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Optical Waveguiding and Electro-Optic Modulation in Ion Implanted CdTe

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CdTe is one of the most hopeful crystals for optical integrated circuits in II-VI compound semiconductors. It has a high electro-optic coefficient and an ability to obtain a p-n junction diode. H^+ ion implantation into low-resistive CdTe can efficiently remove the free carriers from a thin surface layer. Optical waveguides could be fabricated in this manner [1]. H^+ ion implantation is the advantageous technique for the control of thickness and uniformity. It is interesting to investigate the influence of the heat treatment to the properties of waveguides.

We have fabricated optical waveguides by H^+ ion implantation into CdTe, and found that the optical confined modes existed even after the 600 °C heat treatment. The electro-optic coefficient of the sample has also been examined.

Chemically polished (001)-oriented $7.8 \times 10^{17}/cm^3$ n-type CdTe wafers were ion-implanted at 1 MeV with a dose of 1×10^{15} protons $/cm^2$at room temperature.

Figure 1 shows an experimental arrangement. A He-Ne laser beam at 1.15 μm is focused by an objective lens on the cleaved (110) surface of the sample. The light intensity distribution in the output face is magnified by an objective lens and memorized in a wave-memory by using the rotating mirror and a PbS detector with a fine slit.

The light intensity distribution of the as-implanted sample is shown in Fig.2-(1). Both TE_0 and TM_0 modes are excited . A thickness of the waveguide is calculated to be about 13.5 μm from proton range [2] and it is also considered to be about 13 μm from Fig.2-(1). The sample was annealed at 600 °C in Cd vapor for 10 min. The vapor pressure was maintained at 10 mm Hg to revent from dissociation of CdTe. The light intensity distribution of the annealed sample is shown in Fig.2-(2). The existance of confined modes is evident. This result indicates that the ion-implanted waveguide is stable even after the heat treatment at 600 °C.

An electro-optic modulator was fabricated by evaporating a gold electrode on an ion-implanted layer and an indium electrode on a substrate. A sample was placed between crossed polarizers and measuring the transmittance as a function of the applied forward voltage. Figure 3 shows the experimental results. The solid line is a theoretical plot of the modulation equation

$$I/I_0 = \sin^2\left(\frac{\pi}{2}\,\frac{V+3.6}{217}\right).$$

Using γ_{41}=2.24 x 10^{-12} m/V [3)], n=2.792, η=1, λ=1.15 μm, d=13 μm and L=1.420 mm, the half-voltage of the guide is calculated as the following

$$V_{\frac{1}{2}} = \frac{\lambda}{\eta n^3 \gamma_{41}} \frac{d}{L} = 217 .$$

The 3.6 V offset is due to the small difference of the propagation constants between TE_0 and TM_0 modes. Below 15 V, the data are in fair agreement with a theoretical plot. This fact implies that the electro-optic coefficient of the ion-implanted region after annealing is the same value as that of a bulk CdTe.

Properties of optical waveguides and modulators fabricated by using LPE growth will also be presented.

References

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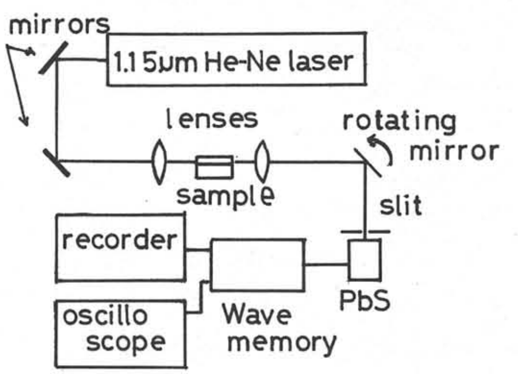

Fig.1. The experimental arrangement.

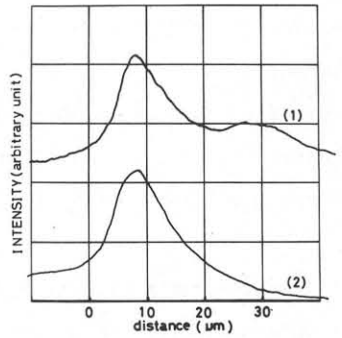

Fig.2. The light intensity distribution in the output face of
(1) the as-implanted sample,
(2) the sample after annealing at 600 °C.

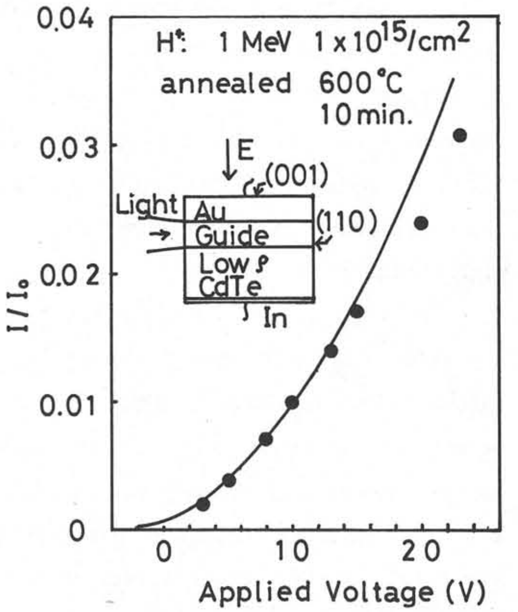

Fig.3. Transmittance of the waveguide, placed between crossed porizers, as a function of the applied-forward voltage.