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B—4—2 Thin Film Optical Circuit Fabrication Using CO_2 Laser

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CO_2 laser irradiation on SiO_2-Ta_2O_5 sputtered films has been found to cause refractive index decrease of the films.[1)2)] This paper reports fabrication of thin film optical circuits using the refractive index decrease phenomena.

SiO_2-Ta_2O_5 films, with 2.056 refractive index at 0.633μm wavelength, sputtered on Corning Vycor glass substrates, were used for the experiment. The Gaussian beam from cw CO_2 laser with 10.6μm wavelength was focused vertically onto the film. The relative scanning speed of the film to the irradiation beam was fixed at 500μm/sec. The refractive index profile of the irradiated track was measured by the prism-film coupler method at 0.633μm wavelength.[3)]

Figure 1 shows the irradiation power dependence of the index change for various irradiation beam radii. The refractive index change is obtained when beam power is larger than the threshold power which increase with an increase in irradiation beam radius. Maximum index change was -4×10^{-2} (2%). No film thickness dependence of the index change was observed within from 0.5 to 1.5μm thick. The irradiation leads to a film thickness increase in a few hundred Å, simultaneously with the index decrease.

The refractive index profile across the irradiated track is shown in Fig.2. The profile is expressed with good accuracy by a Gaussian distribution $n=n_0(1-\Delta e^{-\frac{2y^2}{\alpha^2}})$, where n_0, Δ, α, and y are film refractive index, maximum index change, index change width, and distance from track center, respectively, shown in Fig.3.

(Mirror) When the propagated light beam in the film is incident into the irradiated track at angle θ, as shown in Fig.3, the incident beam is reflected at angle θ. By solving the ray equation, θ is given by

$$\theta = \tan^{-1}\left\{\sqrt{2\Delta(e^{-2a^2/\alpha^2} - \frac{\Delta}{2}e^{-4a^2/\alpha^2})}/(1-\Delta e^{-2a^2/\alpha^2})\right\}, \quad (1)$$

where a is the minimum distance between light beam locus and track center. From Eq.(1), maximum angle θ_c is obtained with a=0:

$$\theta_c = \tan^{-1}\left\{\sqrt{\Delta(2-\Delta)}/(1-\Delta)\right\}. \quad (2)$$

(Branching Circuit) When a beam parallel to the track, whose width is sufficiently smaller than that of the index change, is incident into the track center, the beam is branched in two beams, as shown in Fig.4. Branching angle θ_b is given by 2 θ_c.

(Channel Waveguide) When the two closely positioned parallel tracks are formed, propagation light is confined in the region channeled by the two tracks. Figure 5 is a photograph of the light streak in the curved waveguide. Here, the width between the two tracks is 300μm and the bent radius is 10mm. Propagation loss for TE_0 mode was 1.9dB/cm in the curved section.

(Cross Waveguide) Figure 6 shows the two channel waveguides crossing each other at angle ϕ. When cross angle ϕ and maximum reflecting angle θ_c satisfy the relation $\pi-2\theta_c>\phi>2\theta_c$, guided light in waveguide 1 does not leak into waveguide 2.

Thus, the CO_2 laser irradiation technique is useful for fabricating thin film optical circuits, because they can be fabricated simply without complex processes.

References

(1) H.Terui and M.Kobayashi, Appl.Phys.Lett.32,666(1978).
(2) H.Terui and M.Kobayashi, Electro.Lett.15,79(1979).
(3) P.K.Tien and R.Ulrich, J.Opt.Soc.Am.60,1325(1970).

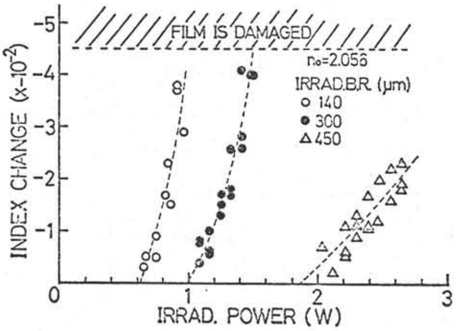

Fig.1 Irradiation power dependence of the index change

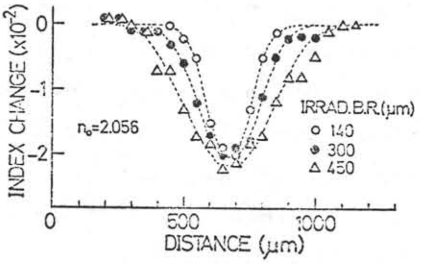

Fig.2 Index change profile of the irradiated track

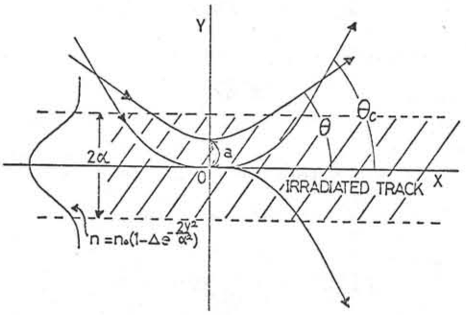

Fig.3 Guided light ray locus

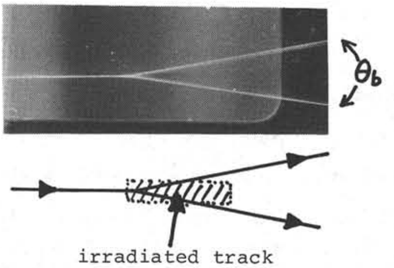

Fig.4 Branching circuit

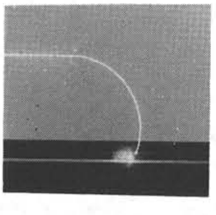

Fig.5 Bent channel waveguide

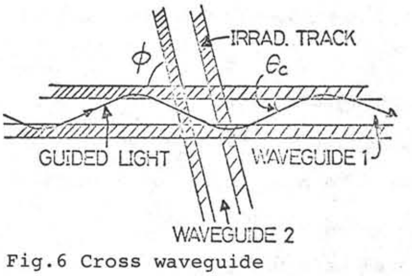

Fig.6 Cross waveguide