Optical Gate Switch Using Phase-Change Material and Si Wire Waveguide

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ABSTRACT

The optical gate switch using phase-change material (PCM) and Si wire waveguide was reported. We successfully demonstrated switching by laser pulse irradiation. The wavelength of laser pulses was 660 nm. We used a laser pulse with a width of 400 ns and a peak power of 15 mW for crystallization, and a laser pulse with a width of 12 ns and a peak power of 70 mW for amorphization. 'ON' to 'OFF' to 'ON' switching with an averaged extinction ratio of around 7 dB was observed seven times at the wavelength of 1550 nm.

Key words: Optical switch, Phase-change material, Optical circuit, Si wire waveguide

INTRODUCTION

The optical switch using phase-change material (PCM) is suitable for flexible and large capacity network. In past, we proposed and fabricated the optical switch using PCM [1-5]. This switch is compact, fast, and low power consumption. It can be very small because PCM has large difference in complex refractive index between the amorphous and crystalline states. Moreover, it has switching time of only 20-400 ns and the self-holding characteristics. In this paper, we demonstrated switching of the optical gate using PCM and Si wire waveguide.

STRUCTURE OF THE OPTICAL GATE SWITCH

Fig. 1 depicts the structure of the optical gate switch using PCM. We used $Ge_2Sb_2Te_5$ (GST225) as PCM. The complex refractive indices of GST225 were $4.4 + 0.098i$ for the amorphous state and $7.1 + 0.78i$ for the crystalline state at the wavelength of 1550 nm, respectively. This switch had a 25-nm-thick GST225 layer on Si wire waveguide with a cross section of 450 x 190 nm^2. A 50-nm-thick ZnS-SiO_2 passivation layer was also deposited on PCM. On the other hand, the input/output Si wire waveguides with the cross section of 450 x 210 nm^2 were covered with thick (~2 μm) SiO_2 over cladding. The length of switching region was only 5 μm. The scanning electron microscopy (SEM) image of this switch was shown in Fig. 2.

EXPERIMENTAL

We changed the state of GST225 by laser pulse irradiation. The experimental setup is shown in Fig.

3. The electric pulse from the pulse generator (PG) directly modulated the laser diode (LD). Fig. 4 shows the electric pulse waveforms from PG. We used a pulse with a width of 400 ns and a peak power of 15 mW for crystallization, and a pulse with a width of 12 ns and a peak power of 70 mW for amorphization. The optical pulse from LD with the lasing wavelength of 660 nm was focused by lens on GST225 layer. The spot diameter was about 1 μm.

The transmission characteristics of the switch were measured with continuous wave emitted from a tunable LD with a wavelength of around 1550 nm. This input light was coupled to the Si waveguide with focusing lens. The output light from the Si waveguide was also collected by the same lens. The initial state of the as-deposited GST225 layer was considered to be “amorphous”. Thus the crystallizing pulse was irradiated on to the gate region at first (‘ON’ to ‘OFF’ switching). After that, the amorphizing pulse was irradiated (‘OFF’ to ‘ON’ switching). We repeated these actions and measured the transmittance by the power meter. The change of the output power as laser pulse irradiations is shown in Fig. 5. The output power included the coupling loss occurred in the waveguide facets. After 9 irradiations, quasi-stable switching with an averaged extinction of 7 dB was successfully observed 7 times. The output power was dropped by the crystallizing pulse and recovered by the amorphizing pulse. We can see that the output power decreased gradually. It resulted from the spread of the crystalline region. The spot of the crystallizing pulse was somewhat large as compared with that of the amorphizing pulse. The loss due to the unnecessary crystallization will be improved by using the optical pulse with flat-top profile.

CONCLUSION

We fabricated the optical gate switch using PCM ($Ge_2Sb_2Te_5$) and Si wire waveguide. 'ON' to 'OFF' to 'ON' switching operation with an averaged extinction ratio of around 7 dB was successfully observed seven times.

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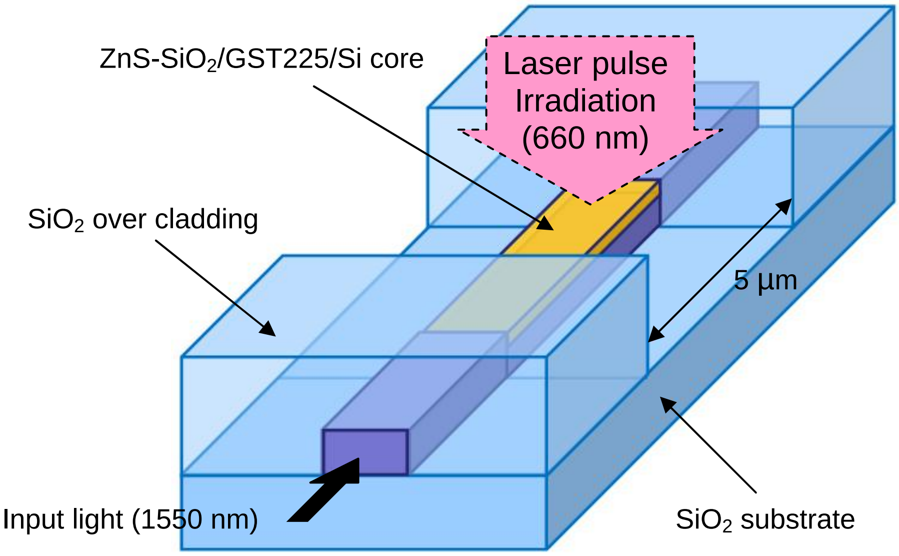

Fig. 1. Structure of the optical gate switch.

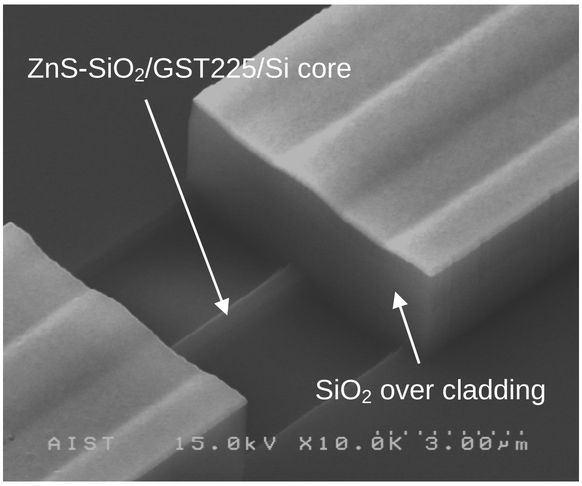

Fig. 2. SEM image of the optical gate switch.

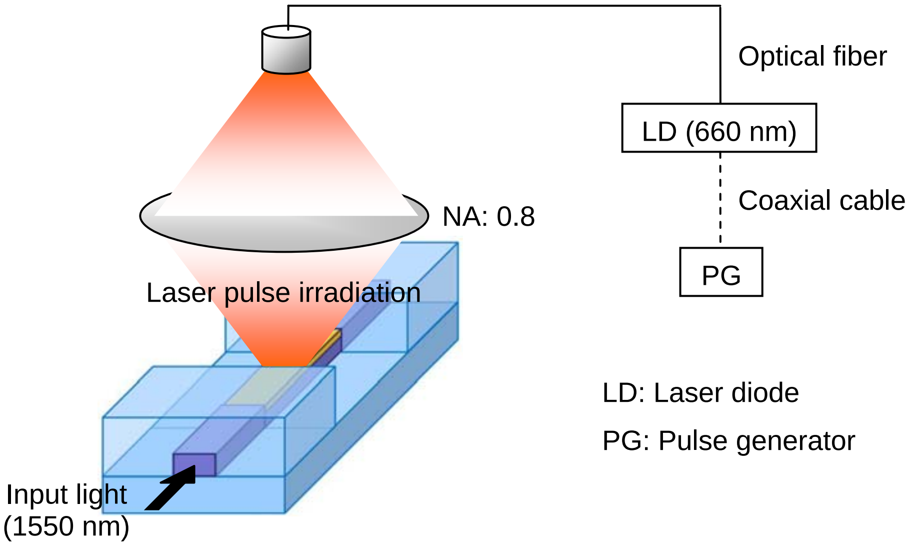

Fig. 3. Experimental setup for laser pulse irradiation.

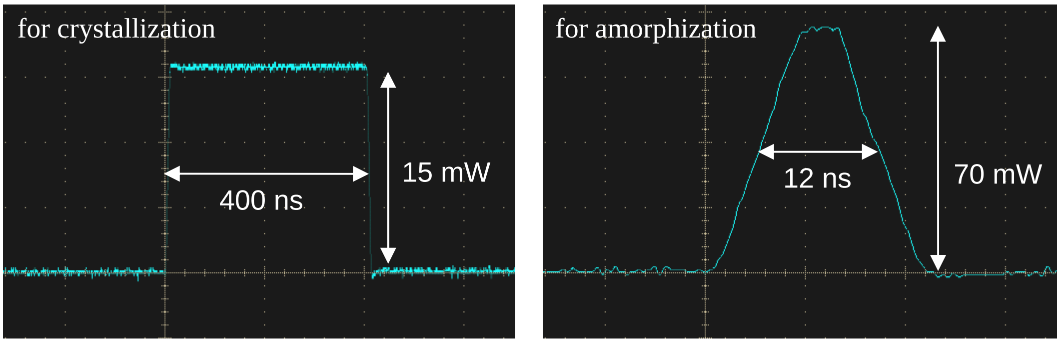

Fig. 4. Electric pulse waveforms from PG (a) for crystallization and (b) for amorphization.

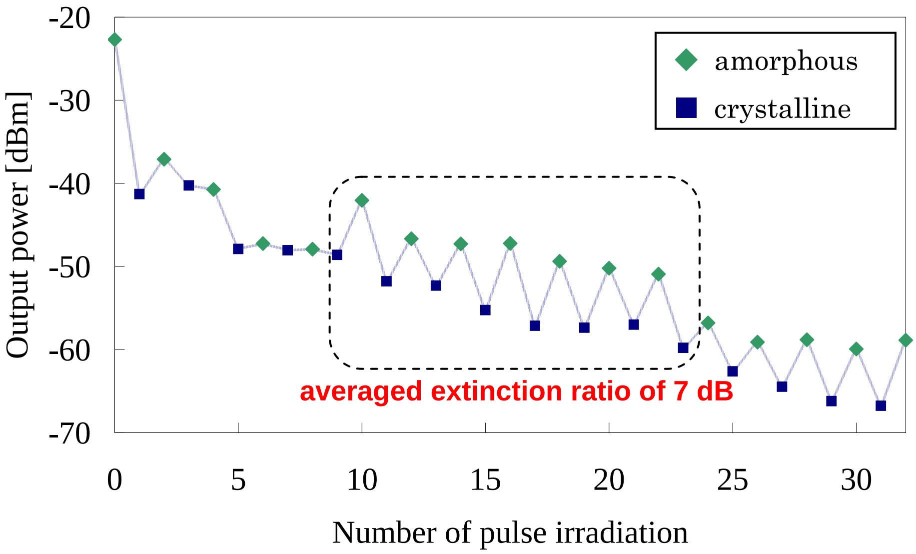

Fig. 5. Change of output power as laser pulse irradiations.