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Low-Loss Multimode Waveguides Using Organic-Inorganic Hybrid Materials

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Abstract: Multimode channel waveguides were fabricated using a direct UV patterning technology from thick films deposited by the one-step dip-coating of an organic/inorganic hybrid material (ORMOCER®). The core size of the covered ridge waveguide was 43 × 51 μm^2; the waveguides can be readily prepared for multimode applications by direct UV patterning. The waveguides exhibited smooth surface profiles and a low optical loss of 0.07 dB/cm at the most important wavelength (850 nm) used for optical interconnects.

Keywords: optical waveguide, direct UV patterning, organic-inorganic hybrid materials.

Introduction

Organic-inorganic hybrid materials (ORMOCER®s) are well suited to generate patterned layer with well-defined electrical and optical properties. In general ORMOCER®s exhibit negative resist properties and are therefore compatible with the thin-film of electrical and optical interconnection technology. ORMOCER®s have attracted considerable attention for application in waveguide or micro-optical structure.[1,2] These polymeric optical waveguides have become a subject of interest for use in optical communication and optical interconnections[3] because they can offer such advantages as flexibility and productivity.[4,5] Among the several techniques that can be applied to fabricate polymeric optical waveguide, dry etching method such as reactive ion etching (RIE) is often used because these techniques can offer excellent etching profile.[6-8] It has been thought that one of the disadvantages of this technique is its complicated process. Furthermore, this technique is not suitable to define large core dimensions (~ several 100 μm), which may be needed for optical applications such as interconnections. It is reported that direct UV patterning method can be used to fabricate waveguide.[9] For the fabrication of waveguide, the direct UV patterning technology has the advantage of allowing rapid and simple process compared to conventional dry etching method.

In this paper, we described the direct UV patterning process, which can fabricate the large core size waveguide simply and cost effectively. The characterization of optical properties of resulting waveguide is also demonstrated.

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Experimental.

ORMOCER®s are hybrid materials synthesized by the sol-gel process. This process starts by building up an inorganic network through controlled hydrolysis and condensation of organically modified Si alkoxides. In a subsequent step the polymerizable groups, which are fixed to the inorganic network, react with each other in a thermal or UV-initiated process. In this two-stage process an inorganic-organic copolymer is synthesized.[1,2]

Direct UV patterning process is schematically represented in Figure 1.

In the direct UV patterning technology, a silicon wafer is covered with an ORMOCER®s buffer layer (clad material: refractive index is 1.5280 at 850 nm) of precise thickness of 20 μm by spin-coating. After polymerization of this buffer layer, a second ORMOCER®s layer (core material: refractive index is 1.5433 at 850 nm) with a thickness of 51 μm is spin-coated. The definition of the waveguide structures is realized by UV-polymerization through a mask aligner resulting in waveguide channels. The non-polymerized part in the layer is dissolved with propylacetate/iso-propylalcohol mixture similar to a development process in photolithography. In next step, an upper clad layer is spin-coated and polymerized.

Results and Discussion

Organic-inorganic hybrid materials have been used to fabricate multimode waveguide. Organic parts offer ease of processibility and toughness, and inorganic parts offer superior thermal resistance and compatibility with common inorganic substrates. The optical microscopy images of the

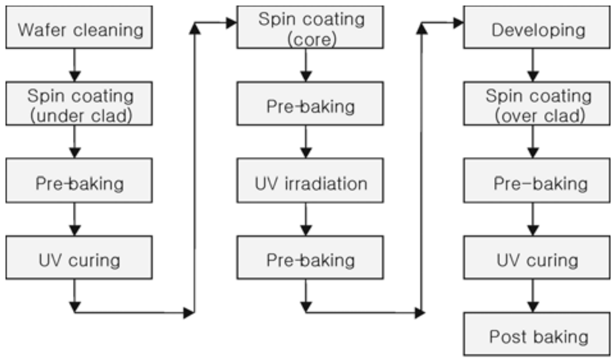


Figure 1. The steps involved in the fabrication process.

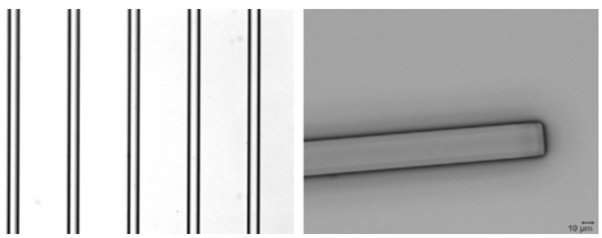


Figure 2. Top view of channels after development.

channel after development are shown in Figure 2.

It can be seen that all the channels are well defined with no visible defects, indicating the very high photocontrast for the ORMOCER®s materials. The high photocontrast is very important as it permits the control of device geometry and allows for fabrication of high-density waveguide arrays for complex structures. Geometrical characterization included qualitative examination of the structure of the photo-defined devices by the optical microscopy and the scanning electron microscopy. Figure 3 shows the optical microscopy images of the channel and the covered ridge waveguides.

Figure 3 shows microscopy images of a cross section of the channel after development and the covered ridge waveguide array. The mask opening for the exposed channel was 43 μm. The results of these measurements are a good indication of the high quality of the fabrication process. The height of core is 51 μm, which is correspondent with thickness of core layer.

The optical loss depends not only on the material loss but also very strong on the roughness of the core-cladding interface. The surface roughness, impurities, Rayleigh scattering and inhomogeneous curing effects on the attenuation. Figure 4 shows AFM images of the top and the sidewall region of the channel after developments.

The surface roughness of the channels top and sidewall after developments are about 2 and 5 nm, respectively. The smooth side wall surface is also desirable for low scattering loss. Due to the low shrinkage and solvent free nature of the ORMOCER®s, thick films and therefore large-dimension devices have been produced.

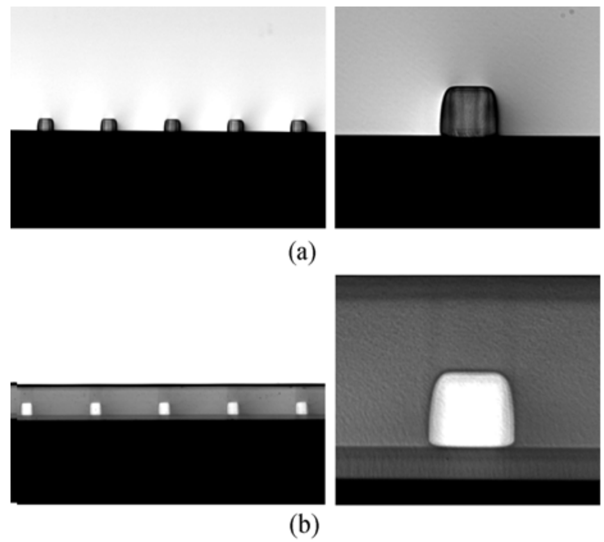


Figure 3. Cross sectional view of (a) the channel after developments and (b) the covered ridge waveguide.

The output profile and intensity of a covered ridge waveguide irradiated by 850 nm wavelength was investigated and the near field pattern is shown in Figure 5.

No scattering from localized defects was observed along the 5 cm guide, which demonstrated a highly homogeneous and uniform structure. The output intensity profile of the guide is virtually rectangular and simply reflects the shape of the waveguide cross section. The propagation loss of the waveguide was measured by the cutback method, its value was 0.07 dB/cm at 850 nm as shown in Figure 6.

Figure 7 shows the attenuation of the multimode waveguide array. The average attenuation was 2.46 dB for adjacent 12-channel waveguide at length of 4.5 cm. The uniform attenuation characteristics verified that the multimode waveguides were successfully fabricated.

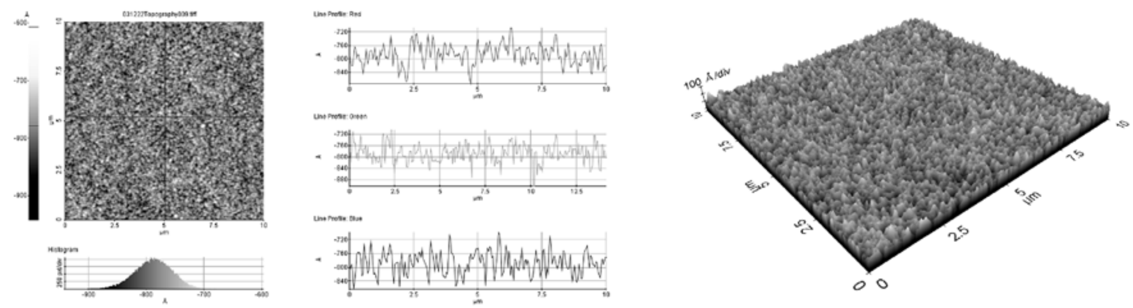
Conclusion

The multimode channel waveguides were fabricated through a direct UV patterning process. Resulting waveguide exhibited a smooth surface profile and a square cross section of the core. The propagation loss of fabricated waveguide was measured to be 0.07 dB/cm at 850 nm. Thus, direct UV patterning process is simple and promising for fabricating a variety of structures. The direct UV patterning process can fabricate multimode waveguides in a simple and cost effective manner. It can also be applied to fabricate optical devices at low cost.

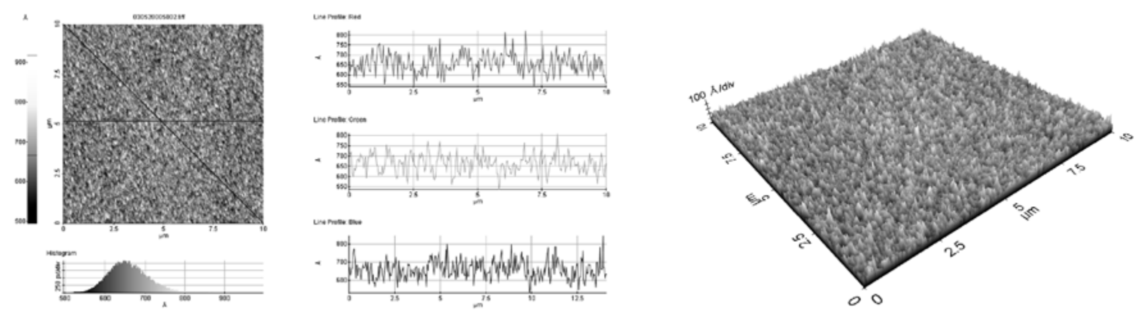
References

(1) U. Streppel, P. Dannberg, C. Wächter, A. Bräuer, L. Fröhlich, R. Houbertz, and M. Popall, *Opt. Mater.*, **21**, 475 (2002).

(2) A. Bräuer, P. Dannberg, G. Mann, and M. Popall, *MRS Bull.*,



(a)



(b)

Figure 4. AFM image of (a) the top and (b) the sidewall of the channel.

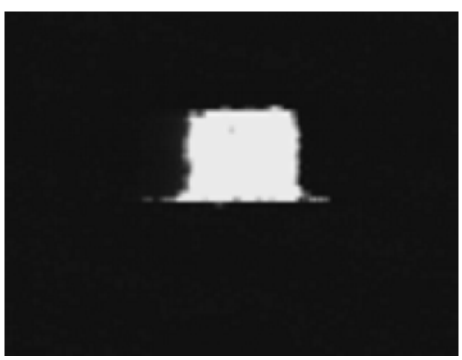


Figure 5. The near field pattern of a covered ridge waveguide.

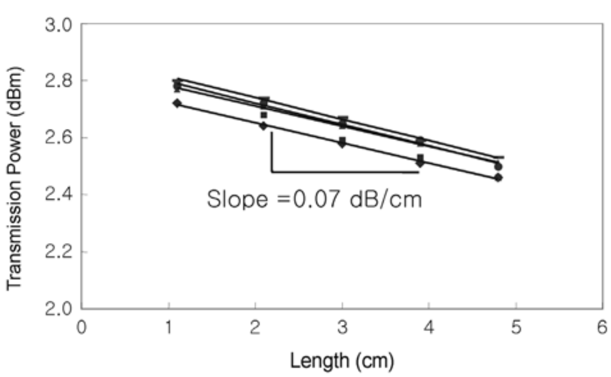


Figure 6. The propagation loss of multimode waveguide.

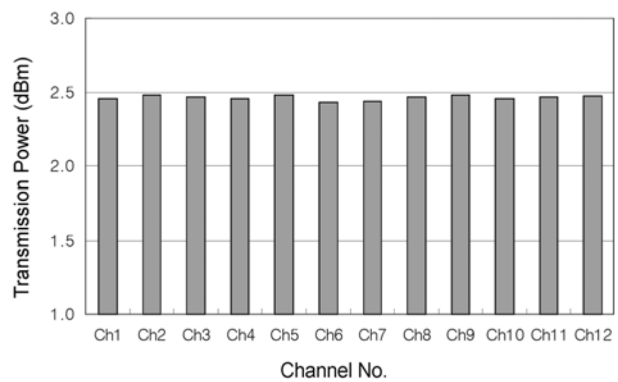


Figure 7. The uniformity of multimode waveguide array.

26, 519 (2001).

(3) L. Eldada, C. Xu, K. M. T. Stengle, L. W. Shacklette, and J. T. Yardley, *J. Lightwave Technol.*, **14**, 1704 (1996).

(4) G. Fischbeck, R. Moosburger, C. Kostrezewa, A. Achen, and K. Petermann, *Electron. Lett.*, **33**, 518 (1997).

(5) K. Han, *Korea Polymer J.*, **8**, 165 (2000).

(6) R. Yoshimura, M. Hikita, S. Tomaru, and S. Imamura, *Electron. Lett.*, **33**, 1240 (1997).

(7) M. Kagami, H. Ito, T. Ichikawa, S. Kato, M. Matsuda, and N. Takahashi, *Appl. Opt.*, **34**, 1041 (1995)

(8) T. Watanabe, M. Amano and S. Tomaru, *Japan. J. Appl. Phys.*, **33**, 1683(1994).

(9) S. Lehmacher and A. Neyer, *Electron. Lett.*, **36**, 1052(2000).