Thermally Tunable Silicon Topological Photonic Add-Drop Filter

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Abstract: By exploiting the robust transport of light along the edges formed by two types of valley photonic crystals, we experimentally demonstrated a thermally tunable silicon topological photonic add-drop filter in the telecom band. © 2022 The Author(s)
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1. Introduction

Valley photonic crystals (VPCs) provide an intriguing approach to suppress backscattering at sharp turns and realize topologically protected transport of light with all-dielectric structures in the telecom band [1-4]. However, the studies on the thermo-optic devices based on VPCs are still missing in literature. Here, we propose and experimentally demonstrate a silicon topological photonic add-drop filter which can be thermally tuned at telecom wavelengths.

2. Results and Discussions

Figure 1(a) presents the topological photonic crystal (TPC) edge formed by two types of VPCs, VPC1 and VPC2. They have the same band structure shown in Fig. 1(b), where the band gap covers a wavelength range of 1504 - 1600 nm. The H_z field distribution of the edge mode in one period along the x direction is calculated and depicted in Fig. 1(c). By using topological edges between the two VPCs, we can build an add-drop filter as schematically illustrated in Fig. 1(d). To evaluate its performance, we simulate the device using 3D FDTD methods. The on-resonance electric field distribution and the transmission spectra at the through and drop ports are plotted in Figs. 1(e) and 1(f), respectively.

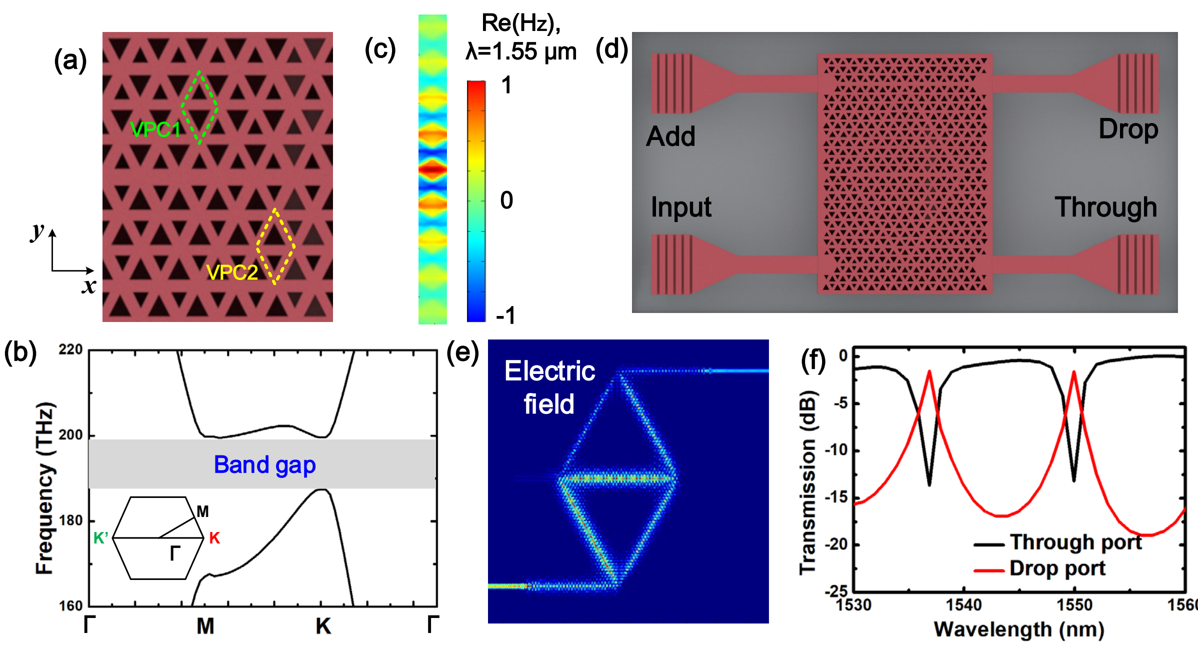

Fig. 1. (a) Topological edges formed by two types of VPCs, VPC1 (in the green dashed rhombic circle) and VPC2 (in the yellow dashed rhombic circle). The red and black colors represent silicon and silica, respectively. The lattice constant is a = 430 nm. The side lengths of the big and small triangular holes are d_1 = 290 nm and d_2 = 170 nm, respectively. (b) Band structure of the VPCs with the reciprocal space shown in the inset. The band gap is shaded in grey. (c) H_z field distribution of the edge mode in one period along the x direction. (d) Schematic of the VPC-based add-drop filter. The edge mode in the TPC is excited by the TE mode in a 900 nm-wide silicon strip waveguide. (e) Simulated electric field distribution in the TPC when the rhombic microloop is on resonance. (f) Transmission spectra at the through and drop ports of the add-drop filter.

The device was fabricated on a SOI wafer (220 nm-thick silicon on 3 μm-thick BOX) using E-beam lithography (Vistec EBPG 5200+) followed by inductively coupled plasma dry etching (SPTS DRIE-I). Then, a 1-μm-thick silica cladding layer was deposited over the devices by plasma enhanced chemical vapor deposition (PECVD, Oxford Plasmalab System 100). After that, titanium (Ti, 100 nm) was sputtered on the silica to form the 2-μm-wide microheaters. Gold (Au, 300 nm) was evaporated to define the electrical wires and contact pads using a lift-off process. The SEM images and the micro photo of the fabricated device are shown in Figs. 2(a) and 2(b), respectively. In the measurements, TE-polarized light from a tunable laser (Keysight 81960A) was coupled into and out of the chip by grating couplers. An optical power meter and a photodetector (Keysight 81636B) were used for optical calibration and receiving the transmitted power, respectively. A voltage-current source-meter (Keithley 2400) was employed to implement the thermo-optic tuning. Figure 2(c) presents the measured transmission spectra at the through and drop ports of the filter with different heating powers, which are all normalized to that of a reference grating coupler pair fabricated on the same wafer. The insertion losses are less than 5 dB and the extinction ratios are higher than 10 dB in a wavelength range of 1535 - 1547 nm. The 3-dB bandwidths are ~1.5 nm. The tuning efficiency is 0.176 nm/mW, as shown in Fig. 2(d).

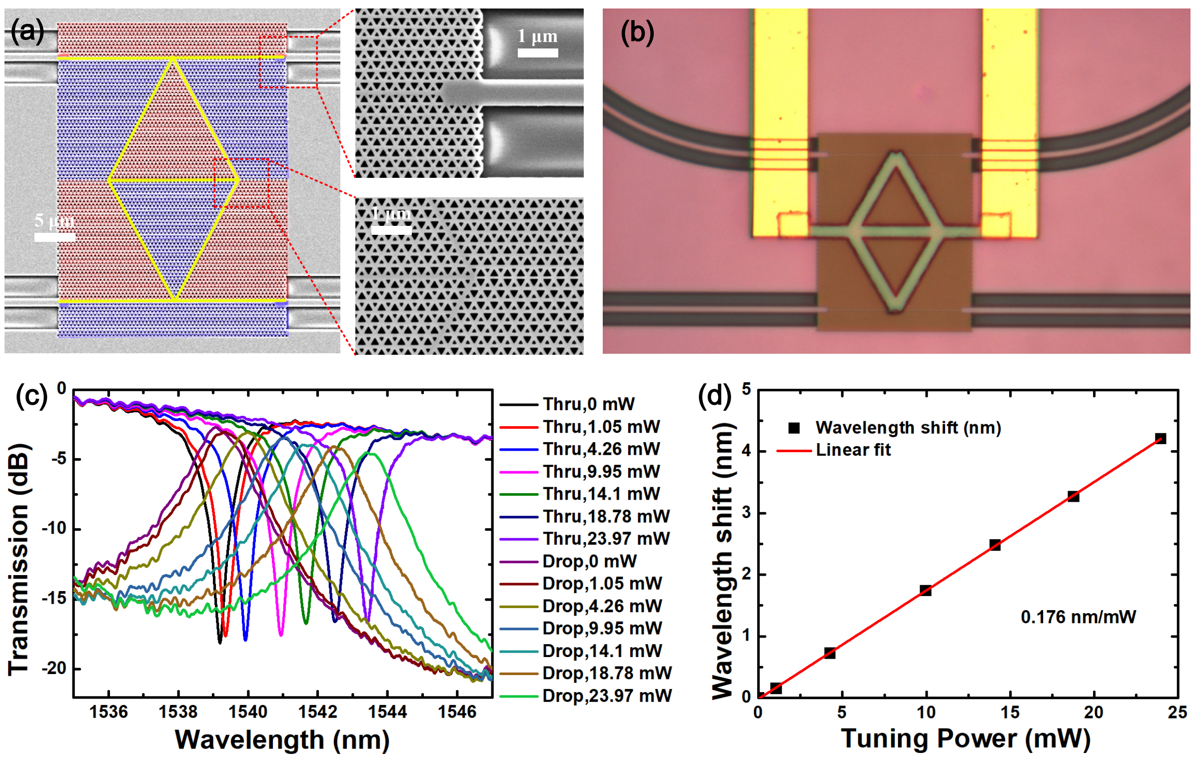

Fig. 2. (a) SEM images of the TPC add-drop filter. The VPC1 and VPC2 areas are shaded in red and blue, respectively. The waveguiding edges are highlighted in yellow. The zoom-in SEM images of the areas encircled by the red dashed boxes are shown in the insets. (b) Micro photo of the fabricated device. The grey part is the titanium microheater while the golden strips are the electrical wires linked to the contact pads. (c) Measured transmission spectra at the through and drop ports of the fabricated device with various tuning powers. (d) Fitting curve of the resonance wavelength shift as a function of the tuning power.

3. Conclusion

In conclusion, we have proposed and experimentally demonstrated a thermally tunable silicon topological photonic add-drop filter. Thanks to the high confinement of light enabled by TPCs and therefore the efficient interaction of light with the thermal field generated by the microheaters, thermally tunable add-drop filtering phenomena have been observed in a wavelength range of 1535 - 1547 nm, with overall insertion losses less than 5 dB, extinction ratios over 10 dB, 3-dB bandwidths of ~1.5 nm, and a tuning efficiency of 0.176 nm/mW. Our results show potential for implementing thermo-optic topological photonic devices based on VPCs which have never been reported before.

4. References

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