論文2000-37TE-3-1

Fabrication of Coupled Optical Modulator By using Self -Aligned Thin film Electrodes

(자기정렬 박막전극을 이용한 결합형 광 변조기 제작)

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(Ki-Sung Kang and Jae-Sung Roh)

Abstract

A waveguide of coupled optical modulator was fabricated on $LiNbO_3$ based on proton exchange with self-aligned thin film electrode method. The electrode pattern was designed using a self-aligned method. After proton exchange process, the waveguide was prepared by annealing process. The initial crossover state of the fabricated 2×2 coupled optical modulator was observed with controlling the annealing process variables and the structure of self-aligned thin film electrodes. It was shown form the present work that the measured crosstalk is -29.5[dB] and 8.0[V] of detected modulating voltage.

I. Introduction

Invention of semiconductor laser and development of optical electronic engineering leads to taking advantage of laser light source instead of electricity. In order to transfer optical signal is conversion electrical signal from optical signal using photo diode and the method going steps of optical signal utilized laser diode and of switching employ profitable of optical switch. For to make Integrated optics device put material electro optic coefficient to good use represented efficiency about electrical field of optical waveguides, $LiNbO_3$ uniaxial. Ferroelectric crystal is satisfied this item and fited to make clause optical wave is low guided loss to make single mode optical waveguide on $LiNbO_3$ substrate and approve electrical field through electrode to electrode-optic effect can give change to refractive index of electrode waveguide. Optical modulator make good use of this refractive index alteration input power let it modulation or switching go like this basic several types. It is proceeding actively to research about intergrated optics utilized concept of guided-wave for supplying the light signal source[1]. Research and development of coherent optical fiber communication systems have been accelerated because of the possibility of receiver sensitively improvement reaching 25dB and the possibility of frequency division multiplex (FDM).However, the practical applications of the systems have been almost given up mainly because of the poor spectral purity and frequency stability of semiconductor lasers, and because of the system complexity. In this study, we device new methods to overcome the limiting factors for coherent optical communications. In this paper,

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接受日字:2000年4月4日, 수정완료일:2000年9月16日

Coupled optical modulator having several input and output ports to take light signal and transport of it; fabricated using of self-aligned method. Coupled optical modulator coupler operates based on the switching phenomenon of optical power between two close by channels of optical waveguide[2]. It is using forward giving and taking optical power between closing two channels of optical waveguide. When input light source applied in input port of Coupled optical modulator, the measured of switching voltage, crosstalk, modulation rate ; analyzed for character of Coupled optical modulator.

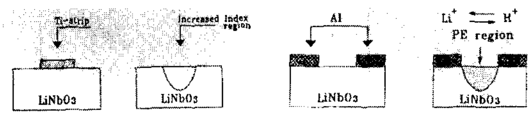
Ⅱ. Experimental Procedure

1. Patterning of guided-wave

The fabrication of Coupled optical modulator is the method for making a little low optical waveguide in the guided wave inner for control of refractive index problem the most important in fabricated condition optical modulator[3]. The refractive index was decided through the annealing process of the substrate with flowing enough quantity of oxygen into 400[℃], 60[min] for deep diffusion of exchange proton(H+) 200[℃], 60[min] on surface. The typical fabricating method of waveguided are illustrated : Ti-indiffusion method and Proton exchange method (Fig. 1)[4]. As the method to make optical waveguide little loss by increased refractive index on substrate $LiNbO_3$ can offer representative on behalf of processing proton exchange and Ti-indiffusion. The process of Ti-indiffusion penetrate into toward depth by diffusion let it surface diffusion for hours in high temperature after lifting up with film form Ti part make optical waveguide. After that refractive index become increasing and optical waveguide following trace, Ti thick and width in diffusion time and temperature and towarding part let it diffusion. The process of proton exchange make with metal mask to be opened only intending to make part on substrate $LiNbO_3$. And than Li+ ion of $LiNbO_3$ and acid or hydrate met become to stir up. It's applied heat to them H^+ ion supplied from Li^+ ion of $LiNbO_3$ and acid or hydrate met which must be grown surface refractive index got produced reactively into acid or hydrate met $LiNbO_3$ on substrate.

Chemical reactive equation of proton exchange goes like this.

$$LiNbO_3 + xH^+ \text{ ------ } Li_{1-x} H_x NbO_3 + xLi^+$$

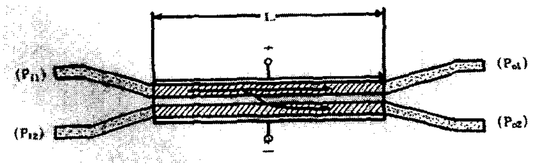


(a) Ti-indiffusion (b) Proton exchange
Ti:100[Å],Width:6[μm] Al:2000[Å],waveguide:6[μm]

Fig. 1. Method of Ti-indiffusion and Proton exchange.

2. Patterning of electrode

As shown in the Fig. 2, the mask of proton exchanges for patterning optical wave guide[5]. The self-aligned electrode structure is fabricated on 2×2 Coupled optical modulator without using aligner[6],[7]. To fabrication Coupled optical modulator having input and output ports to the waveguides made 6[μm] [8],[9].



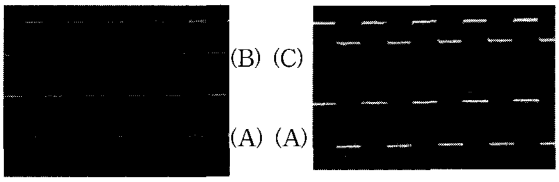
L: electrode(4[mm])

Fig. 2. Structure of Coupled optical modulator using self-aligned method.

Ⅲ. Results and Discussion

1. Output characteristics

For measuring the optical modulation phenomenon of the fabricated Coupled optical modulator, the modulated output power were obtained from the output ports of channels W1[Fig. 3(a) and W2(output)] by applying 8.0[V] of square wave to the electrodes, after irradiating the incident light form light source (He-Ne Laser λ=0.6328[μm]) into the input ports of channels [Fig. 3(a) and (b)]. The length of coupling area is like with transfer length the reason of becoming maximum after input power transfer in cross-overstate when input voltage of certain degree without maximum optical power transfer in cross-over state when input voltage 0[V] becoming is because of existing phase mismatch between optical two waveguide at the beginning switch area and transfer length. Fig. 4 shows the magnification of Fig. 3(a) from input 8[V] to 500[μs/div] for measuring the crosstalk [-29.5 db] of the remain output power of W1 at cross-over state, when the input light was irradiated to W1. Fig. 5 is the modulator situation appeared by optical power from 2 ×2 driving 8.0[V] square wave input voltage of frequency can appear with variation of optical power of optical output 2×2 counted with theory controlled from 100[KHz] to 400[MHz]. Fig. 6 show in measurement system. In generally, electrode of optical transfer modulator become to make aligning in suitable position by perfect fabricating optical waveguide. In this case is difficult to make in correct points of the width of μm and tens of the length of mm by this simulation the efficiency of electric field experiment to proton exchange without aligned working become repeated using Al. Electrode fabricated with self-aligned because become closing up maximum with optical waveguide will appear very high in considering. To apply Mach Zender interferometric modulator to X-switch type modulator or directional couples by forming electrode by method self aligned will obtain very big effect with the method of going down crosstalk. Also to confirm the process of forming of optical waveguided by proton exchange is sure surface single optical waveguided, photo surface of single optical waveguide. It is having phase mismatch causing difference of width of optical waveguide error by annealing. We know the truth of variation with multi mode in single mode by variation width of optical wave guide by annealing time. The control of optical waveguided by annealing become good comparably temperature control in furnace of exist present time by correctly temperature when it put into and pull out sample is as like difficult correct time control isn,t fixed time.

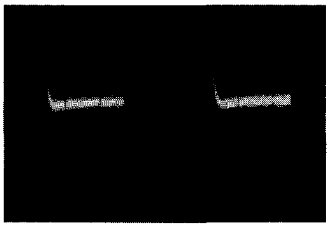


(A) Input(W1) (B) Output(W2) (C) Output(W1)
time/div : 500[μs/div], input : 8[V]

(a) Switching power W2 at input waveguide(W1)

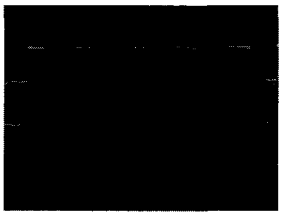
(b) Output power W2 at input waveguide(W1)

Fig. 3. Output Characteristics of optical waveguide with applied square wave.

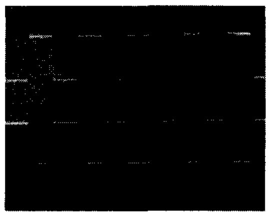


time/div : 100[μs/div]
input : 2V/div

Fig. 4. Enlarged photographs of crosstalk of input waveguide(W1).

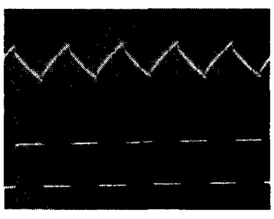


(a) 100[KHz]



(b) 500[KHz]

(c) 1[MHz]



(d) 100[MHz]

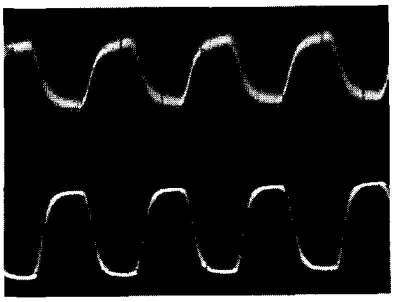


Fig. 5. Output characteristics of input waveguide (W1) to the applied frequency.
fre(time/div : 500[μs]),input : 5[V/div]

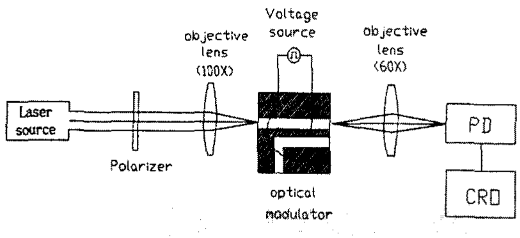


Fig. 6. Measurement system.

Table 1 was Shown in the results of measuring the characteristics of the 2×2 Coupled optical modulator light modulation on the conditions of Fig. 5. It gives the relationship among the optical output power(by photo detecter), the crosstalk at the cross-over state and the bar state of each channel (W_1 and W_2)

Table 1. Crosstalk and output voltage of electrode-optical modulator applied incident input light source at guided wave W_1.

classified	Volt/div	time base	Vp-p(input)	8[V]
A(input) : W_1	5.0[V]	500[μs]	Vp-p (W1)	Output: 3.5[V]
B(output): W_2	2.0[v]	500[μs]	Vp-p (W2)	Output: 3.9[mv]
C(output): W_1	5.0[mv]	500[μs]	Crosstalk	-29.5[dB]

Ⅳ. Conclusion

The 2×2 electro-optical coupler fabricated on $LiNbO_3$ can optimize the efficiency of electrodes and electric field. For using by electrode only necessary part of mask used for proton exchange made self-aligned method. In this study, the following results were obtained from the analysis of the measured optical output power of waveguides after applying the input light to the wave guide of the 2×2 coupled optical modulator.

1) The input light applied to W1 of the waveguide and the drive voltage to the electrodes, We obtained 3.5[V] of W1, 3.9[mv] of W2, and -29.5[dB] of crosstalk.
2) The modulation phenomenon was obtained proton exchange 200[℃], 60[min], annealing time 400[℃], 60[min], respectively.

The performance of the proposed coupled optical modulator was very superior to that of reported. It was concluded that a stable condition and the accurate annealing time of the process of the waveguide are necessary for making a device with less crosstalk and better modulation voltage.

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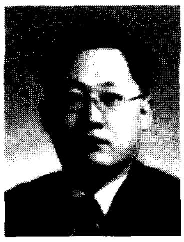

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