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Velocity of SAW on Proton-Exchanged and Annealed Proton-Exchanged Z-cut LiNbO3 using Octanoic Acid

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Abstract

The acoustic velocities of surface acoustic waves (SAWs) on proton-exchanged (PE) and annealed proton-exchanged (APE) z-cut y-propagation $LiNbO_3$ waveguides using octanoic acid are investigated. It is revealed that the SAW velocity is decreased by the proton exchange. However, post-annealing on proton-exchanged samples will result in a restoration of the decreased velocity. Besides, post-annealing will also result in an improvement of the acoustic insertion loss.

Keywords: *Surface Acoustic Wave (SAW), Proton Exchange, Post-annealing, Octanoic Acid*

I. Introduction

Proton exchange is a very convenient method for the fabrication of optical and acoustic waveguides on $LiNbO_3$ substrates. This process is a low-temperature operation, easy to control and inexpensive. It is carried out by immersing the substrate into the molten proton sources, such as benzoic acid [1-5], phosphoric acid [6-7] and pyrophosphoric acid [8-9], etc.

In this study, the acoustic velocities (V_p) of surface acoustic waves (SAWs) on proton-exchanges (PE) and annealed proton-exchanged (APE) z-cut y-propagation $LiNbO_3$ waveguides using pure octanoic acid [10-11] as the new proton source are investigated. Octanoic acid is adopted because it is nontoxic and has a dissociation constant similar to that of benzoic acid. On the other hand, the z-cut $LiNbO_3$ is used as the substrate to avoid the surface damage during the PE process.

II. Experiments

Planar PE samples were fabricated by immersing precleaned z-cut y-propagation $LiNbO_3$ substrates (Crystal Technology, U.S.A.) into the pure octanoic acid kept at the exchange temperature, T, of 200~220°C. The exchange time, t, ranged 22~28 hr. After the PE process, the samples were washed by DI water and acetone to remove excess acid. Post-annealing of the samples is carried out in a horizontal furnace at 400°C for 4 hr under a dry O_2 gas flow.

To excite the SAW, a standard technique through the use of IDTs with split electrode geometry is adopted to reduce undesired finger reflection effect. The parameters of designed IDTs are listed in Table 1. A patterning process involving lift-off technique and photolithography is applied for split electrode fabrication. Aluminum electrode is made by vacuum evaporation with the thickness to be about 1500 Å measured by the Ellipsometry. The frequency response of SAW is measured by the HP 8702 network analyzer.

III. Results and Discussion

The velocity of SAW is determined by $V_p = f_0 \times \lambda$, where f_0 is the center frequency of the transducers measured by the HP 8702 network analyzer. The variations of V_p on PE and APE z-cut y-propagation $LiNbO_3$ waveguides as a function of the exchange time are shown in Fig. 1. It is obvious that the V_p decreases with the increase of t for the PE samples. However, the SAW velocities of the exchanged samples are smaller than that of the unexchanged one, which is determined to be about 3900m/sec. The reduction of velocity indicates that the elastic constants are softened by the proton exchange.

Besides, it is found that the acoustic velocities of SAWs are recovered by post-annealing at T=200°C as shown in Fig. 1. The result indicates that the annealed proton-exchanged z-cut $LiNbO_3$ waveguides may result in a restoration of the piezoelectric properties in the PE layer. This phenomenon is similar to that of optical $LiNbO_3$ waveguides, which is well known the annealed PE waveguide exhibits lower optical propagation loss than unannealed one, and results in a restoration of the electro-optic effect and the nonlinear coefficients.

The insertion loss (IL) of SAW before and after annealing at T=200°C is listed in Table 2. The results show that the values of IL are almost independent of t for the PE samples. However, the IL of the annealed PE samples is smaller than that of the unannealed ones. The result indicates that post-annealing will result in an improvement of IL, which may be due to the increased piezoelectric properties of the

PE layer.

IV. Conclusions

We have investigated the acoustic velocities of SAWs on PE and APE z-cut y-propagation $LiNbO_3$ waveguides using pure octanoic acid. By careful control of the exchange time and/or exchange temperature, the desired V_p of SAW can be obtained. The results in this study show that the acoustic velocity is significantly reduced in the PE layer and the acoustic insertion loss of SAW is almost independent of t for the PE samples. The reduction of V_p can be applied to develop acoustic waveguides, lenses and reflective gratings similar to those fabricated by Ti-indiffusion processes. Meanwhile, post-annealing will result in a restoration of the reduced velocity in the PE layer. On the other hand, it will also result in an improvement of the insertion loss of SAW. The results indicate that the annealed PE z-cut $LiNbO_3$ waveguides can be expected to apply to the guided wave SAW, guided optical wave and acoustooptic (AO) devices.

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VI. References

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Figure 1

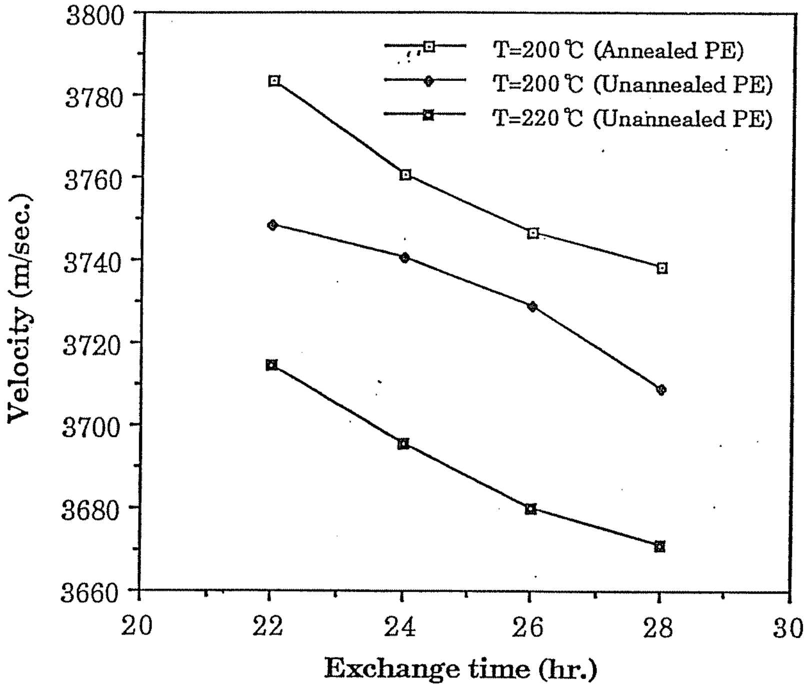

Table 1. The parameters of designed IDTs.

Parameters	Values
N1 (input IDT)	20 finger-pairs
N2 (output IDT)	6 finger-pairs
λ (wavelength)	46 μm
D (distance)	5060 μm (110λ)
W (aperture)	3220 μm (70λ)

Table 2. The insertion loss of SAW before and after annealing at T=200℃.

t (hr.)	IL (dB) (PE)	IL (dB) (APE)
22	19.7	18.1
24	20.1	18.0
26	20.5	18.3
28	20.9	18.7

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使用辛酸作質子交換以探討在鈮酸鋰基板上表面聲波波速變化的情形

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摘　　要

本研究係使用辛酸作質子交換以探討在鈮酸鋰基板上表面聲波波速的變化。實驗結果顯示經過質子交換後，其波速減小。然而，在經過退火處理後，其損失的波速將被恢復一些。同時，聲波內損也將恢復許多。

關鍵詞：表面聲波，質子交換，退火處理，辛酸

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