3P1-16

Proceedings of Symposium on Ultrasonic Electronics, Vol. 30 (2009) pp. 453-454
18-20 November, 2009

SAW Propagation Characteristics of Buried Type Optical-waveguides on $LiNbO_3$ Substrates

$LiNbO_3$ 基板に形成した埋め込み光導波路の SAW 伝搬特性

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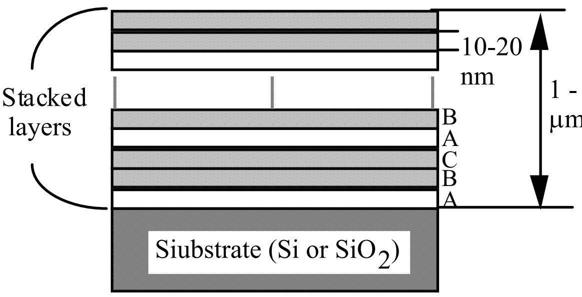
1. Introduction

We previously proposed silica based superstructure film composed by periodic nanometer laysers of $Ge:SiO_2$, $Ti:SiO_2$ and $Sn;SiO_2$. Poling treatment to superstructure film causes piezoelectricity and pyroelectricity. In the superstructure films, we also observed visible light luminescence excited by UV and /or cathode ray. We also investigated stimulated emission in the superstructure films and obtained a suggestion of optical amplification in short wavelength range around 400 nm. To make use of the superstructure film for active optical devices, it is desired to construct optical waveguides on $LiNbO_3$ substrates. SAW controlled and/or electro-optical controlled active optical devices may be possible by this configuration. In this paper, we propose buried type optical waveguides on LN substrates.

2. Optical properties of the superstructure film

Figure 1 is a cross sectional view of the silica based superstructure film. Poling treatment for the film causes piezoelectricity and other phenomena accompanying the polarization[1-3]. Furthermore, the film performs visible luminescence by UV excitation[3]. Figure 2 shows an example of the luminescence spectrum of the film. Luminescence from violet to green with peaks around 400 and 500 nm was observed.



A: $Ge:SiO_2$ B: $Ti:SiO_2$ C: $Sn:SiO_2$ or $Zr:SiO_2$

Fig.1. Silica based super-structure film.

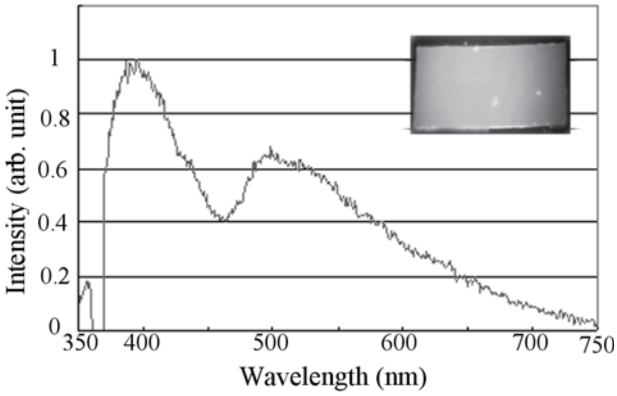
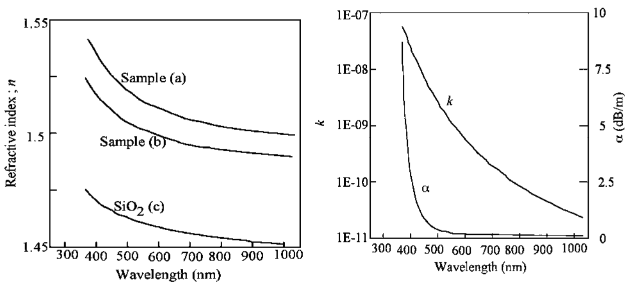


Fig. 2 Luminescence spectrum.

We measured complex refractive index of the silica-based superstructure film by ellipsometry. The real part, n, of the complex refractive index is shown in **Fig. 3** (a). Although the n values varied by about 1% with the samples, the refractive index of the film was larger by 3-4 % than that of pure silica glass. An imaginary part, k, of the complex refractive index (extinction rate) and attenuation constant α are shown in Fig. 3 (b). The attenuation constant was only about 10 times that of pure silica and the optical absorption is fairly small.



(a) (b)

Fig. 3 Refractive index and attenuation constant.

3. Observation of light amplification

We examined light amplification at 405 nm by using the superstructure waveguide fabricated on Si substrates. In **Fig. 4,** (a) shows output optical signal of a waveguide without excitation, and (b) corresponds to the optical signal with UV excitation.

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The amplification factor was about 1.5 dB/cm.

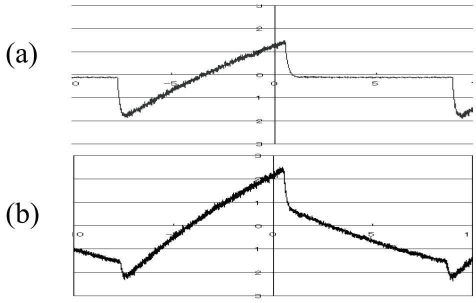

Fig. 4 Amplification at 405 nm.

4. Waveguide on $LiNbO_3$ substrates

Experimental result shown in Fig. 4 suggests the possibility of active optical devices by waveguides of the superstructure films. Fabrication of the waveguides on $LiNbO_3$ (LN) substrates enables SAW control and/or EO control of the device characteristics. Therefore, preparation of superstructure film optical waveguide on LN substrates is desired.

Figure 5 shows a configuration of the waveguide on 128˚RY LN substrate. The propagation characteristic of Rayleigh mode SAW depends on the film thickness as shown in **Fig. 6**. The electromechanical coupling constant is relatively large for $H/\lambda < 0.3$, however it rapidly decreases with the film thickness for $H/\lambda > 0.3$.

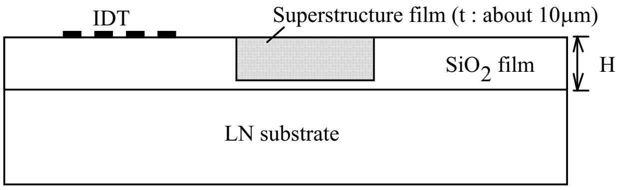

Fig. 5 Configuration of the waveguide.

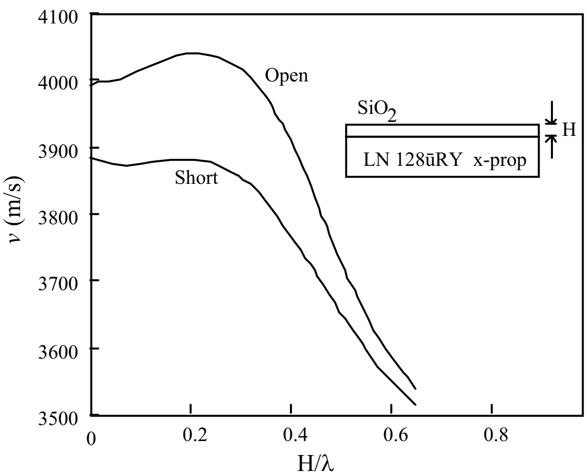

Fig. 6 Rayleigh mode velocity.

This suggests that for frequencies higher than 100 MHz, the effective coupling constant becomes very small. To obtain high coupling in Rayleigh mode, a buried type waveguide shown in **Fig. 7** is suitable. The SiO_2 film operates as a clad layer of the optical waveguide. Furthermore, the thickness can be easily adjusted at $0.1 < H/\lambda < 0.3$ which corresponds to the high electromechanical coupling condition. Although acoustical mismatching at the boundaries causes SAW reflection, more than 80 % SAW power propagates into the superstructure film waveguide.

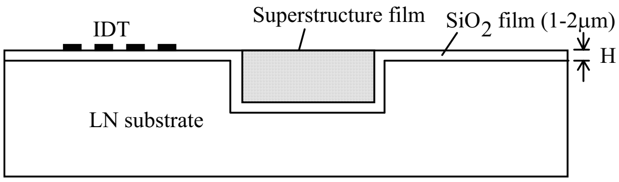

Fig. 7 Buried type optical waveguide on the LN substrate.

For the buried type waveguide, groove formation on LN is necessary. Reactive etching is applicable for that purpose.

5. Conclusion

Light amplification in silica superstructure film waveguide was observed. Amplification gain of 1.5 dB/cm was obtained at 405 nm. Configurations of light waveguide by silica superstructure on 128˚RY $LiNbO_3$ substrate were investigated. Buried type optical waveguide is desirable to obtain high electromechanical coupling.

Acknowledgment

This work was supported by the Grant-in-Aid for Science Research from the Ministry of Education, Culture, Sports, Science and Technology of Japan (No. 19560322).

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