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Ni-Diffused Lithium Niobate Wide-Angle Y-Branch Waveguide with Proton-Exchanged Microprisms

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Abstract – A novel Ni-diffused Y-branch waveguide on $LiNbO_3$ using proton-exchanged microprism is presented. Experimental results show that the normalized transmitted power is 42% for a branching angle of 20°.

I. Introduction

Y-branch waveguides are key components widely used in many devices such as Mach-Zehnder modulators. Unfortunately, its branching angle is usually kept small to have a loss within an acceptable range. It is then important to fabricate a low-loss wide-angle Y-branch waveguide in order to reduce the device area for a higher packing density on a substrate.

Recently, a wide-angle low-loss Y-branch waveguide structure has been proposed [1]. In their design, a pair of microprisms with the same refractive index n_1 are used to compensate the phase mismatch caused by the branching area, and a microprism with a refractive index n_2 ($n_1 > n_2$) is set to push the leakage optical power into the branching waveguides. Though the design is good, the device is too complicated to be realized because microprisms of two different indexes are involved. To simplify the fabrication process, we let the lower refractive index n_2 equal to the substrate refractive index n_s as shown in Fig.1. Our proposed Y-branch waveguide structure has a pair of microprisms of the same index n_p and a pair of cutting angles in the vicinity of the branching area. By means of a simple phase compensation rule, formulas for n_p can be systematically derived as given by

$$n_p = n_s + n_{eff} \cdot \frac{W_{eff}}{(W_p - W_{eff})} \cdot \left\{ \frac{\sin^2(\theta/2) + m}{\cos(\theta/2) \cdot [1 - \cos(\theta/2) + m]} \right\} \qquad (1)$$

where

$$m = (W_{eff} / W_p) \cdot \cos^2(\theta/2) \qquad (2)$$

θ is the half branching angle, n_{eff} is the effective refractive index of the straight waveguide, W_g is the waveguide width, W_{eff} is the effective width of the waveguide, W_p is a design parameter of the microprisms.

II. Fabrication and Measurement

The Y-branch waveguide is fabricated on a z-cut, x-propagating $LiNbO_3$ substrate. Fig.2 illustrates the fabrication process [2]. First, a silicon film of thickness 4000Å for the microprisms is deposited on the $LiNbO_3$ substrate, as shown in Fig.2 (a). In order to form the Ni-diffused waveguide, a nickel strip of width 4μm and thickness 300 Å is deposited. Note that the nickel strip is placed on top of the silicon film as shown in Fig.2 (b). Thus, during the diffusion at 850°C for 30 min, no nickel ions enter into the microprism region of the substrate. Then, a 600Å Cr and a 600Å Au film are sequentially deposited as the proton-exchange (PE) mask, as shown in Fig.2(c). When the substrate is put into a solution of buffered oxide etch, the silicon film is etched away and the metal films on top of it are removed to reveal a groove of microprism shape, as shown in Fig.2 (d). To form the PE microprism, the substrate is immersed in a benzoic acid at 240°C for 4 h. After the PE process, the remaining metal film is removed. as shown in Fig.2 (e), which is the overall structure.

Y-branch waveguide of θ = 8° and 10° with and without microprisms are fabricated for comparison. Fig.3 shows the Y-branch before Ni diffusion. The loss measurement is made at the wavelength 0.6328μm using a chopped beam and a lock-in detection to filter out the background light. Fig.4 shows the detected optical field contours. The normalized transmitted power is calculated by referring to the transmitted power of a straight waveguide. The experimental results show that the normalized transmitted power of the Y-branch waveguides without microprisms are less than 1%. However, for the Y-branch waveguides with microprisms, the normalized transmitted powers become 51% and 42% for θ= 8° and 10°, respectively.

III. Conclusion

A novel wide-angle low-loss Y-branch waveguide in $LiNbO_3$ is successfully fabricated. The measured normalized transmitted power is greater than 40% even at a branching angle of 20°, which is believe to be the best result reported so far. Further application of the Y-branch in the fabrication of waveguide devices such as

Mach-Zehnder interferometer, etc. will be of great interest in the future. This work is supported by National Science Council, Taipei, Taiwan, ROC under contract No. NSC89-2215-E-002-009.

References

[1] J. M. Hsu and C. T. Lee, *IEEE J. Quantum Electron.*, vol. 34, no. 4, pp. 673-679, Apr. 1998.

[2] T. J. Wang and W. S. Wang, *IEEE J. Select. Topics Quantum Electron.*, vol. 6, no. 1, pp. 94-100, Jan. 2000.

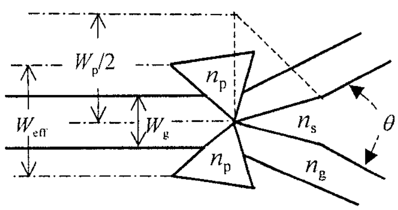
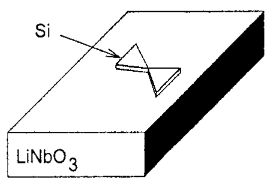
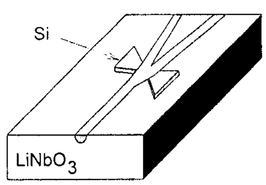


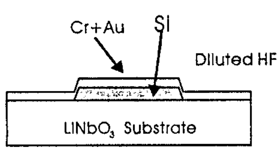
Fig.1 The proposed Y-branch structure



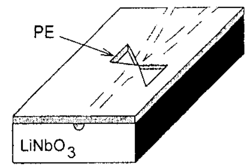
(a) Silicon microprism deposition



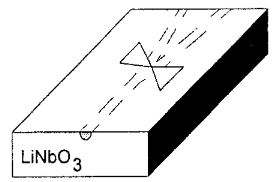
(b) Nickel strip deposition



(c) PE mask deposition



(d) Prism groove etching



(e) Final structure

Fig.2 Fabrication process

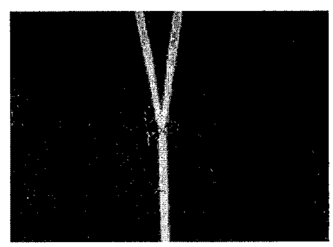


Fig.3 Y-branch before Ni-diffusion (2θ=20°)

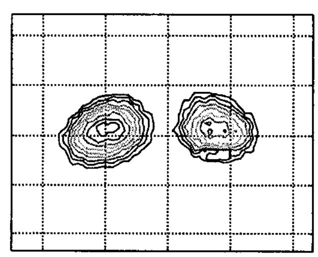


Fig.4 Optical field contours (2θ=20°)