Design and Fabrication of a Polymer Micro Ring Resonator with Laser beam Direct Write Lithography Technique

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Abstract: In this article, we describe our work on design and fabrication of a polymer Micro Ring Resonator. This device has been constructed by laser beam direct write lithography technique (LBL).We used ORMOCORE photoresist for fabricating a micro ring resonator due to its very low losses at wavelengths 1550 nm and 1300 nm and also used a tapered fiber to couple light into the bus waveguide and received the signal from the output port of the waveguide by using another tapered fiber which the gap between bus waveguide and ring waveguide is then filled with nitrobenzene liquid by micropipette (which has large dependence of the refractive index on temperature) for increasing efficiently coupling to ring waveguide. The signal has been monitored by using an optical spectrum analyze .This micro ring resonator in the laterally coupled geometry for wavelength 1550 (nm) have band width ($\Delta\lambda$) 0.3 (nm), free spectral range of 0.8 (nm) and finesse of 2.6.

1. INTRODUCTION

Micro Ring Resonators have lots of application in integrate photonic circuits for optical communication and are very promising candidate for very large scale integration and have been studied extensively in recent years due to their potential important role in highly integrated photonic circuits [1]. Most of the microring resonator devices have been fabricated using semiconductor materials. Micro ring resonator is typically in the form of a microring (that can be circuit, racetract or ellipse) closely coupled to one waveguide or two waveguids, and offers unique properties such as high quality factor, high non linearity and narrow bandwidth filtering.

A large range of functionality has been exploited using microring resonator-based devices for future optical communications,including channel add/drop filters, WDM demultiplexers, true ON–OFF switches, dispersion compensators, lasers, and enhanced nonlinear effects. most of the microring resonator devices have been fabricated using semiconductor materials. Fabrication of semiconductor microring devices involves patterning by electron beam (ebeam) lithography and dry etching [2] but in this article, we present the fabrication of polymer microring devices [3] with ORMOCORE material by laser beam direct write lithography technique. The using of polymer materials offers a number of advantages over semiconductor materials which the first one is to reduce loss. It has been identified experimentally that surface roughness resulting from dry etching can induce large scattering loss, which is the main loss mechanism in the fabricated microring devices. Such a high loss places a significant limitation on the practical use of these microresonator devices. Since scattering loss from surface roughness is proportional to (n2WG – n2*C),* where *n*WG and *nC* are the refractive indices of the waveguide and the cladding, respectively, the use of low refractive index polymers will significantly reduce such loss. The second advantage is to provide better coupling efficiency to optical fibers than previously demonstrated semiconductor waveguides due to the low index and the large cross section of the polymer waveguide. This not only facilitates the experimental characterization, but also reduces the device insertion loss. The third advantage is to allow us to easily explore nonlinear optical effect for active devices by using many existing nonlinear optical (NLO) polymers [3]. We can also say that direct write laser beam lithography system allow flexible structuring of photoresists.

2. Concept and design

First of all we briefly discuss the principles of microring resonators as we mentioned before, a microring resonator device is composed of one or two straight waveguide coupled with a ring waveguide where the microring acts as an optical resonator. For a waveguide that is coupled with a microring the input ($E1$), output ($E3$), and circulating field inside the ring ($E2$ and $E4$) can be described by the following coupled-mode equations:

$$E_3= a_i(tE_1+j\, kE_2), \quad E_4= a_i(j\, kE_1+ tE_2), \qquad (1)$$

where t and k is the amplitude transmission and coupling coefficient, respectively, and ai is the insertion loss due to the waveguide mode mismatch in the coupling region. By introducing the single-pass amplitude attenuation factor a, we can write $E2=aej\, ØE4$, where Ø is the single-pass phase experienced by light traveling inside the microring, which is equal to $2\Pi\, neffL/\lambda$. Here, $neff$ is the effective refractive index of the propagation mode, L is the circumference of the microring, and λ is the vacuum wavelength. Together with Eq.(1), we can get the transmission through the waveguide that is coupled to a ring resonator as According to this equation, resonance occurs as $Ø=2m\Pi$ (which m is an Integer in this equation), and the transmission through the waveguide shows a periodic dip behavior as a function of input wavelength.

3. Fabrication Method and measuring

To fabricate polymer waveguides in microring devices, as we know, especially closely coupled waveguides with a gap distance of 100–200 nm and a waveguide height of at least 1.5 µm,conventional patterning and reactive ion etching (RIE) processes are very difficult to apply. But in this article we just chose the laser beam direct write lithography technique to fabricate microring resonators because of its compatibility with polymer processing. We have developed this approach in the device fabrication. First of all; we developed the laser beam direct writhe lithography (LBL) setup which the LBL setup is shown in Fig. 1.

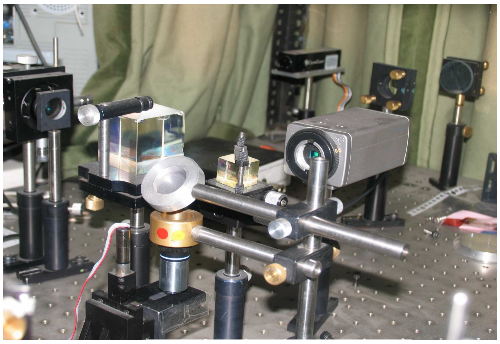

FIG. 1. LBL setup

We first wrote two polymer straight waveguides and one ring (racetrack ring) between two straight bus waveguides by LBL technique. We used a photoresist polymer (ORMOCORE and ORMOCLAD) because of its high optical quality. The fabricated microring device is shown in Fig.2.

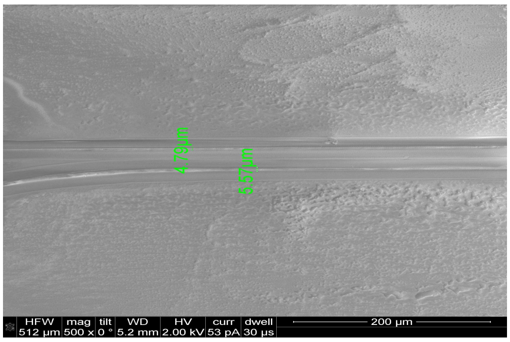

FIG. 2. SEM picture of a micro ring resonator

which consists of ORMOCORE waveguides of 8 µm in height with a coupling gap distance of 2000 nm between themicroring and the straight waveguide.

in order to better coupling after that, the gap(which is 2 micron) of the fabricated microring resonator is then filled with nitrobenzene liquid by micropipette(which has large dependence of the refractive index on temperature) for increasing efficiently coupling to ring waveguide. Finally we used a horizontal setup for coupling light into the bus waveguide and the schematic of the process coupling is shown in Fig.3.

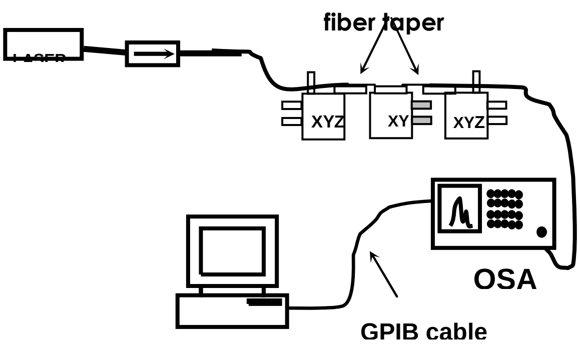

FIG. 3. Horizontal setup for coupling light into the bus waveguide

In this setup we used a tapered fiber to couple light into the bus waveguide and received the Signal from the output port of the waveguide using another tapered fiber. The signal has been monitored using an optical spectrum analyzer therefore we could analyses the output form drop port of top waveguide which it is shown in figure4.

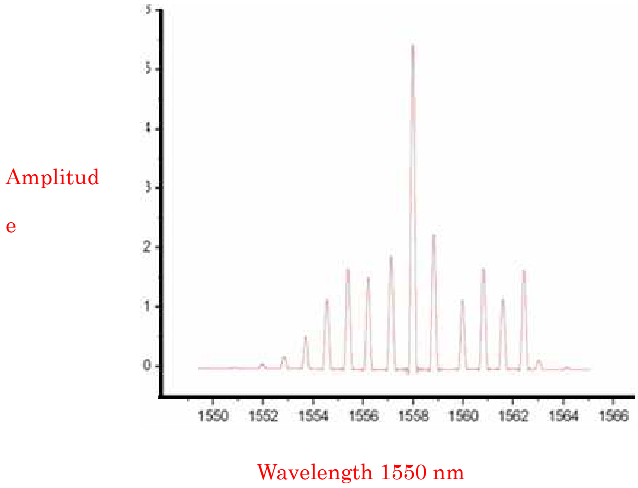

FIG. 4. the out put form drop port

4. Conclusion

Polymer microring resonators were successfully fabricated by laser beam direct write lithography technique with new kind of ormocore photoresist. We used ORMOCORE photoresist for fabricating a micro ring resonator due to its very low losses at cominacation wavelenght and also used a tapered fiber to couple light into the bus waveguide and received the signalfrom the output port of the waveguide by using another tapered fiber. The signal has been monitored by using an optical spectrum analyze.This micro ring resonator in the laterally coupled geometry for wavelength 1550 (nm) have band width (Δλ) 0.3 (nm), free spectral range of 0.8 (nm), finesse of 2.6

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