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High Q-factor Si_3N_4 Ring Resonator for Optical Sensor Application

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Abstract

In this research, we fabricated the ring resonators with the radius of ring as 50 μm, width of waveguide 1.1 μm and the gap 0.35 μm. In the first step, we firstly prepared the Si_3N_4 film with a thickness of 900 nm to test the availability of the waveguide structure. In the second step toward sensor applications, we used the thinner Si_3N_4 layer having the thickness of 400 nm with 380 nm etching depth. The corresponding transmission spectra are investigated. And the Future work as how to reduce the optical loss and obtain higher Q factor is also given.

1. Introduction

The ring resonator is the promising optical device for a variety of applications. There are numerous advantages of the ring resonators due to the devices' small size design and low cost fabrication. Therefore, the optical ring resonators have demonstrated optical sensors based on their wavelength selectivity [1-3]. The ring is characteristic in its high-Q factor resonator, which realizes the highest sensitivity for sensor application. Recently, the silicon nitride (Si_3N_4) has been well studied for the material of choice because of the simple deposition of the thin film with the desired thickness under the mild experimental condition. Furthermore, the dry etching of the Si_3N_4 is easier than such as silicon, thus resulted waveguide has a low loss property for the light propagation. More recently, the Si_3N_4 waveguide has been used with the electro-optic (EO) polymer for the hybrid optical modulator. In this work, we propose the ring resonator device based on the Si_3N_4 and EO polymer material for the novel sensing application. We have investigated the details of the parameter to enhance the Q-factor of the ring and demonstrated the optical resonation.

2. Experimental

2.1. Section Title

The schematic configuration of the full pass optical ring resonator is shown in Fig. 1. The full pass ring resonator device consists of a bus waveguide and a micro ring. Design of the radius of the ring, the width of the waveguide, and the gap between the ring and the bus waveguide are all the important factors to obtain the high-Q resonator, regarding the bending loss, the propagation loss and the coupling efficiency [1]. For the optical sensor application in our study, we fabricated the full pass ring resonators and measured their transmission spectra to discuss and optimize the Q-factor and propagation loss [2, 3].

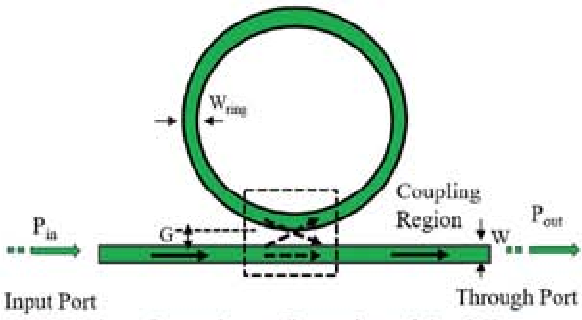

Fig. 1 The schematic configuration of the full pass ring resonator

In this research, we fabricated the ring resonators with the radius of ring as 50 μm, width of waveguide 1.1 μm and the gap 0.35 μm. In the first step, since thicker core film can help get higher Q factor, we firstly prepared the Si_3N_4 films with a thickness of 900 nm to test the availability of the waveguide structure. The dry etching was carried out to fabricate rings to figure out their influence on the final propagation loss and Q-factor. We chose the etching depth of 810 nm for this 900 nm-thick film. In the second step, since our final target for the novel sensing application requires the light propagate in the EO polymer cladding layer, the thickness of the Si_3N_4 layer was decreased as 400nm with 380 nm etching depth to reduce the confinement as in 900 nm-thick film. The corresponding transmission spectra is investigated.

3. Results and Discussion

We made the FDTD simulation for the designed ring resonators as shown in Fig.2. The results showed the bus waveguide coupled well with the 50 μm micro ring and the resonant peak shifted using different effective refractive indexes.

The calculation indicates that the resonance is sensitive to the effective refractive index, which may change in a variety of sensor applications.

The change of the output laser power intensity

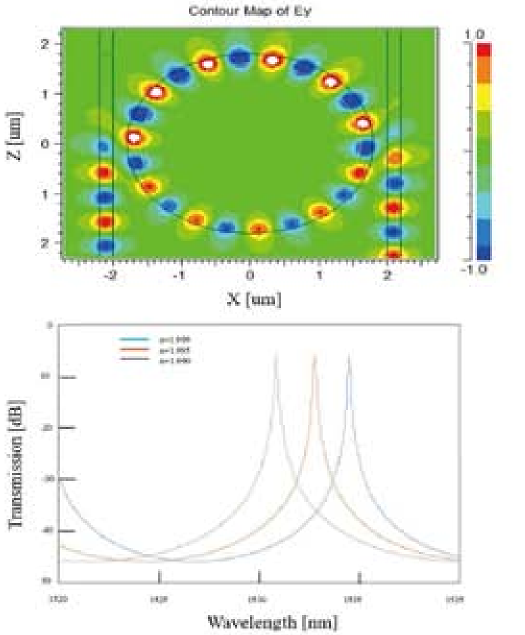

Fig.2 FDTD simulation result of the ring resonator

for the waveguides with different lengths is detected. The power of the laser source is 13 dBm. The insertion loss can be estimated to be about -20 dB for the waveguide with 900 nm-thick Si_3N_4 film. While the propagation loss is of 7.8 dB/cm can be obtained from the slop of the plots. The transmission spectrum of the fabricated ring is detected. The Q-factor is measured of around 21,000 at 1,556 nm while the FSR is quite large enough. It shows the well potential of this waveguide structure.

Since the thicker Si_3N_4 film well confined the light mostly propagated inside the core, we reduced the thickness of Si_3N_4 layer in the next step in order to modulate the light propagate outside the core. The Q-factor is measured as around 8,000 for the ring with 400 nm-thick Si_3N_4 film. Generally, the resonance of the ring is sensitive to the change of refractive index in 10^{-3} order as shown in Fig. 3. The wavelength shift should be 0.48 nm while the corresponding extinction ratio will be -11 dB. Therefore, the higher Q is preferred to realize the sensor application. It's obviously not high but we can further optimize the Q-factor in the future work by enhancing the parameters affect the bending loss, the propagation loss and the coupling efficiency, which are all the Q-factor sensitive to.

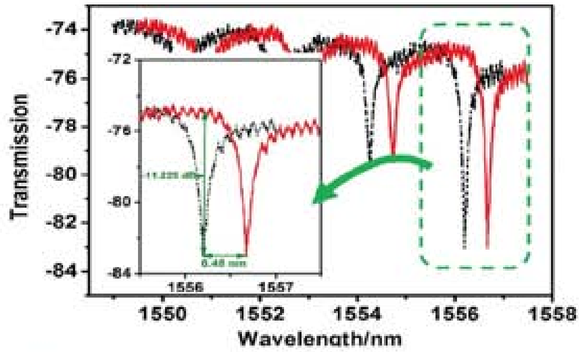

Fig. 3 The theoretical red shift of 50 μm radius ring resonator when the refractive index increasing 10^{-3}

4. Conclusion

We can estimate the useful Q-factor of the ring for the sensor application and demonstrate he sensitivity to the refractive index change, and hen further optimize the Q-factor in the future work by enhancing the parameters affect the bending loss, the propagation loss and the coupling efficiency.

Reference

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