A Novel Fabrication Method of PDMS Based µ-Bragg Grating Optical Sensor

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In this work, cost-efficient polydimethylsiloxane (PDMS)-based µ-Bragg grating (BG) sensors were fabricated by reactive casting process. The master structures were manufactured by the combination of electron-beam lithography, dry etching and photolithography technologies. PDMS based µ-BG optical sensors were optically characterized.

1 Introduction

During the past few years, polymer based optical sensing devices are drawing more and more attention due to its wide spectral transparent window and high sensibility to the environmental parameter changes. Compared to fragile glass fiber sensors, Bragg grating optical sensors made of polymer material present much higher flexibility, better biocompatibility, lower cost, simpler and faster processing abilities [1].

There are various research groups working on the fabrication of polymeric Bragg grating integrated waveguides. The most used technique have more or less the same fabrication procedure. Usually, the polymeric waveguide structures were patterned during the first fabrication step and then the Bragg gratings were transferred by using either a phase mask [2] or two beam interference technologies [3] onto the photosensitive waveguide polymeric structures in another separated step. Such kind of two-step processes are complicated and time consuming due to the extra precise alignment demand in the Bragg grating manufacturing step. In order to avoid such kind of problem, we present a straightforward one-step duplicating process to fabricate polymeric µ-Bragg grating integrated waveguide structures. By using this duplication method, µ-Bragg grating integrated waveguide sensors could be fabricated with high simplicity and high reproducibility.

In this work, µ-Bragg grating sensors were fabricated by reactive casting technology. PDMS-based silicones with various refractive indices were used as the waveguide core and cladding material respectively. By using reactive casting process, Bragg grating filters could be defined on the waveguide without any extra precise alignment demands. In this paper, PDMS-based waveguide integrated with two Bragg gratings were fabricated. By incorporating multiple sensors with different Bragg grating modulation periods along a single waveguide, the absolute change of local parameters, such as deformation, could be separated directly from the influence of the global parameter changes, such as temperature and humidity.

2 Experiment

The fabrication of PDMS based µ-Bragg grating optical sensors is basically a two-step process, as illustrated in Fig. 1. First of all, master structures were generated by electron-beam lithography, reactive ion etching (RIE) and standard photolithography technologies. After that, structures of the master wafer would be transferred finally to the PDMS-based elastomer using reactive casting technology. In this work, optical grade silicone-based elastomer with refractive indices of 1.50 and 1.41 were used as the core and cladding materials respectively.

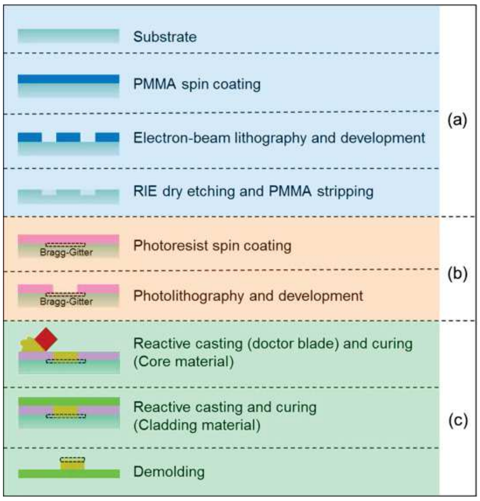

Fig. 1 *Schematic of the fabrication process of µ-BG optical sensor (a) Bragg grating fabrication by electron-beam lithography and RIE technologies, (b) Waveguide master structure fabrication by standard photolithography technology and (c) µ-BG optical sensor fabrication by reactive casting technology.*

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3 Results and discussion

The Bragg gratings with modulation periods of 200 nm and 220 nm were fabricated on an oxidized silicon wafer using electron-beam lithography and the following dry etching technology. SEM investigation results shown in Fig. 2 illustrated the 1:1 line to space ratio.

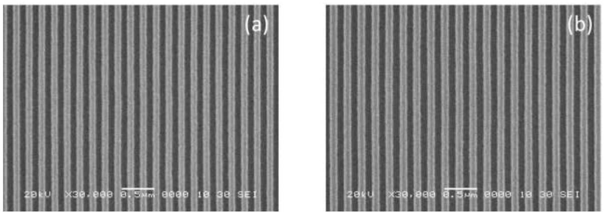

Fig. 2 *Bragg gratings with period of (a) 200 nm and (b) 220 nm on the same waveguide.*

After the fabrication of the master structures, the final PDMS waveguide integrated with µ-BG sensors were manufactured by the following reactive casting process. The image of the final device was illustrated in Fig. 3. As shown in the figure, series of flexible PDMS based µ-Bragg grating optical sensors were fabricated successfully. The dimension of the PDMS waveguide is 10 µm in width, 10 µm in height and 55 mm in length.

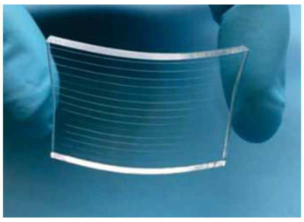

Fig.3 *PDMS waveguide based optical sensor.*

The structure of the optical sensors was further investigated by SEM and the images were illustrated in Fig. 4. As shown in Fig. 4(a), high quality Bragg grating structures with feature size of 100 nm were successfully replicated on the PDMS waveguide. A very small tilt of the side walls was presented on the waveguide structures (Fig. 4(b)). Compared to the vertical side walls, tilted side wall profile would improve the fabrication yield in the casting process, since it makes the demolding step much easier.

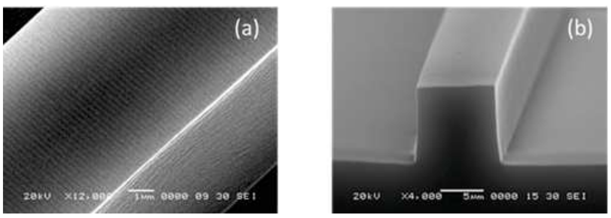

Fig.4 *SEM images of (a) PDMS waveguide integrated with BGs and (b) PDMS waveguide end facet.*

After the reactive casting process, the resulting PDMS based µ-Bragg grating optical sensors were optically characterized. In the measurement setup, a broad spectrum light source was used as the input signal. At the end facet of the waveguide, the transmitted light was detected using a fiber coupled spectrometer. The obtained transmission spectrum is shown in Fig. 5.

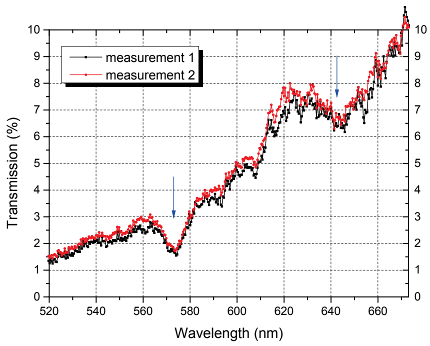

Fig.5 *Transmission spectrum of the PDMS based µ-Bragg grating optical sensors.*

As shown in the measurement, The transmission spectrum has two dips at the central wavelength of 573.5 nm and 644.5 nm, which satisfied very well with the first order Bragg condition with the Bragg grating modulation periods of 200 nm and 220 nm respectively. The relatively lower intensity of the peak-dip of the transmission spectrum were due to the short Bragg grating length (50 µm) which could be improved in the future research work.

4 Summery

In this work, we have successfully fabricated optical PDMS-based µ-Bragg grating sensors with the combination of electron-beam lithography and reactive casting technologies. This process combination ensures the high-resolution requirement of the optical Bragg grating devices and simultaneously improves the fabrication throughput with high reproducibility for practical applications.

5 References

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