Towards Athermal Slotted Silicon Microring Resonators with UV-Trimmable PMMA Upper-Cladding

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Abstract: We demonstrate that PMMA upper cladding on the slotted silicon micoring resonators can reduce the resonance thermal dependence from 91 pm/° to 27 pm/°C. UV trimming can shift the resonance wavelength 0.5 nm.

OCIS codes: (230.5750) Resonators; (130.7408) Wavelength filtering devices

With the advances of the silicon photonics technologies [1, 2], silicon submicrometer waveguide-based on-chip optical interconnect has proven to be a feasible alternative to the conventional metal wire connection in resolving the bandwidth and power bottleneck. However, due to the large thermal-optic (TO) coefficient of the silicon material, small ambient temperature variation will cause a significant refractive index change, and hence change the photonic device performances.

Here we present slotted microring resonators with PMMA upper-cladding to reduce their resonance temperature dependence. The electrical field in the slotted waveguides is highly concentrated in the slot region for TE polarization (electric field parallel with the chip plane) and hence it can interact more with the filled material inside the slot [3-5]. PMMA has the opposite thermal-optic (TO) coefficient to the core silicon material, and thus by proper design, the resonances of the slotted microring resonators can be maintained steady under temperature variations [6]. The PMMA layer can also be trimmed by UV light, such that the resonance wavelength can be precisely controlled.

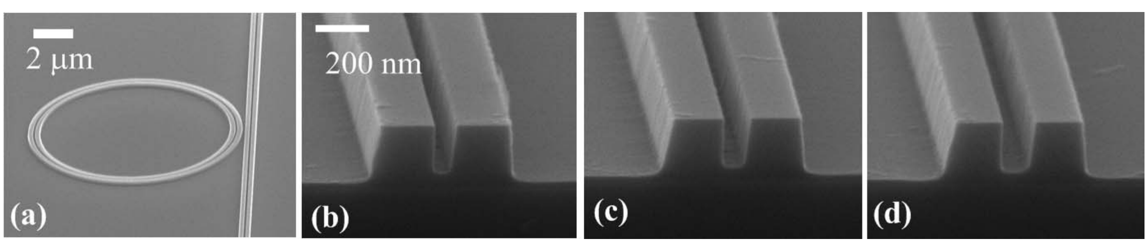

Fig.1. (a) Scanning electron microscope (SEM) image of a slotted microring resonator. Microring resonator radius is 5 μm. (b)-(d) Zoom-in SEM images of the slotted waveguide cross-section with various slot widths of (a) 100 nm, (b) 120 nm, and (c) 140 nm. Waveguide width is fixed at 0.5 μm.

We fabricated the slotted microring resonator devices using a silicon-on-insulator (SOI) wafer with top silicon layer thickness of 0.26 μm and buried oxide (BOX) layer thickness of 2 μm. The wafer was exposed using Raith 150 e-beam lithography system and directly dry-etched using HBr-Cl_2 gas-based reactive-ion-etching (RIE) in a Transformer Coupled Plasma (TCP) Lam Etcher. The dry etched depth is ~0.21 μm.

Figure 1(a) shows the scanning electron microscope (SEM) image of the fabricated slotted microring resonator. The microring resonator radius is 5 μm. The slotted waveguide width is 0.5 μm with a thin slot in the waveguide center. The gap between the mirroring resonator and straight waveguide is 0.15 μm. Note that slotted waveguides

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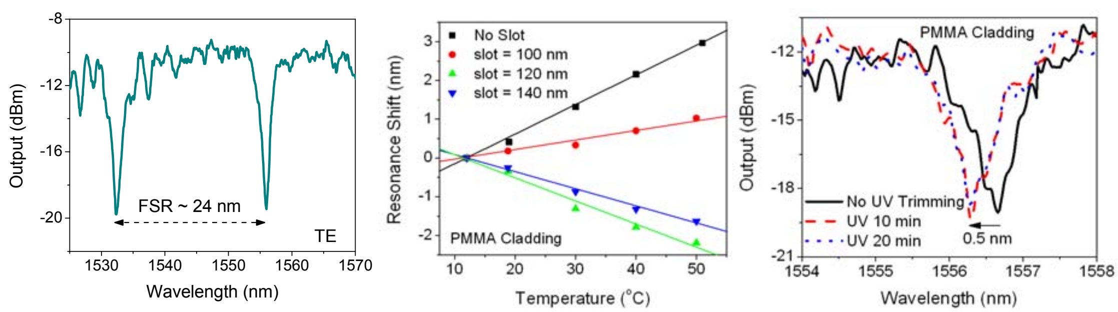
are used for both the straight waveguide and microring resonator waveguide for better coupling (phase matching) between them. Figures 5(b)-(d) show the zoom-in views of the slotted waveguide cross-sections with three different slot widths of 100 nm, 120 nm and 140 nm. As the waveguide width is fixed at 0.5 μm, the two silicon strips forming the slotted waveguide are narrowed for the wider slot.

Figure 2(a) shows the measured TE-polarized transmission spectrum of the slotted micoring resonator with 140 nm slot width. The resonance free spectral range (FSR) is ~24 nm, and the group index is deduced to be $n_g \approx 3.2$. The resonance Q-factor is ~10^3 and resonance extinction ratio is ~9 dB. Figure 2(b) show the resonance shift as a function of substrate temperature with PMMA cladding. The resonance shift curves for a regular microring resonator (no slot) are also included as a comparison. Regular microring resonator has the highest thermal sensitivity of 76 pm/^{o}C and the slotted microring resonator with 100 nm slot has the lowest thermal sensitivity of 27 pm/^{o}C. Both the slotted microring resonators with 120 nm and 140 nm have negative thermal sensitivity, which indicates that their thermal coefficients are both over-compensated by PMMA upper cladding.

UV trimming of the PMMA cladding also provides a convenient way to accurately control the resonance wavelength. PMMA layer can change its refractive index upon UV light radiation, and as a result, the resonance wavelengths can be changed. Figure 2(c) shows the resonance spectra before and after UV trimming for the slotted microring resonator with 100 nm slot. The resonance wavelength blueshifted ~0.5 nm after 10 min trimming,



(a) (b) (c)

Fig.2. (a) Measured TE-polarized transmission spectrum for the slotted microring resonator with 140 nm slot width. (b) Resonance shift varies as a function of substrate temperature for the slotted and regular (no slot) microring resonator devices with PMMA-cladding. Straight lines are the linear fitting. (c) Resonance shift upon UV trimming of the slotted microring resonator with PMMA cladding.

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