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Thermo-optic phase shifter based on amorphous silicon carbide

Elisa D. Mallemace[1,2], *Yaoqin* Lu[2], *Xiaodong* Shi[2], *Didier* Chaussende[3], *Vincent* Tabouret[3], *Sandro* Rao[1], *Haiyan* Ou[2,*], *Francesco G.* Della Corte[4]

[1]Mediterranea University of Reggio Calabria, DIIES Dept., 89124 Reggio Calabria, Italy
[2]Technical University of Denmark, DTU Electro, 2800 Lyngby, Denmark
[3]Université Grenoble Alpes, CNRS, Grenoble INP, SIMaP, 38000 Grenoble, France
[4]University of Naples Federico II, DIETI Dept., 80125 Naples, Italy

Abstract. We report the preliminary experimental results for an amorphous silicon carbide (a-SiC) thermo-optic phase shifter (TOPS). This device is based on microring resonator (MRR) structure with a titanium (Ti) heater placed on the top of the device, separated by 1.5 μm thick SiO_2 to reduce the optical loss. The proposed a-SiC microring has a thickness and a radius of 1.1 μm and 33 μm, respectively. By applying an electrical power in the Ti heater, a resonance wavelength shift at an optical wavelength of λ=1550 nm is shown, and the extracted thermal tunability is 52.2 pm/mW.

1 Introduction

Silicon Carbide (SiC), a wide bandgap semiconductor material, is emerging as a promising platform for photonic integrated circuits (PICs) [1]. By taking advantage of the wide bandgap of SiC, which enables a wide transparency window from visible to mid-infrared, and combing it to other excellent properties, such as high thermal conductivity, strong second and third order non linearities it has attracted attention for nonlinear optics, optoelectronics, and quantum photonics applications.

Among its many polytypes, 3C-SiC, 4H-SiC, and 6H-SiC are the most common employed for photonics applications. In recent year, these materials have been extensively investigated to realize PIC platforms in which a good light-confinement is reached, and several SiC-on-insulator (SiCOI) platforms are successfully reported. Although SiCOI platform, especially 4H-SiCOI [2], has reached good performances with low propagation losses, the large-scale realization is technologically challenging as it requires expensive and complicated fabrication process. As an alternative, the direct deposition of amorphous silicon carbide (a-SiC) on a SiO_2 layer provides an easy, low cost as well as CMOS-compatible way for the realization of SiC PIC platforms [3].

For PICs, one important functionality is the tunability of the material optical properties enabled by electro-optic and thermo-optic effect. The thermo-optic effect, consisting of the variation of the refractive index due to a temperature change, allows the design of devices with small size, large scalability, and low power consumption. The drawback could be the operating speeds (response time of a few microseconds) [4]. The study of the thermo-optic effect in a-SiC has been previously investigated by the same authors [5,6].

In this work, we carry out a preliminary study on the fabrication and experimental investigation of the thermo-optic effects in a microring resonator based on a-SiC.

2 Device structure

We fabricated the microring resonators on a silicon wafer with a 2.5 μm-thick thermally growth SiO_2, on which a 500 nm-thick a-SiC film was deposited using plasma-enhanced chemical vapor deposition (PECVD) technique.

The a-SiC film is patterned by electron-beam (e-beam) lithography (EBL), and an inductive coupled plasma-ion etching (ICP-RIE) is used to etch it. The microring resonator width and radius are 1.1 μm and 33 μm, respectively. The coupling gap between bus and microring waveguides is designed to range from 260 to 440 nm.

Then, a 1.5 μm thick SiO_2 layer is deposited as cladding layer using PECVD on the top of the a-SiC microring. This way, optical losses are kept low and an efficient heat transfer from the heater to microring is achieved. Finally, 200 nm thick titanium (Ti) heater patter is defined by EBL, deposited on the top of the device by e-beam evaporator followed by a lift-off process. The width of the Ti heater is 1.4 μm.

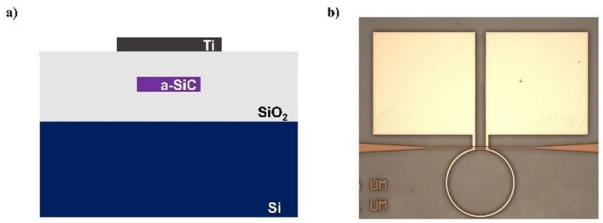

Fig. 1. Schematic cross-section (a), and optical microscope image (b) of the thermo-optic based on a-SiC.

* Corresponding author: haou@dtu.dk

The geometrical parameters of the device are summarized in Table 1. Fig 1a and 1b show the schematic cross-section and an optical microscope image of the fabricated device, respectively.

Table 1. Geometrical properties of the device.

Parameters	Value (µm)
Heater width	1.4
Heater thickness	0.2
Microring width	1.1
Microring thickness	0.5
SiO_2 (substrate) thickness	2.5
SiO_2 (cladding) thickness	1.5

3 Experimental results

The experimental setup used to investigate the performance of the thermally tuned a-SiC microring is schematically illustrated in Fig 2. In brief, the light from a tunable laser (TSL-550, Santec) is launched in the a-SiC bus waveguide through a single-mode fiber and a polarization controller to ensure the transverse electric (TE) polarization mode. The output light is connected to a power meter (MPM-210H, Santec) using another fiber to obtain the transmission spectrum. Finally, the drive signal is applied to the Ti heater by means a source meter (2450, Keithley).

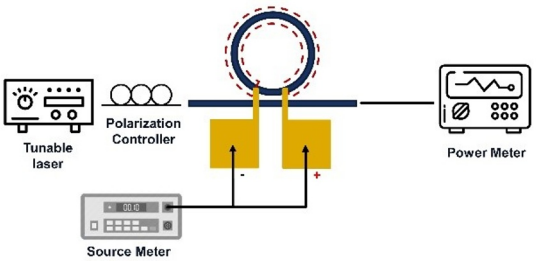

Fig. 2. Sketch of the experimental setup.

To investigate the thermo-optic tunability of the device, the transmission spectrum of the microring under different electrical power applied to the heater is collected. Fig. 3 shows the transmission spectra around the resonance wavelength λ_{res}=1549.1 nm at zero-bias (black line) while applied voltages in Ti heater range from 0 to 12 V.

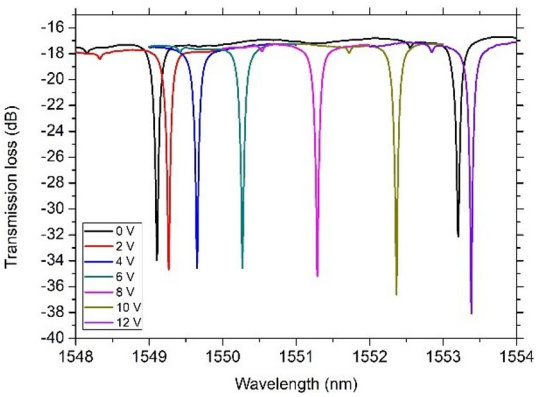

Fig. 3. Transmission spectrum under different applied voltage to metallic heater.

It is observed that the resonance wavelength of a-SiC microring is red-shifted as the applied voltage increases. Without the external bias, at resonance wavelength, the transmission spectrum shows a drop of approximately 16 dB, with a free-spectral range (FSR) of 4.1 nm.

In Fig. 4 the linear fitting of the resonance wavelength shift as function of the applied power in Ti heater is reported, and 52.2 pm/mW of thermal tunability is evaluated.

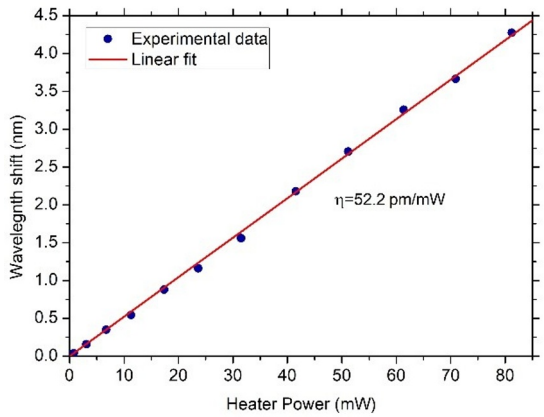

Fig. 4. Resonance wavelength shift as a function of the applied power to microheater.

4 Conclusions

In conclusion, the preliminary study about the fabrication and characterization of a thermo-optic phase shifter based on amorphous silicon carbide (a-SiC) is reported. The proposed device is defined by integrating a Titanium (Ti) heater on the top of 33 µm radius a-SiC microring resonators. The transmission spectra of the microring under different voltage applied to the heater is evaluated. It demonstrates that, as the applied voltage increases, the resonance wavelength is red-shifted, and the applied power-dependent wavelength shift of 52.2 pm/mW is extracted.

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