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PHOTOSTABILITY OF NONLINEAR OPTICAL COPOLYMER UNDER IRRADIATION WITH INFRARED LIGHT

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Abstract Nonlinear optical copolymer with 4-dimethylamino-4'-nitrostilbene as a side chain group was investigated for the photostability by irradiation of infrared light. The light at 1.313 μm, which is very low absorptive for the material, was coupled into the polymeric channel waveguide formed by photobleaching technique. Transmission loss of the infrared light through the channel waveguide has been negeligibly changed even after for a long irradiation. Also, the refractive index change in slab waveguide is undetectable. The nonlinear optical polymer used in this study turns out to be quite reliable in terms of photostability.

INTRODUCTION

Nonlinear optical polymer has emerged as an attractive material for important application, such as optical information processing, telecommunication and integrated optics[1,2]. This is attributed to the large nonlinearity, low dielectric constant and fast response time and so on. Nonlinear optical polymer waveguide devices such as electro-optic switches and modulators with a few tens of GHz bandwidth have already been demonstrated recently[3].

Since the devices for optical communication are dealt with infrared light at the wavelength of 1.3 and 1.55 μm, the effect of the infrared light on the waveguiding properties should be investigated even though the absorption of the infrared light is very weak compared to the ultraviolet and visible light. When the infrared light propagates through the channel waveguide, the light is confined in extremely small area so that the intensity becomes very high even though input power of the launched light is low. High intensity of the confined infrared light may cause damage in the waveguide so that the confinement of the light becomes poor[4]. This, in turn, results in the severe optical loss in the propagation of light and associates with poor

photostability of the device. Actually, it is known that the transmission of 1.3 μm with a few mW through the waveguide decreases by half of the initial power after the irradiation for a couple of days[5].

In this paper, the effects of very strong infrared light of 1.3 μm on the waveguiding properties formed by photobleaching technique in the nonlinear optical polymer are investigated.

EXPERIMENTAL

The stilbene derivative copolymer, of which chemical structure is shown in Figure 1, was obtained from Hoechst-Celanese Co., and used without any futher purification. The solution of the copolymer was formed into thin films by spin-coating on the silicon wafer which was already coated with UV curable epoxy-derivative polymer as a bottom cladding layer. The thicknesses of the active and the cladding layer are 4 μm and 6 μm, respectively. The spin-coated thin films were baked at 160 °C for a couple of hours to evaporate the residual solvent before using. There was no upper cladding layer for allowing the active layer to contact with oxygen in air.

The channel waveguide was formed by photobleaching technique using ultraviolet light. The mask was placed by contact with the polymer film for patterning the waveguide and 200W Xe lamp was used as a photobleaching source. The width of the channel in this study was 7 μm. Infrared light of 1.313 μm obtained from Nd:YLF laser(Quantronix) was coupled into the waveguide by butt coupling with optical fiber. The input power of the infrared light was above 2W. Transmission of the propagated light through the channel waveguide was measured with Ge-photodiode as a function of time. In order to monitor the laser power fluctuation, the intensty of the light splitted before coupling to the waveguide was measured as seen in Fig. 2. The refractive index change as a function of irradiation time were measured by prism coupling method[6] and the inverse WKB method[7]. In this case the infrared light of 1.3 μm generated from the laser diode was used for the measurement.

RESULTS AND DISCUSSION

According to the absorption spectrum in the near infrared region, the absorption at 1.3 μm is negligible compared to the absorption in visible region. However, 1.3 μm lies between C-H vibrational overtone and combination bands, hence strong intensity of the

infrared light might be a source of the waveguide attenuation[8]. Furthermore, the oxygen can be excited into singlet oxygen at 1.27 μm, which is able to react with the C=C bond in chromophore resulting in the photodegradation[4,9].

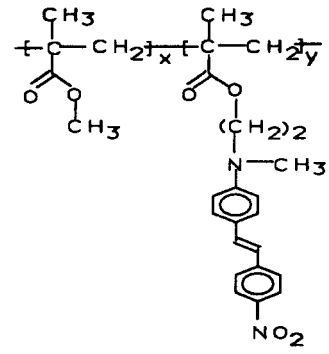

FIGURE 1 Chemical structure of the copolymer under this study.

In order to investigate the effect of the infrared light on the nonlinear optical copolymer, we confined the infrared light in the waveguide by coupling with optical fiber. The output power of the infrared light from the end of the optical fiber was about 3W, and the output power from the channel waveguide was about 3 mW after the butt coupling. This means that at least the intensity of 10 KW/cm^2 is confined in the waveguide. This amount is comparable to the confined intensity using typical laser diode with the power of a few mW. The large coupling loss is due to the large difference between the diameter of optical fiber and the cross sectional area of the channel waveguide. 24 hours irradiation gives total irradiated photon energy of 10^9 J/cm^2. It was reported that the waveguide was degraded by 3dB within an hour with the total irradiated photon energy of about 1.5X10^9 J/cm^2 under the assistance of oxygen[4]. The degradation of waveguide using infrared light was thought to be due to the reaction between singlet oxygen formed by excitation with infrared light and the C=C bond in chromophore[4]. The photon energy used in this experiment is comparable to the previously reported one. Therefore, this amount was also expected to be enough for degradation of the polymer. However, it is hard to observe any reduction of the transmission as manifested in Fig. 3. Transmission was changed at most less than -0.5dB. Here, the transmission loss is obtained by the ratio between the transmittance to the initial transmittance. The mode size from the waveguide has been changed negligibly.

The refractive index change was also measured to confirm the effect of strong infraed light on the polymer. The light from laser diode with the power of 2-3 mW was

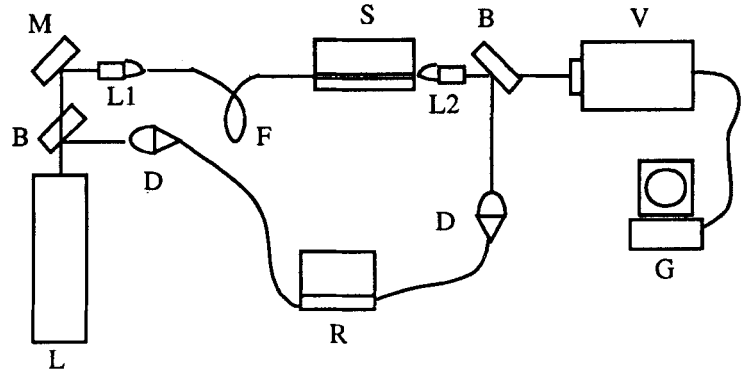

FIGURE 2 Experimental setup for the measurement of transmission through the waveguide of infrared light. L : Nd:YLF laser(1.313 μm), S : sample (waveguide), V : vidicon camera, F : optical fiber, D : Ge photodetector, L1,L2 : objective lens, R : X-t recorder, G : Frame grabber, M : Mirror, B : Beam splitter

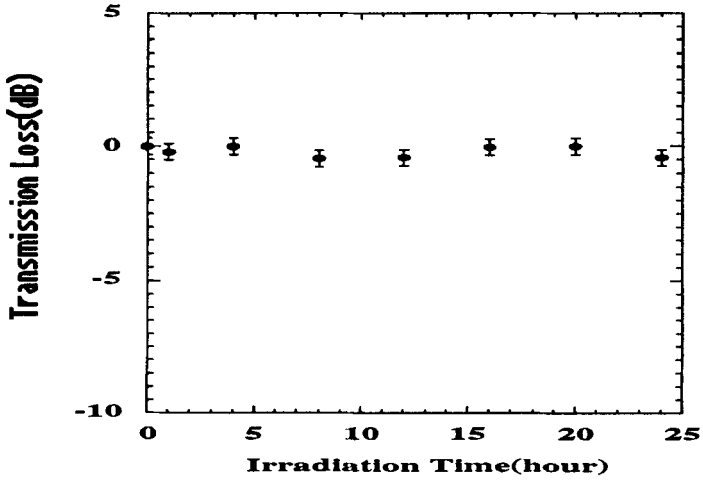

FIGURE 3 Transmission change after propagating through the channel waveguide as a function of irradation time of 1.313 μm light.

coupled into the polymer film through prism coupling technique and the film had been irradiated for a month. The size of coupling region was about 3mm diameter so that most of the light was coupled into the film except the amount due to the reflection from the prism. Fig. 4 shows the changes in refractive index as a function of irradiation time. The refractive index is only changed within experimental error.

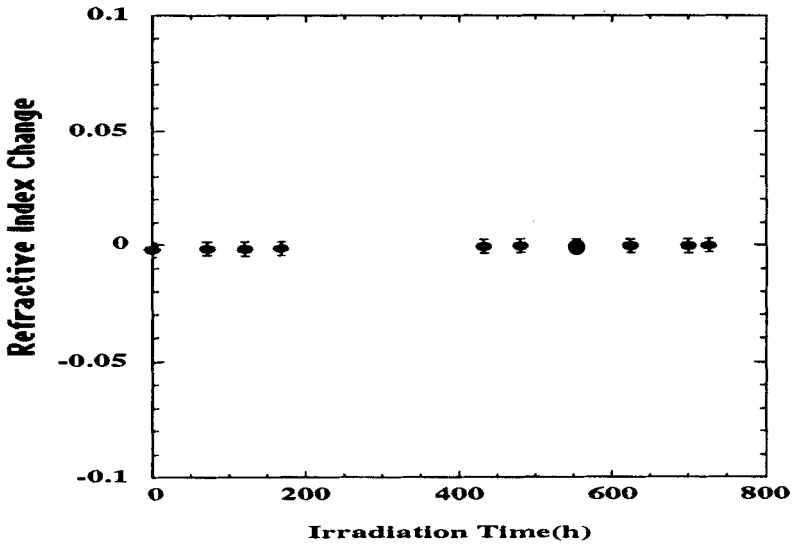

FIGURE 4 Refractive index change as function of irradiation time of infrared light of 1.3 μm with the power of 3 mW.

The reason why the degradation did not happen in this study in contrast to the previous report[4,5] may be thought as follows: i) there may be a stiff damage threshold and our total irradiational photon energy or intensity may be just below the threshold so that damage did not happen, ii) the different drying process may result in the different amount of residual oxygen in the polymer film so that the oxygen in our film is not enough to be a defect source. The oxygen in air can diffuse into the polymer film, but the diffusion depth is less than 100 Å[9]. Therefore, the contribution of oxygen in air to the degradation may be neglected. Finally, photoinduced damage process may be initiated with the accumulation of the photogenerated defect. The defect such as the photodegraded product or photosensitizing impurity formed with infrared light may not be generated with our light intensity.

CONCLUSION

Nonlinear optical copolymer with side chain group was investigated for the photostability by irradiation of infrared light. The change in the transmission of the propagated infrared light of 1.3 μm through the channel waveguide is hardly observable after long irradiation time. Also, the refractive index change in slab waveguide is also undetecable. The nonlinear optical polymer used in this study turns out to be quite reliable in terms of the photostability.

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