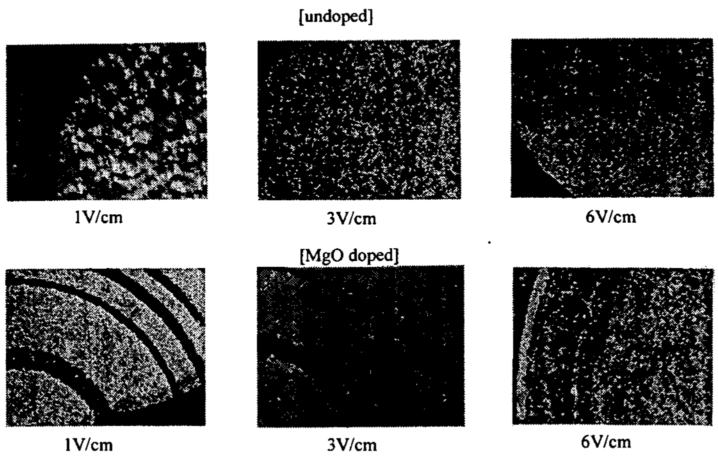


Fig. 3.Etched patterns of undoped and MgO doped crystals after poling

Table I. The resulting poling conditions for undoped and MgO doped crystals

Sample	Applied field (V/cm)	Result
undoped	1	poor in part
undoped	3	good
undoped	6	good
5mol%MgO doped	1	poor
5mol%MgO doped	3	poor in part
5mol%MgO doped	6	poor in part

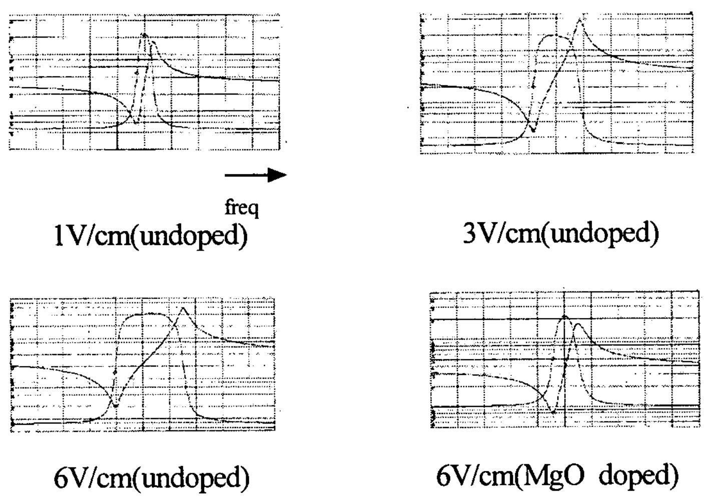


Fig. 4. Impedance-frequency graphs of poled crystals

Table II. The values of electromechanical factors of poled crystals

Samples	undoped	undoped	undoped	MgO doped	MgO doped	MgO doped
Applied field	1V/cm	3V/cm	6V/cm	1V/cm	3V/cm	4V/cm
Kp	0.028	0.043	0.053	-	0.017	0.028