Mach-Zehnder Interferometer Optical Switch Using Low-loss N-doped GeTe Thin Film

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ABSTRACT

The self-holding, small Mach-Zehnder interferometer (MZI) optical switch using N-doped GeTe, was proposed. N-doped GeTe thin films with various doping concentration were prepared by sputtering and refractive indices were measured. The switching characteristics of the 2×2 MZI optical switch using N-doped GeTe were simulated. It was shown that the transmission losses could be less than 1 dB for both cross and bar operation, and the crosstalks could be less than -21 dB.
Key words: N-doped GeTe, MZI optical switch

1. INTRODUCTION

We had proposed the MZI optical switch using undoped GeTe [1], and demonstrated switching operation of the optical gate using $Ge_2Sb_2Te_5$ and Si wire waveguides [2].

They have self-holding characteristics; therefore, low-power consumption can be achieved. Moreover, the size of the switch using phase change material (PCM) can be very small because the refractive index changes largely. In order to improve the switching characteristics, it is effective to decrease the absorption of PCM. In this paper, N-doped GeTe thin films with various concentrations were fabricated and their characteristics were measured. The switching operation of the 2×2 MZI optical switch using the N-doped GeTe was simulated.

2. N-doped GeTe

-The N-doped GeTe thin films [3] on Si substrate were prepared by reactive sputtering of a GeTe target using the Ar/N_2 gas mixture. The compositions were varied by changing the Ar/N_2 ratio. We changed the Ar/N_2 ratio, 10/0, 9.5/0.5, 9.3/0.7, 9.0/1.0, 8.5/1.5.

-The complex refractive indices for amorphous state and crystal state at a wavelength of 1550 nm are shown in Table 1. When N_2 concentration in the gas was more than 10%, the absorption of the N-doped GeTe was much smaller than that of undoped GeTe.

-We annealed the N-doped GeTe thin film with an Ar/N_2 ratio of 9.0/1.0 by 315 ℃ and it turned into the crystalline state. We could perform the amorphization and the recrystallization of the annealed sample by the laser radiation (Figure 1). The wavelength and the spot size of the laser are 660 nm and 1 μm respectively. When performing the amorphization, the width and the power of that were 70 ns and 180 mW respectively. When doing the crystallization, they were 400 ns and 80 mW respectively.

3. Mach-Zehnder Interferometer Optical Switch

-Figure 2 shows the schematic illustration of the optical switch. The width and the height of a silicon waveguide were 450 nm and 210 nm respectively. The width, the thickness and the length of the N-doped GeTe thin film were 450 nm, 50 nm and 6.5 μm, respectively. In the switching simulation, the N-doped GeTe thin film on one of the arms was switched between the amorphous state and the crystalline state while that on another arm was maintained in the amorphous state. The N-doped GeTe film fabricated with an Ar/N_2 ratio of 9.0/1.0 was used for calculation. The input light was divided equally into the two arms by the 3-dB directional coupler. When the N-doped GeTe thin films on both arms were in the amorphous state, the light was guided to the cross port (the cross operation); and when one of the films was in the crystalline state, the light was guided to the bar port (the bar operation).

Table 2 shows the transmission losses from the input port to the bar port and to the cross port for the cross operation and the bar operation. The transmission losses were less than 1 dB for both

operations; and the crosstalks were less than -21 dB. Compared to the previous report [1], both the transmission losses and the crosstalks were reduced because of the decrease in the absorption of PCM.

4. CONCLUSION

The N-doped GeTe thin films with various doping concentrations were fabricated. When the N_2 concentration in the gas was more than 10%, the absorption of the N-doped GeTe was much smaller than that of undoped GeTe. In the switching simulation, we could obtain less than 1 dB transmission losses for both operations, with crosstalk of less than -21 dB.

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Table 1 Complex indices of refraction at a wavelength of 1550 nm.

Ar/N_2 ratio	Amorphous	Crystal
10/0	4.02-0.09*i*	5.45-0.14*i*
9.5/0.5	3.79-0.14*i*	5.24-0.47*i*
9.3/0.7	3.60-0.01*i*	4.67-0.27*i*
9.0/1.0	3.39-0.00*i*	4.06-0.04*i*
8.5/1.5	3.25-0.00*i*	3.79-0.02*i*

Table 2 Transmission losses to the bar port and to the cross port.

	Bar port	Cross port
Cross operation	23.01dB	0.01dB
Bar operation	0.97dB	22.22dB

Figure 1 Microscopic photos of the N-doped GeTe thin film; (a) amorphous mark, and (b) erased mark by the crystallization

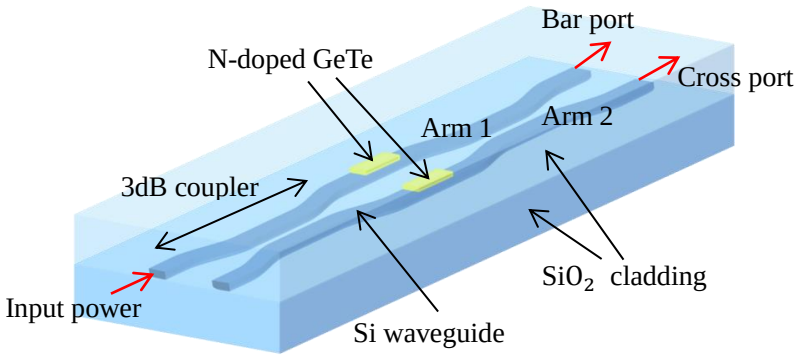

Figure 2 Schematic illustration of switch