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Amorphous silicon-carbide modulator based on the thermo-optic effect

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In recent years, silicon carbide (SiC) has gained increasing attention as a promising platform for optoelectronic applications due to its excellent optical, thermal, and mechanical properties, such as wide bandgap, large refractive index [1,2]. Among its more than 200 polytypes, 3C, 4H and 6H are the three most commonly employed in electronic and optoelectronic applications. Although they are widely investigated, they require complicated and expensive processes to realize good light-confinement structures with strong refractive index contrast. One of the most common solutions is the SiC-on-insulator (SiCOI) integrated platform. An alternative solution could be the use of amorphous silicon carbide (a-SiC), widely investigated due to its potential in optical applications, especially the fact that it can be directly deposited on SiO_2-on-Si substrates, achieving a platform for low-cost and large-scale CMOS compatible processes [3-4].

In this work, we present preliminary results about the design, fabrication and characterization of an a-SiC thermo-optic (TO) modulator based on a microring resonator. Although in literature there exist examples of TO phase shifters, to our knowledge this is the first TO modulator based on a-SiC.

The microring resonator fabrication begins with 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 refractive index of a-SiC is 2.45 at the wavelength of 1550 nm. The designed pattern of the microring is defined by electron-beam lithography (EBL) and inductive coupled plasma-ion etching (ICP-RIE). Then, a 1.5 μm-thick top cladding PECVD SiO_2 is deposited to separate the microring from the heater, preventing optical losses. Finally, the heater is formed on the top of the device by EBL, subsequent to the deposition of 200 nm-thick titanium with a width of 1.4 μm, and lift-off. The a-SiC microring is defined by a waveguide width of 1.1 μm, a radius of 30 μm, and a coupling gap between the bus and the ring ranging from 260 to 420 nm. An optical microscope image and the corresponding schematic cross-section are reported in Fig. 1.

The spectral response of all the fabricated devices was characterized through a tuneable laser source (TSL-550, Santec) and the output light was detected by a power meter (MPM-210H, Santec). Then, in order to ensure that only TE modes could propagate through the microring, a polarization controller was used. The constant bias voltage is applied to the heater by means of a source meter (2450, Keithley). To detect the dynamic response of the thermo-optic modulator, a pulsed electrical signal from a waveform generator was applied, while the transmitted signal was collected by a commercial photodetector, the output of which was connected to an oscilloscope. The experimental setup is shown in Fig. 2.

To evaluate the static thermo-optical response of the modulator as temperature changes, the transmission spectrum was monitored under different electrical power applied to the heater. As the applied power increases, the temperature of the microring resonator increases, and a red-shift in the resonance wavelength is induced, consequently. Starting from the resonance wavelength around the fiber-optic communication wavelength (λ=1550 nm), its shift as a function of the applied power is evaluated (Fig. 3a). The expected linear response has allowed extracting a thermal tunability of 52.2 pm/mW.

Concerning the dynamic response, shown in Fig 3b, a 10 kHz square wave with an amplitude V_{pp}=2V, such that the heater dissipates 3 mW power, was applied to the heater while an optical beam at a resonance wavelength λ=1549 nm was launched into the microring. Finally, the rise and fall time of the thermo-optic modulator were evaluated to be 16 μs and 13 μs, respectively. The modulation depth, at the considered frequency, is higher than 90%.

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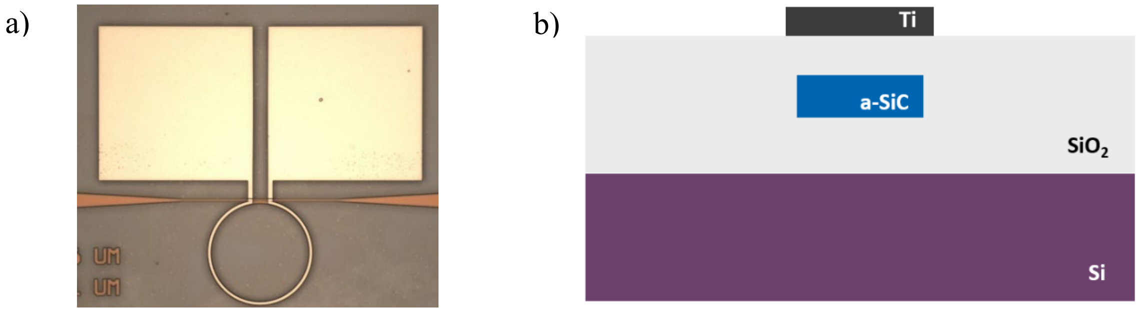

Fig. 1. Optical microscope image detail of microring and microheater (a), schematic cross-section (b).

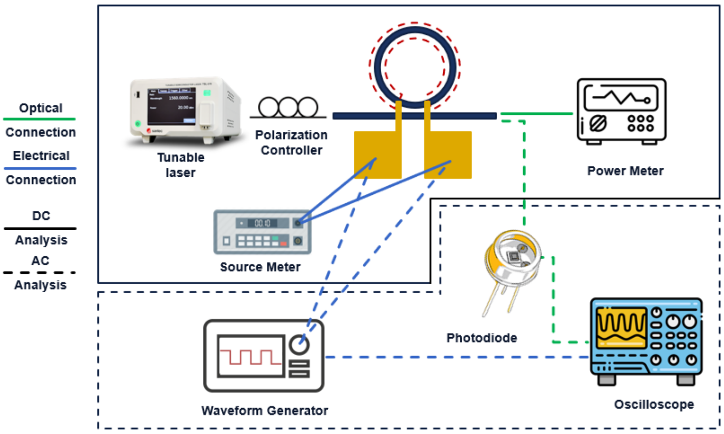

Fig. 2. Experimental Setup.

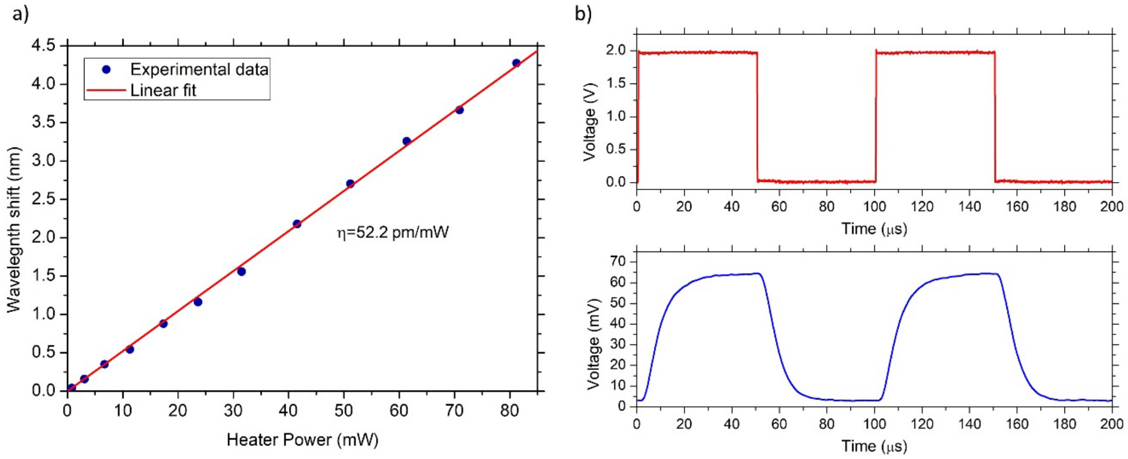

Fig. 3. Experimental results: static behaviour, wavelength shift as a function of the applied power (a), dynamic results, f=10 kHz square electrical drive signal (top), and modulator optical response (bottom) (b).