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POLYMER NANO-BRAGG GRATING WAVEGUIDE USING MEMS PROCESS

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A polymer waveguide is successfully fabricated by a new method, which is implemented by a Micro-Electro-Mechanical System (MEMS) process including a stamping transfer technique incorporated with holographic interference, a lithography procedure and soft molding tecnnology. The polymers used in these experiments are OG146 and OG154 with different refractive indices. The near-field measurement for the channel waveguide has shown that the polarization dependent loss is very low. This process is simple, easy and suitable for mass production.

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1. Introduction

Recently, polymer optical waveguides have attracted much attention due to their low cost, easy fabrication and high process ability. [1-3] Their possible applications include optical components in optical interconnects and optical communication systems. [4,5] There are a number of simple methods to fabricate polymer waveguides, including photocrosslinking, photobleaching, reactive ion etching, photolocking, and laser/electron beam writing, etc.. There are other many replication processes which are simple and easy fabrication and can be used for mass productivity, such as hot-embossing , UV-embossing , and micro-transfer molding method. [6] Use of a LIGA (Lithographie Galvanoformung Abformung)-like process to fabricate micro-optical components shows great mass production potential. [7] LIGA technique came from Germany [8] and can implement some non-silicon materials like metals, cermaics and plastics through X-ray masks and synchrotron radiation source. Following a molding process, optical component mass production can be achieved .

Many relative LIGA-like processes are developed such as UV-LIGA and Laser-LIGA techniques are used to fabricate polymer optical waveguides. In UV-LIGA technique, a negative photoresist SU-8 is usually used to solve the adhesive problem between substrate and the photoresist. [9] In order to reduce the residual stress in the waveguide, which is induced by different materials of the core and cladding of the waveguide, the waveguide is fabricated in terms of the nearly similar materials. The polymers used in the waveguide are UV epoxy (OG146) which is provided by the EPOXY TECK Company and OG154. The refractive indices of the polymers are between 1.52~1.56, which is close to the refractive index of the optical fiber, therefore the OG polymer waveguide can effectively reduce the Fresnel reflection. In this study, we adopt an asymmetric waveguide coupling to carry out this desired compoent. In this optical component, the light signal is transmitted in the bigger refractive index layer due to the total reflection.

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2. Experimental

In this section, the procedure of fabricating polymer nano-Bragg grating waveguide on the ITO glass is described. First, the formation of gratings on the OG146 polymer by He-Cd laser through the holographic interference technology has been published elsewhere. [10,11] Second, SU-8 negative photoresist is spinned over the OG146 polymer with spin rate 1000rpm/sec and then is put into oven for 15secs soft baking. The OG146 polymer gratings are then revealed by exposing UV light under photolithigraphy mask. The flow chart of SU-8 channeled waveguide component is shown in Fig.1. Third, the fabricated SU-8 channeled waveguide component combined with PDMS to perform a stamping transfer molding through the soft molding technology. The PDMS is spinned on the top of SU-8 and put into the oven to speed up the solidification. After the separation of PDMS and SU-8, the stripe pattern of gratings would stamp into the PDMS layer. Then, the PDMS layer can be used repeatedly to put the gratings on the OG146 polymer. The stamped PDMS gratings are shown in Fig.2. An observation of PDMS molding with nano-Bragg gratings by optical microscope is also depicted in Fig.3.

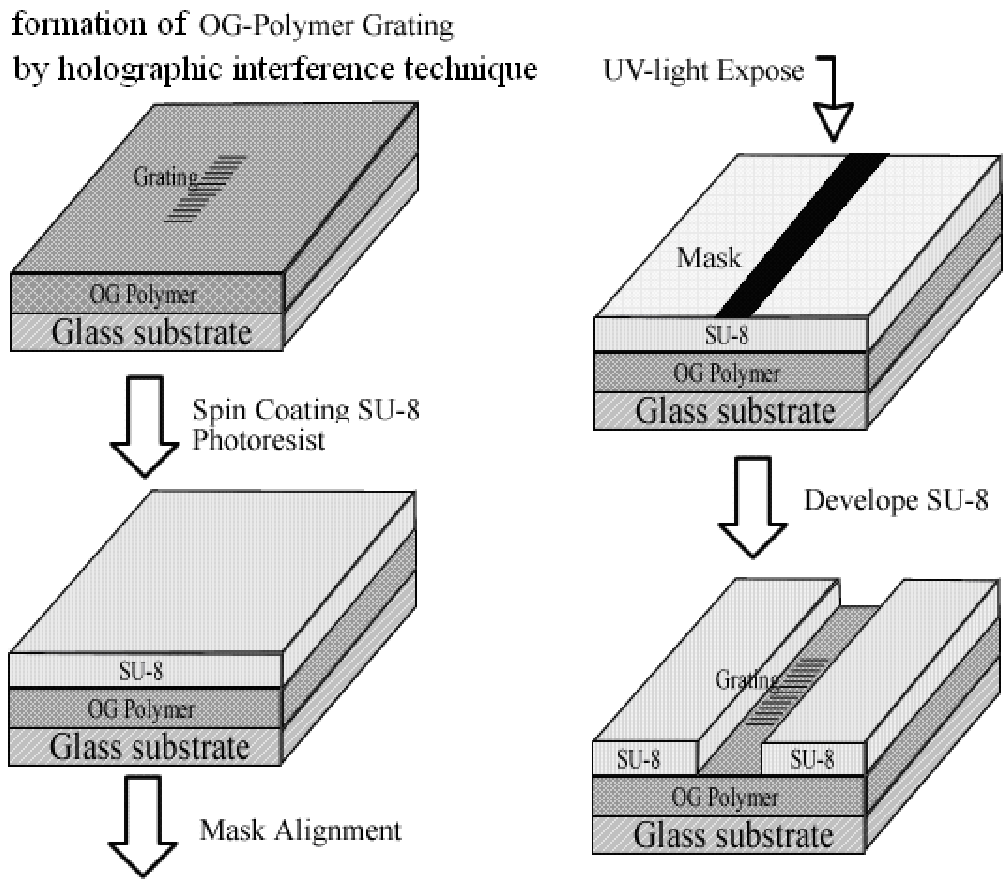

Fig.1. Flow chart of SU-8 channeled waveguide component

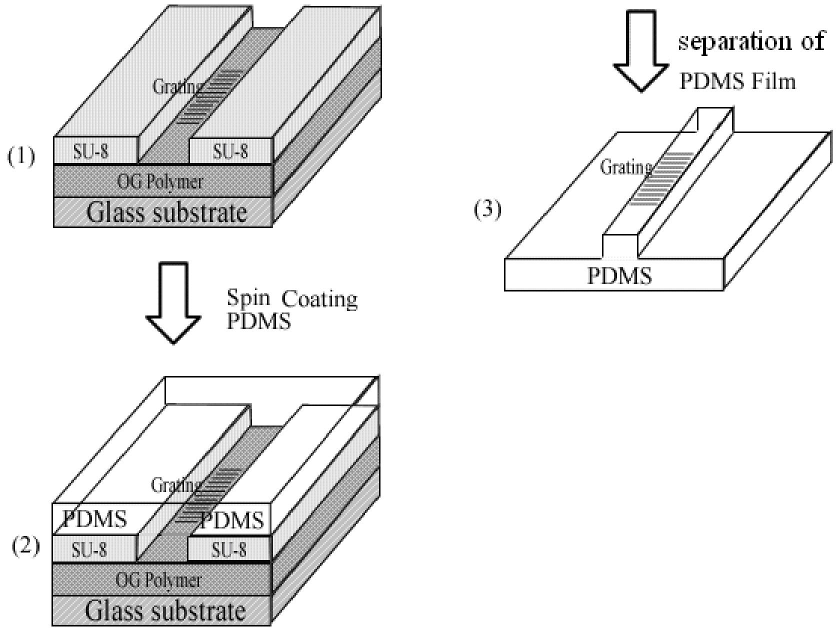

Fig.2. Flow chart of a ridged PDMS grating waveguide component

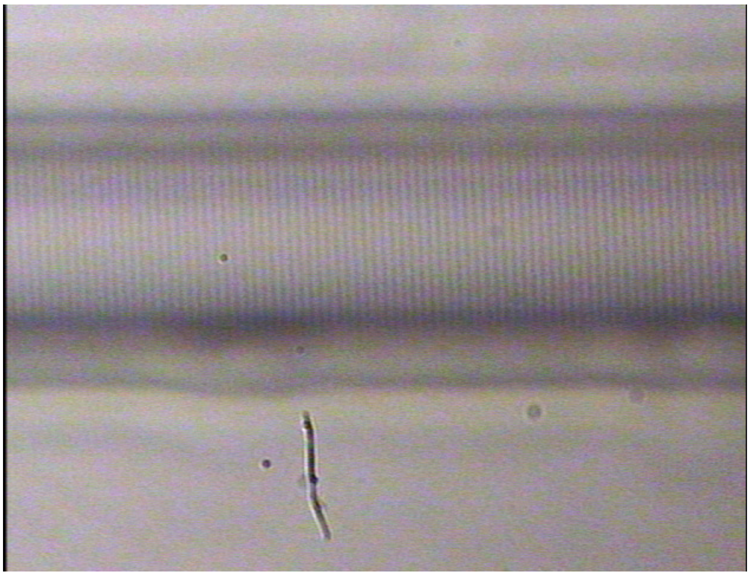

Fig.3. An observation of PDMS grating mold with Bragg grating by optical microscope.

Polymer waveguides are fabricated on a 4cm x 2cm ITO glass. The similar process is adopted to form the cladding layer of the waveguide as shown in Fig.4(a) by the ridge mold. A spacer is put between the OG146 and the mother mold PDMS, and is shown in Fig.4(b). After injecting the second polymer, OG154, into the tunnel, the sample is simultaneously exposed to UV light with wavelength 300-400nm and is shown in Fig.4(c). The epoxy in the tunnel is cured by exposing the UV light for 1-2 minutes, the upper glass is removed, and the PDMS layer is peeled off from the sample. After separating with the PDMS mold, the solidified polymer could become the cladding layer of polymer waveguide and the final product of the polymer nano-Bragg grating waveguide is obtained.as shown in Fig.4(d). During the MEMS processes, PDMS polymer is made to cover on the polymer groove, both of the groove and the PDMS layer are supported by a piece of glass separately, and a pressure was used to clad both materials.

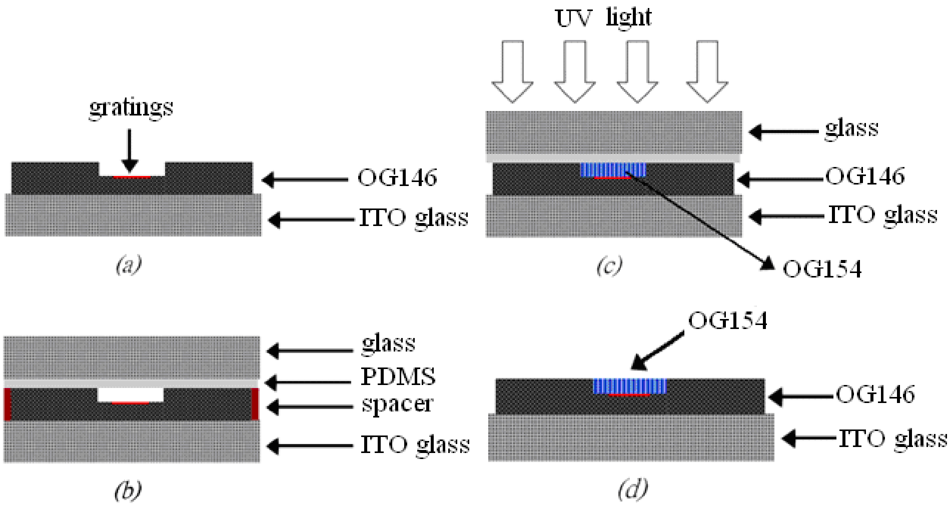

Fig.4. Flow chart of a final nano-Bragg grating polymer waveguide

3. Results and discussion

The near-field pattern of the polymer waveguide mode is measured in terms of end-fired coupling technique. The propagation experiment with broadband to observe the samples is performed at a 633nm wavelength using a 10W He-Ne as a light source. The optical measurement system is shown in figure 5. The top of the figure shows the experimental setup for waveguide loss measurement and a real end-fire coupling system is shown in the bottom of the figure. It is coupled with the laser beam into the optical fiber and then the laser beam is guided into the waveguide component. Finally, the laser beam comes out and into the convex lens which deliver the output signal to focus on the the screen through the infred CCD. From the result of Fig.6, the power we inputed is 4mW and the output distribution shows the phases of optical strength of wavguide are saturated on vertical and horzional. Thereofore, it nearly has no transmission loss from the input through waveguide to CCD. The output results show that the all red light almost focuses on the core layer of the waveguide to propagate; therefore the energy loss of the light propagating through the waveguide is very small.

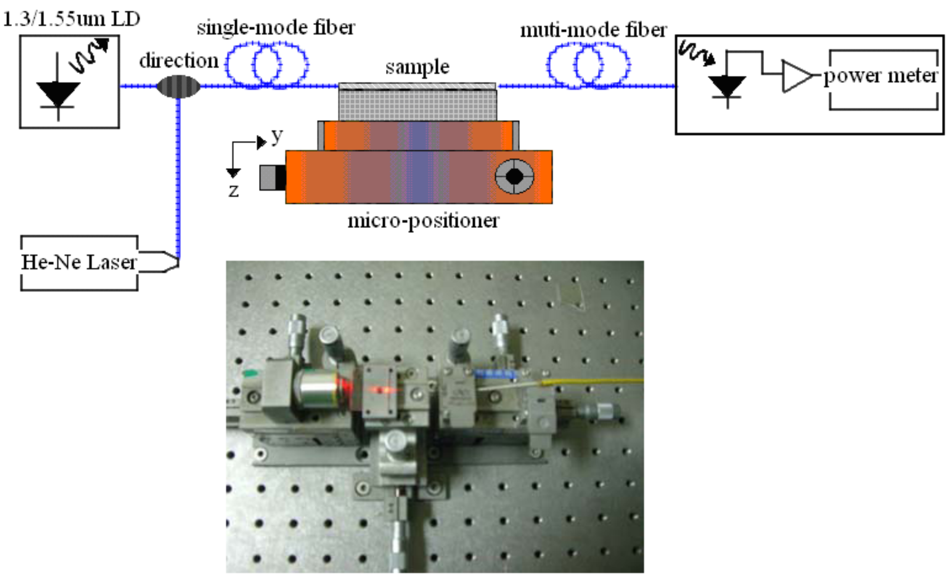

Fig.5. Illustrated and real structures of the end-fire measurement system

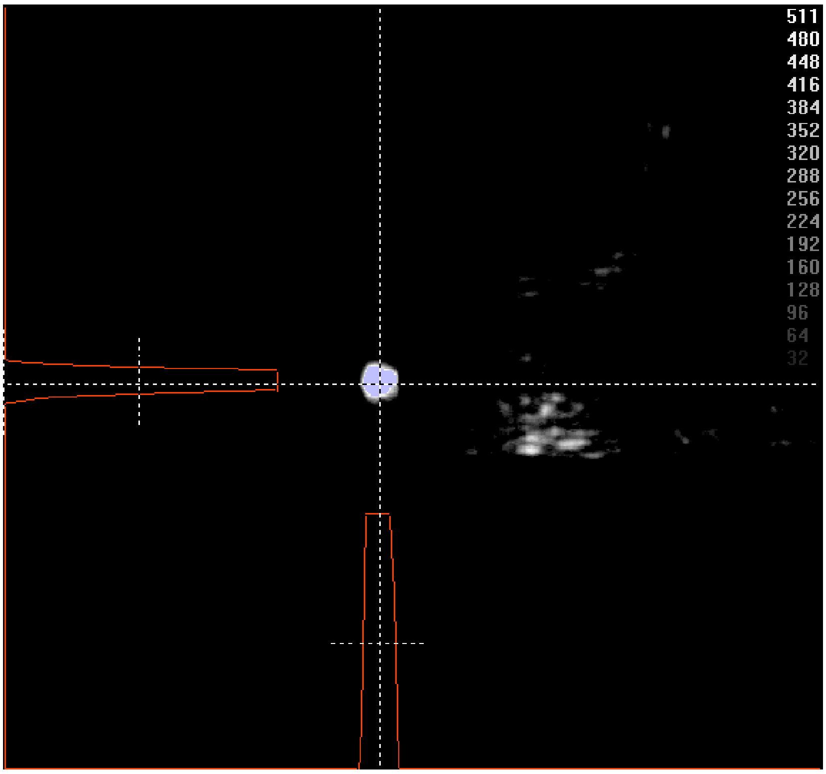

Fig.6. Optical strength in a waveguide output measurement

For Bragg grating, it is also called reflective grating or periodic grating. When the wavelength of light is equal to twice of grating period (achieved the Bragg condition), the light entered the grating is reflected, and the phase of reflective light of every period will be accumulated where the else of waves will pass through the grating and their reflective transmitted coefficients are negative. [12] Since the reflective optical signals are transmitted in the core, the two equivalent refractive indices of modes of forward and backward are equal (n_1= n_2). The equation of achieving Bragg grating condition is given as below:

$$\lambda_B = 2n_{eff}\Lambda$$

,where the λ_B expresses the reflective wavelength of Bragg grating condition, n_{eff} and Λ are the effective refractive index and period of Bragg grating. From the measurement of optical spectrum analyzer (OSA), the wavelength output response is shown in Fig.7. As shown at the wavelengh λ=1552.66 nm, it is found that the difference from peak to bottom is up to17dB and therefore it also can be a good optical filter. Because the period of Bragg grating (Λ) is measured by AFM and equal to 512 nm [10,11], thus the effective refractive index (n_{eff}) can be estimated to be $n_{eff} = \lambda_B / 2\Lambda$ =1.52. This value is located between 1.52~1.56, which is close to the refractive index of the optical fiber, therefore the proposed polymer nano-Bragg grating waveguide can match to the optical fiber system.

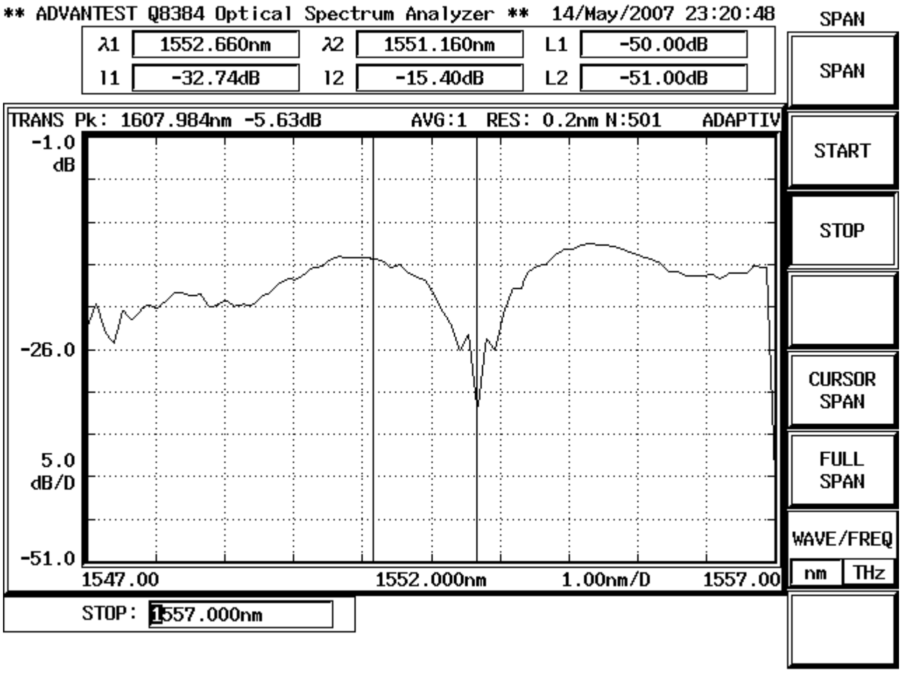

Fig.7. Experimental wavelength response measured by OSA.

3. Conclusions

A polymer nano-Bragg grating waveguide is fabricated by the LIGA-Like process, which is simple and easy fabrication process. The refractive indices of the waveguide materials could be changed by using OG146 and OG154 polymers. This process could successfully fabricate any shape of polymer waveguides. The experiment of the near-field measurement with end-fire coupling had shown that the propagating light loss is very small.

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