UV written waveguides using crosslinkable PMMA-based copolymers

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We report the first results on UV direct writing of waveguides in the poly(methylmethacrylate/2-methacryloylethylmethacrylate) copolymer system (P(MMA/MAOEMA)). The photosensitivity mechanisms in thermally crosslinked layers are investigated and used to write low loss (<1dB/cm) channel waveguides.

The expansion of high capacity optical transmission techniques into highly price-sensitive areas such as datacomms and access networks requires a major reduction in the cost of optical components. Furthermore, the complexity of fabrication of conventional glass and crystal materials is likely to prevent their use for the most cost sensitive applications. Polymer waveguides are potentially very simple to process and are promising for low cost devices[1,2].

In this paper we report UV written waveguides using novel crosslinkable polymers. The polymers used in this study have a number of attractive features, it is possible to control both their refractive index and photosensitivity through the monomer feed ratios. Unlike PMMA, the copolymers can be either thermally or UV crosslinked. This makes the system highly suitable for UV direct writing of waveguides, but has necessitated a thorough study of crosslinking in this material. In this work we report on the crosslinking studies and show with appropriate choice of conditions we can write low loss optical waveguides.

We have prepared copolymers of hydroxyethylmethacrylate (HEMA) and methylmethacrylate (MMA) and have introduced crosslinkable sites onto the hydroxyethyl side chains to afford poly(methylmethacrylate/2-methacryloyl ethylmethacrylate) (P(MMA/MAOEMA))[3] (Fig.1).

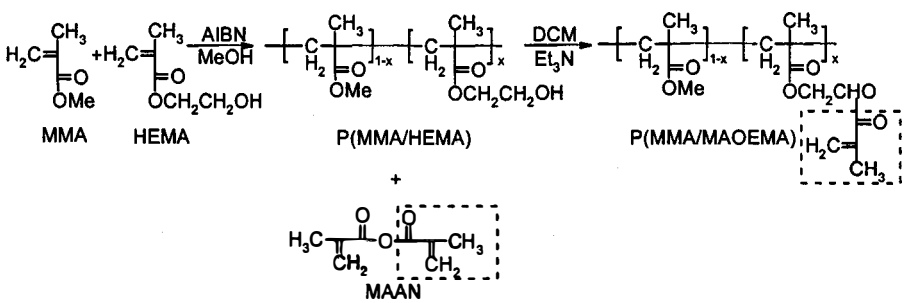

Fig.1. Copolymerization of MMA and HEMA and esterification of P(MMA/HEMA) with methacrylic anhydride (MAAN).

The flexibility to achieve crosslinking via either thermal or with UV exposure is critical for forming channel waveguides. The reduction in intensity of the carbon-carbon double bond absorption at 1637 cm^{-1} in the IR spectrum (Fig. 2) under UV lamp exposure provides clear evidence that the alkene side chains have been removed during photo-induced crosslinking of the polymer. Solid state NMR was used to investigate the further structural changes occurring with UV irradiation of thermally crosslinked polymers. This UV-induced processes revealed in thermally crosslinked P(MMA/MAOEMA) provides the mechanism that allows us to write UV induced refractive index waveguides.

The photosensitivity of thermally crosslinked P(MMA/MAOEMA) was studied by measuring the refractive index after UV exposure with the 244nm frequency doubled Argon ion laser. The film was scanned under the UV laser beam with a 3mm spot size unfocused beam of 0.140 W corresponding to a power density of 0.02 W/mm^2. The refractive index increase of the thermally crosslinked polymer upon UV exposure was found to be proportional to fluence up to 1.9J/mm^2 (Fig. 3). The UV induced photosensitivity of the thermally crosslinked P(MMA/MAOEMA) is sufficient to fabricate good quality channel waveguides.

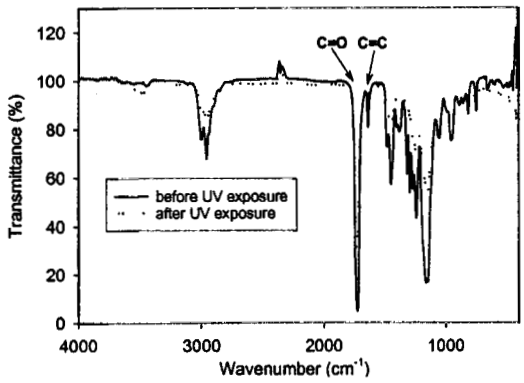

Fig.2. FT-IR spectral changes of 47% HEMA-content P(MMA/MAOEMA).

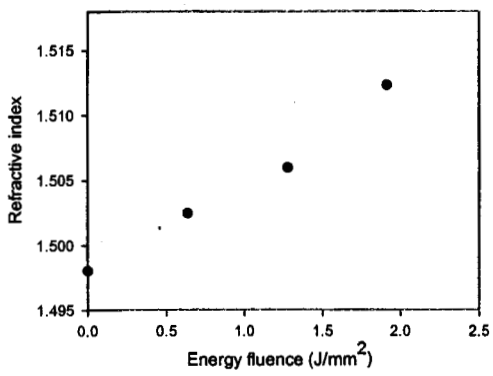

Fig.3. Refractive index vs energy of thermally.crosslinked P(MMA/MAOEMA) measured by prism coupling.

For the waveguide fabrication silica with a refractive index of 1.457 served as the undercladding layer. The core layer was thermally crosslinked P(MMA/MAOEMA) and the channel was created by UV writing[4] with the 244nm laser. The overcladding was again the same P(MMA/MAOEMA) which was thermally crosslinked after deposition.

The laser power was 1.0 mW (corresponding to power density of 12.73 W/mm^2). Using the cut-back technique the propagation loss through the channel waveguides was calculated to be less than 1 dB/cm at 633nm with a coupling loss of around 4 - 7 dB.

In conclusion, we have presented convincing evidence for distinct crosslinking mechanisms under thermal treatment and UV exposure. This effect has been exploited to write low loss waveguides.

[1] L. A. Hornak, *Polymers for lightwave and integrated optics* (Marcel Dekker Inc, New York, 1990).
[2] B. L. Booth, "Low loss channel waveguides in polymers," J. Lightwave Technol., **7(10)** 1445-1453 (1989).
[3] J. Koo, M. C. Grossel, M. J. Whitcombe, P. G. R. Smith, and R. B.Williams, in preparation.
[4] L. Eldada, K. M. T. Stengel, L. W. Shacklette, R. A. Norwood, c. Xu, C. Wu, and J. T. Yardley, "Advanced polymer systems for optoelectronic Integrated Circuit Applications," Proc SPIE, 3006, 344-361 (1997).