12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

12E4-2

Polarization independent microring resonator filter using internal stress and temperature control

Naoki Kobayashi Nobuhiro Zaizen Yasuo Kokubun

Yokohama National Univ., Graduate School of Eng., Dept. of Electrical and Comp. Eng.,
79-5 Tokiwadai, Hodogayaku, Yokohama, JAPAN 240-8501
E-mail: ykokubun@ynu.ac.jp

Abstract The polarization dependence of resonant wavelength of vertically coupled microring resonator filter was eliminated using the photo-elastic effect induced by the internal stress and the temperature control.

1. Introduction

To realize a polarization independent waveguide filter, two methods were proposed. One is a method using half-wave plate inserted in the device, which was adopted for the arrayed waveguide grating filter[1]. However, this method is difficult to be applied to ultra compact photonic devices such as microring resonators with several tens micron radius, because the thickness of $\lambda/2$ plate is ten micron. Another method is the control of aspect ratio of waveguide cross section. However, this method is also difficult to be applied to high index contrast waveguide devices, such as microring resonators, due to their small tolerance.

In this report, we propose and demonstrate the third method using the control of temperature, which is applicable to high index contrast waveguide devices. In addition, we can compensate for the residual polarization dependence of resonant wavelength due to the fabrication error by temperature control. Therefore, polarization independent ultra compact device can be realized easily by this method.

2. Temperature dependence control of resonant wavelength by internal stress control

We have reported an athermal waveguide filter[2] using polymer as cladding material. Last year, we experimentally realized an athermal vertically coupled microring resonator as shown in Fig. 1 by the control of internal stress as a nobel athermal waveguide filter without using polymers[3]. This athermalization method is based on the compensation of temerature coefficient of refractive index by their photo-elastic effect induced by the difference of thermal expansion coefficient between the waveguide core and the substrate.

The photo-elastic constant of most silica-based glass materials is negative. In addition, the thermal expansion coefficient of Ta_2O_5-SiO_2 compound glass, which was used as the core material in our device[3], ranges from $0.55\text{x}10^{-6}$ [1/K] to $0.80\text{x}10^{-6}$ [1/K] depending on the Ta_2O_5-SiO_2 content, which is smaller

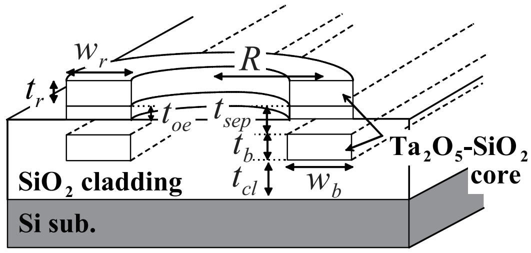


Fig.1 Structure of vertically coupled microring resonator filter.

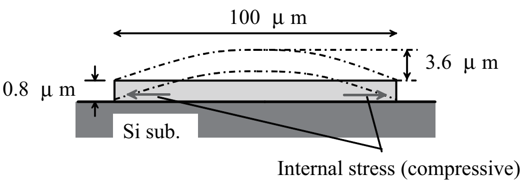
than that of Si substrate ($2.63\text{x}10^{-5}$ [1/K]). Therefore, if the core layer is formed on a Si substrate, the stress of core layer increases with the increase of temperature due to the difference of thermal expansion coefficient between the core and the substrate.

When the internal stress is negligibly small, the photo-elastic effect can be ignored and the temperature coefficient of resonant wavelength $d\lambda_0/dT$ can be calculated in terms of the temperature coefficient of refractive index of waveguide matreials and the thermal expansion coefficient of substrate[2] .

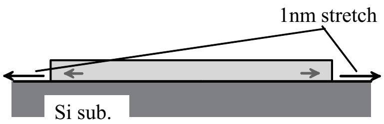
On the other hand, when the internal stress is too strong to ignore, the refractive index of core layer suffers the influence of both the thermo-optic effect and the photo-elastic effect. However, the controllability of the temeperature dependence by the internal stress control was not made clear. Therefore, we numerically analyzed the photo-elastic effect under a strong internal stress using a finite-element solver (ANSYS by ANSYS, Inc.).

3. Numerical investigation of photo-elastic effect

According to our preliminary experiment, a Ta_2O_5-SiO_2 straddle mounted beam structure with 100μm length fabricated by RF sputtering deposition was largely deflected by an internal stress, and the deflection was about 3.6μm. The internal stress depends on the sputtering condition. We numerically analyzed the thermo-optic effect of silica-based core layer enhanced by the strong internal stress in the following way.



(a) Assumed strong internal stress



(b) Stretch by thermal expansion

Fig.2 Numerical analysis steps.

First, the 100μm long beam structure was assumed to suffer a strong internal stress which deflected the beam by 3.6μm (Fig. 2 (a)). When the beam is kept to contact the substrate, a strong stress of the order of 10^9 [Pa] of magnitude is induced to the beam at this time. Next, both the bottom edges are assumed to be stretched by 1nm which corresponds to the thermal expansion of substrate by the temperature increase of 10°C (Fig. 2 (b)). In this occasion, the internal stress is decreased by the order of 10^8 [Pa] of magnitude due to the thermal expansion. The change of the internal stress of a few 10^8 [Pa] can result in the change of refractive index by the order of 10^{-5} of magnitude per degree[4], which almost coincides with the experimental result[3]. The thermo-optic coefficients of TE and TM modes are calculated to be 1.269×10^{-5} [1/K] and 1.053×10^{-5} [1/K], respectively. It was found from this analysis that the photo-elastic effect can be as large as the thermo-optic effect under a strong internal stress, so as to compensate for the temperature dependence of refractive index.

We also analyzed numerically the photo-elastic effect for the case of no intrinsic internal stress. As a result, when both the bottom edges of the beam were expanded in the same way, the change of internal stress was much smaller by 1/100 than the previous case of strong intrinsic internal stress. Therefore, the change of refractive index is negligibly small without the strong intrinsic internal stress.

4. Elimination of polarization dependence

The temperature coefficient of resonant wavelength of the filter with internal stress has a large polarization dependence[3] due to the stress birefringence, compared with conventional microring resonator filters. Therefore, the resonant wavelengths for both polarizations can be equalized at a certain temperature. Fig. 3 shows the temperature dependence of resonant wavelengths of a device with the core width and thickness of 1.4 μm and 0.8 μm, respectively. It is seen that the resonant wavelength for TE and TM polarizations can be equalized at around 70°C. By the precise temperature control, the resonant wavelengths were equalized at 69°C as shown Fig. 4, and a polarization independent filter was successfully realized.

When the spectrum peak of TE polarization is athermalized as realized in Ref. [3], the polarization independent filter can be realized by the temperature control without the wavelength shift of TE peak.

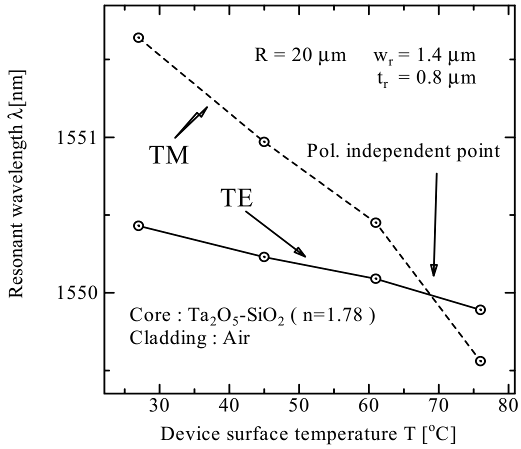


Fig.3 Relation between resonant wavelength and device surface temperature.

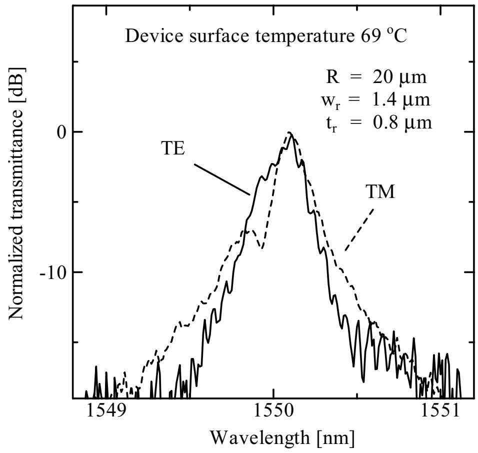


Fig.4 Spectrum response of polarization independent microring resonator filter realized at T=69°C.

Refarrence

1 H. Takahashi, Y. Hibino, and I. Nishi, Opt. Lett., **17**, No.7, p.499, 1992.

2 Y. Kokubun, S. Yoneda and S. Matsuura, IEICE Trans. Electron. **E81-C**, No.8, p.1187, 1998.

3 N. Zaizen, N. Kobayashi, Y. Kokubun, 12th Microoptics Conference (MOC'06), Seoul, G3, 2006.

4 Y. Namihira, M. Kudo and Y. Mushiake, IEICE Trans. Electron. **J60-C**, No.7, p.391, 1977.