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Fast maskless fabrication of electrooptic polymer devices by simultaneous direct laser writing and electric poling of channel waveguides

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The conventional process of fabricating electrooptic (EO) polymer waveguide devices involves electric poling to achieve noncentrosymmetric order and photomasks to define channel waveguides by reactive ion etching or photobleaching. Photomasks add cost and time to the device development, and they limit the flexibility in changing device parameters. To overcome the limitations of photomasks, maskless techniques, such as photopolymerization(1), electron beam writing(2), and laser ablation(3), have been proposed for fabricating channel waveguides in polymer thin films. However, these techniques are restricted to passive waveguides since the temperature involved destroys the EO effect by randomizing the poling order of active molecules. In this paper, we will demonstrate a novel but simple technique of simultaneous direct laser writing and electric poling of arbitrary channel waveguides that have EO properties. This technique can be very useful for the fast prototyping of active devices such as modulators and switches.

The principle of this method is shown in Fig. 1. The sample to be written with channel waveguides consists a substrate, gold ground electrode, three spun layers of polymer (upper and lower passive cladding and active core), and a semi transparent upper electrode. For fiber coupling, the endfaces of the sample are either cleaved or cut with a dicing saw before waveguide writing. The core layer that we used is a disperse red 19 (DR19) containing polymer. The absorption peak of the DR19 chromophores is at 470 nm. Waveguide writing is made with a focused beam of 488 or 515 nm from a cw Ar^+ laser. When the beam scans in the xy plane across the sample without applying the poling voltage or in the area outside the top electrode, the chromophores in the path of the beam are preferentially aligned along the Z direction with, on average, equal number of chromophore dipoles pointing up and down due to photo-orientation(4, 5). The partial alignment parallel to the Z axis increases the refractive index for TM polarization and a passive channel waveguide that only supports the TM mode is made. When the laser beam scans across the area with top electrode and a poling voltage is applied, the chromophores are preferentially aligned with its chromophore dipoles in -Z direction due to a process known as light assisted electric poling(6). An electrooptic channel waveguide is formed.

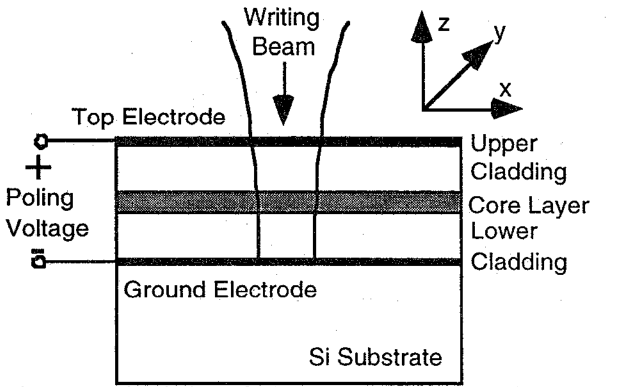

Fig. 1 Principle of the waveguide writing and poling.

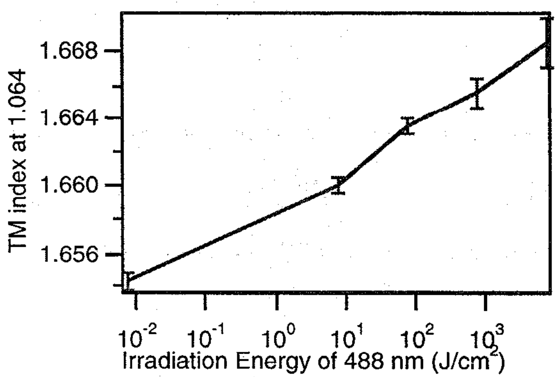

Fig. 2 Increase of the TM index as a function of exposure energy.

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The waveguides are written with a common binocular microscope. The writing beam is fed through one eyepiece and focused on the sample. The spot size of the beam on the sample is adjustable from 1 μm to 50 μm by changing the power of the microscope objective. The optical power of the unpolarized writing beam on the sample is on the order of 1 mW. The microscope is stationary and the sample is held on a X-Y translation stage that moves at a constant speed of 50 to 500μm/sec. A poling field of 100V/μm is used. The change of the refractive index of the TM polarization of a typical polymer thin film irradiated by a laser beam is shown in Fig. 2. The thickness change after waveguide writing is only on the order of 100 Å and, therefore, its effect on waveguiding is negligible. Fig. 3 and 4 are a picture of the waveguide mode and the EO modulation signal, respectively. Single mode condition is easily met by proper choice of core layer thickness and the writing spot size. The modulation comes from the interference between the simultaneously launched channel waveguide TM mode and the TE component of the core layer slab mode. The signal is stable at room temperature. We will present the measurements of the EO coefficient and stability under various poling conditions. In our preliminary experiment, 2 cm long waveguides coupled with standard single mode fiber at the input and a 60x microscope objective at the output have insertion losses between 14 and 20 dB, a level adequate for device testing. The loss is expected to be reduced by better design of waveguide dimensions and smoother stage movement. Passive Y-junctions have also been written without the top electrode, and the power splitting ratio of a fabricated Y-junction is trimmable by addition exposure with the writing beam.

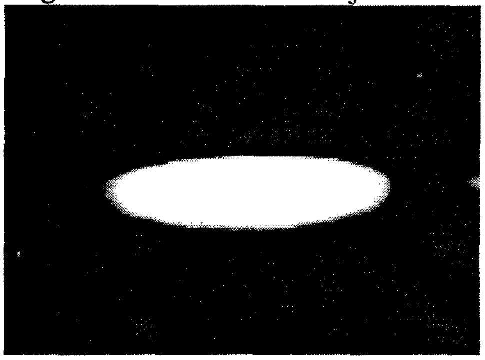

Fig. 3 The near field pattern of a single mode buried channel waveguide made by direct laser writing.

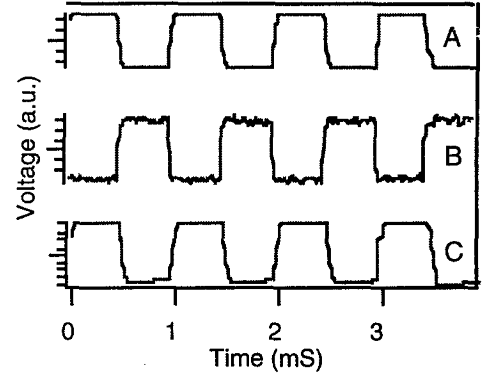

Fig. 4 (A) Modulating voltage on the device. (B) Optical output when the analyzer is at 45°. (C) Optical output when the analyzer is at 135°.

A novel maskless technique that can easily fabricate EO devices with arbitrary shapes of channel waveguides is demonstrated. This method requires only simple equipment such as an Ar^+ laser, a microscope, and a translation stage. Since the endfaces of the sample are prepared before waveguide fabrication, the frustration of losing a device in the last processing step of endface preparation is eliminated. A finished device is obtained after laser writing. No further processing is needed and the device can be tested immediately. This technique is very suitable for testing new device designs and for fast prototyping of active waveguide devices.

1. R.R.Krchnavek, G. R. Lalk, D. H. Hartman, *Journal of Applied Physics* **66**, 5156-5160 (1989).
2. Y. Y. Maruo, S. Sasaki, T. Tamamura, *Journal of Lightwave Technology* **13**, 1718-1723 (1995).
3. H. Franke, T. Sterkenburgh, *Proceedings of the 4th International Conference on Properties and Applications of Dielectric Materials* **1**, 208-210 (1994).
4. Y. Shi, W. H. Steier, L. Yu, M. Chen, L. R. Dalton, *Applied Physics Letters* **59**, 2935-2937 (1991).
5. Z. Sekkat, et al., *Journal of the Optical Society of America B* **13**, 1713-1724 (1996).
6. X. L. Jiang, L. Li, J. Kumar, S. K. Tripathy, *Applied Physics Letters* **69**, 3629-3631 (1996).