Ti-indiffused waveguide polarizers on Lithium Niobate for Fiber Optic Gyroscope

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ABSTRACT

We report our results on polarizing waveguides fabricated by Ti indiffusion technique on x-cut y-propagating $LiNbO_3$. Polarizing Ti indiffused waveguides with polarization extinction coefficient (PER) higher than 47 dB at their outputs, operating at 1550 nm wavelength were demonstrated.

Keywords: waveguide, diffusion, titanium, lithium niobate, polarization extinction coefficent, polarizer.

1. INTRODUCTION

Lithium niobate ($LiNbO_3$) is an attractive material for fabrication of integrated optoelectronic devices. Some applications such as gyroscopes, sensors, high speed modulators, polarization control devices require precise control of the polarization state of the guided light. Guiding of only one polarization is regarded desireable for most of these devices and essential for some applications. To date, several approaches have been reported to achieve polarizing waveguides on $LiNbO_3$. These include metallic overlays [1], proton exchange [2], proton exchanged portions on Ti indiffused waveguides [3], TE/TM splitters [4], Zn diffused waveguides [5]. Each of these methods has its own application specific advantages as well as limitations. Metallic overlays include propagation loss. Proton exchange (PE) method is the industry standart for integrated polarizers with PER values exceeding 40 dB. The technique suffers from lowering of electrooptic coefficient and high propagation losses, both of which can be restored by annealing processes. However, the two-step nature of the PE followed by annealing process increases complexity. In addition, the process is susceptible to high temperature treatments (for example dielectric coating deposition), since the process of PE and post exchange anneal is performed at relatively low process temperatures. In contrast, formation of waveguides by Ti indiffusion technique takes place at much higher temperatures, and final refractive index distribution is accomplished in a single step. Titanium indiffusion method is considered advantageous and employed in a wide range of commercial devices. Therefore, a method of fabricating highly polarizing waveguides compatible with the Titanium indiffusion technology is desireable. In the past, simulations of TE/TM splitters based on mode anisotropy were studied. In the literature, there exists only one report describing the fabrication of polarizing waveguides with PER >33 dB via Ti indiffusion [6]. In this paper, we report our results on polarizing waveguides fabricated on x-cut y-propagating LiNbO3 by Ti indiffusion technique. The effect of several fabrication parameters, such as the diffusion temperature, diffusion time, diffusion atmosphere, pre-diffusion Ti-strip width, and Ti thickness are investigated with emphasis on the polarizing properties of the fabricated waveguides. By optimization of fabrication parameters, polarizing Ti indiffused waveguides with polarization extinction coefficient (PER) higher than 47 dB at their outputs at 1550 nm operating wavelength are demonstrated. The polarizing capability of the Ti indiffused waveguides is attributed to refractive index anisotropy resulting in different respective propagation loss for the fundamental TE/TM modes.

2. METHOD AND DESIGN

To understand the waveguiding and anisotropy-based polarization properties of the waveguides, simulations were performed using diffusion model for the refractive index increment and beam propagation method for the mode confinement. The increment of the refractive index was evaluated as a function of the four process parameters: Titanium waveguide strip width, Titanium coating thickness, diffusion temperature and diffusion duration. To achieve highly polarizing waveguides, the parameter space spanned by the four process parameters was investigated in search for the maximum mode confinement anisotropy between the TE and TM modes. It was found that the refractive index anisotropy was highest when metal thickness was 70 nm, strip width was 7 µm, diffusion temperature was 1010 °C, and the diffusion duration was 9 hours. Planar waveguides (strip thickness very large) were fabricated and used to measure the refractive index change for both the TE and TM polarizations. Effective mode indices were measured using the prism coupling technique, and these indices were in turn used to calculate the refractive index change. Figure 1 shows the calculated refractive index change for planar Ti indiffused waveguides for both the TE and TM polarizations. It was observed that, the refractive index change near the surface was twice as large for the TE polarization indicating much better confinement for the fundamental TE waveguide mode. Next, strip waveguides using the same process parameters were fabricated and characterized.

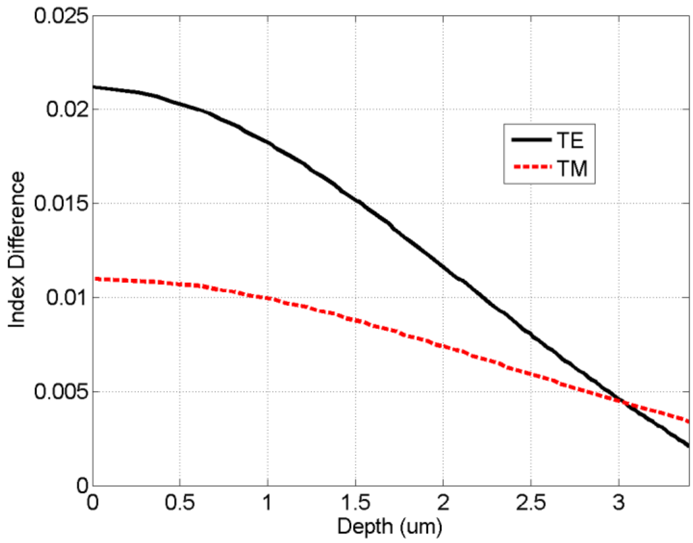

Figure 1. Refractive index change as a function of depth for the TE and TM polarizations measured by prism coupling technique utilizing planar waveguides.

3. WAVEGUIDE FABRICATION

X-cut $LiNbO_3$ samples were prepared by Ti coating in an e-beam evaporator. Metal waveguide strips aligned to the crystallographic y-axis were defined by photolithographic patterning. Titanium in unprotected areas was etched away in an $HF:H_2O_2$ mixture. The samples were heated to temperatures in the range 950°C-1050 °C range for a time around 7 to 11 hours. Diffusions were performed in a multiple heating zone furnace under controlled argon and oxygen flow to prevent lithium outdiffusion. Process parameter variations in waveguide width (6 to 10 µm), diffusion temperature, duration and Ti thickness (60 to 80 nm) were investigated in order to observe the critical effects on throughput and guiding characteristics for the two polarizations. Different combinations of process parameters were experimented with and the resulting waveguides were measured following dicing and edge polishing of the samples.

4. WAVEGUIDE CHARACTERIZATION

The resulting 3 cm long waveguides were measured in a setup that utilizes unpolarized light as input to the waveguides. Light that has propagated through the chip was collected by a microscope objective and the power of the two orthogonal polarizations were measured and the PER was calculated. It was observed that PER values as high as 47 dB were achieved when all four process parameters were optimized (Ti thickness: 70 nm, waveguide strip width: 7 µm, diffusion temperature:1010 °C and diffusion duration: 9 hours). Figure 2 shows the measured PER values for four different values of the diffusion duration when the other three parameters are at their optimum values.

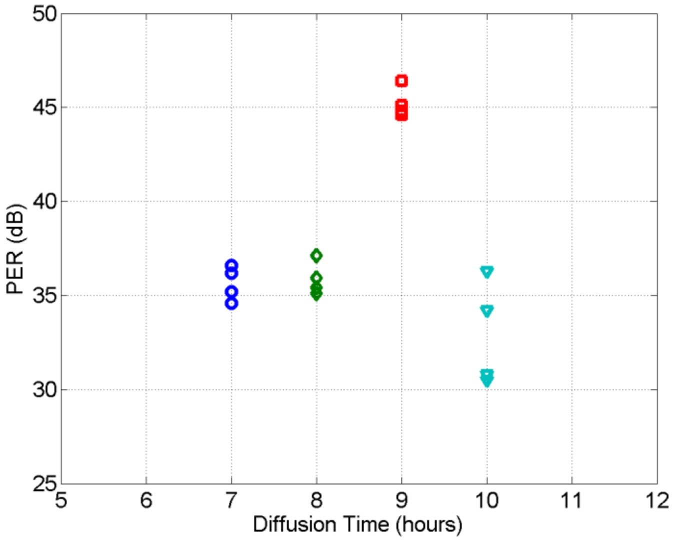

Figure 2. Variation of measured PER for four different diffusion durations.

5. RESULTS AND CONCLUSION

Polarizing Ti indiffused waveguides with polarization extinction coefficient (PER) as high as 47 dB at their outputs at 1550 nm operating wavelength were demonstrated. By changing the four diffusion parameters (Ti thickness, waveguide strip width, diffusion temperature, diffusion duration), it is possible to get high polarization extinction ratio (PER) polarizing waveguides. This shows that titanium diffusion method is a proper alternative to Annealed Proton Exchange (APE) method for obtaining high PER.

6. REFERENCES

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