

Altermalization rolled-up TiO₂ microtube ring resonator for both visible and telecom photonics

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Abstract

One important concern in integrated optics is thermal heating which leads to the unwanted wavelength shift in the integrated system. This shift oftentimes is not suitable for some important applications e.g. optical filtering and switching and etc.. To this end, one needs to fabricate the athermal optical devices instead of the conventional optical devices in the integrated system. In this work, for the first time a hybrid TiO₂-SiO₂ and/or (TiO₂-Si₃N₄) rolled-up microtube ring resonator (RUMRs) with a temperature insensitive resonance (i.e. athermal) is theoretically and experimentally demonstrated. In the first part of this paper, the thermal stability of optical filters based on self-assembled TiO₂ RUMRs by incorporating positive thermo-optic coefficient (TOC) materials (e.g. SiO₂ and/or Si₃N₄) is investigated. The influence of the TOC, refractive index, and thickness of the positive TOC materials on the filtering performance of the TiO₂ RUMRs are theoretically studied. The results illustrate that an increase in temperature leads to a blue-shift in resonant wavelength of the RUMR-based optical filter, which changes at a rate of -33.3 pm/K owing to the negative TOC of TiO₂ ($-4.9 \pm 0.5 \times 10^{-5} k^{-1}$). By increasing the thickness of SiO₂ or Si₃N₄ as a positive TOC material together with TiO₂ the temperature-induced resonant shifts (TIRSs) of TiO₂/SiO₂ and/or TiO₂/Si₃N₄ RUMRs are theoretically obtained. The TIRS varies between -40 pm/K (-22 pm/K) and about 30 pm/K (22 pm/K) for TiO₂/SiO₂ (TiO₂/Si₃N₄) RUMRs. It is shown that thermal stability occurs when the thickness of the SiO₂ (Si₃N₄) layer is ~16 nm (12 nm). In the end of this study, for a proof-of-concept, an experiment is demonstrated by fabricating isolated RUMRs (i.e. not coupled to the waveguides) based on TiO₂/SiO₂ on the flat silicon wafer. In order to study the resonance-temperature-(in-)sensitive, the fabricated devices are excited using He-Cd laser ($\lambda = 442nm$) under different input power via a conventional micro-photoluminescence (μ -PL) setup. The experimental results are represented that by selecting the appropriate thickness ratio of TiO₂/SiO₂, the non-shift (and/or athermalization) of the optical modes is achieved.

It is also shown that by reducing (increasing) the thickness of SiO₂, the blue-shift (red-shift) of the optical modes is observed. This novel approach for athermalization of optical resonators opens up interesting perspectives toward the implementation of vertical and multi-routing coupling between photonic and optoelectronic layers and more specifically in a 3-integration fashion.

Biography:

Abbas Madani is a professor in Cambridge Graphene Centre, and studied in University of Cambridge, Cambridge UK. In 2014, he also joined the Institute Of Integrated Nanoscience and left in 2018.

[16th International Conference on Optics, Lasers & Photonics](#); Prague, Czech Republic- August 20-21,2020.

Abstract Citation :

Abbas Madani, Optical filtering, Optical switching, 3D photonic integration, Self-rolled-up microtubes, Optical ring resonators., Optic Laser 2020, 16th International Conference on Optics, Lasers & Photonics; Prague, Czech Republic- August 20-21, 2020