PECVD Silicon Oxycarbide for Integrated Photonics

Christian De Vita**, Francesco Morichetti, Andrea Melloni

Dipartimento di Elettronica, Informazione e Bioingegneria (DEIB)
Politecnico di Milano, Via Ponzio 34/5, 20133 Milan
**christian.devita@polimi.it*

We report on CMOS compatible high-refractive-index contrast Silicon Oxycarbide (SiOC) waveguides for integrated optic applications. This photonic platform exhibits wide refractive index tunability, high thermo-optic coefficient K=4.58x10 $^{-5}$ °C $^{-1}$,high TPA threshold 5.57 x 10-3 GW/cm^2 and also high nonlinear refractive index 3.29 x 10-14 cm^2/W.
***Keywords**: Photonics, Integration*

1. Introduction

Refractive index contrast is a key metric for the scalability of photonic integrated circuits (PICs). On the one hand a higher index contrast enables device footprint reduction and denser circuit integration, on the other hand it generally implies higher scattering loss. Therefore, materials with wide refractive index tunability are of large interest to tailor the working point of the waveguides to specific applications.

Recently we demonstrated that the refractive index of Silicon Oxycarbide (SiOC) deposited by magnetron sputtering can be controlled from 1.45 (SiO_2) to almost 3 (SiC) by modifying the reciprocal ratio of Si, O and C, while keeping very low propagation loss in the near-IR wavelength range [1]. In this work we investigate the optical properties of SiOC waveguides and PICs realized by using a PECVD deposition process. Wide refractive index tunability, high thermo-optic and nonlinear coefficients are observed, confirming the potential of the SiOC platform for integrated photonic applications.

2. SiOC fabrication and characterization

The PECVD deposition of SiOC thin films was performed at 300 °C by using SiH_4, CF_4 and N_2O precursors gases, and N_2 as carrier gas. The process is compatible with CMOS production lines. The reciprocal ratios between the three gas precursors determines the refractive index of the deposited SiOC film; in particular the N_2O precursor, acting as oxygen source, played a key role, as shown in Fig. 1. Morphological and optical (spectroscopic ellipsometry) characterization show that the SiOC films are compact (no porosity) and transparent from the visible (600 nm) to the near-IR (1700 nm) range.

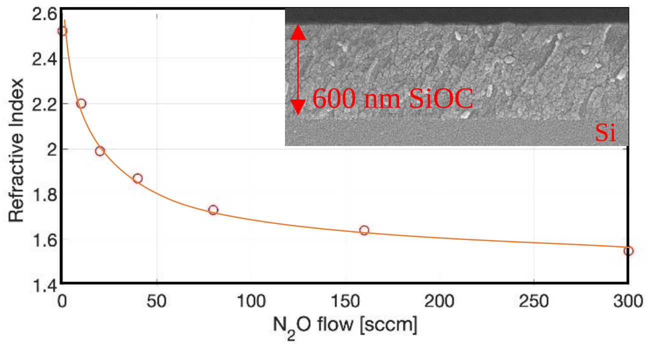

Fig. 1 Measured refractive index of SiOC films versus N_2O flow.. SEM cross section of the deposited film (inset).

For the realization of optical waveguides we selected a SiOC compound with energy bandgap of 2.3 eV, corresponding to a refractive index n = 2 at 1550 nm. The patterning of the film was performed by direct optical lithography followed by RIE-ICP etching in a plasma of CHF_3 and O_2. This resulted in a rectangular shaped waveguide core (1.5 µm x 0.6 µm) on top of 4 µm thick SiO_2 bottom oxide and air upper cladding. Waveguide propagation is about 4 dB/cm at 1550 nm.

As a device demonstrator we successfully realized a microring resonator with a 200 µm radius (see inset of Fig. 2) with a measured Q_{factor}=23.000 and a bandwidth B = 8.5 GHz. By measuring the wavelength shift of the microring frequency response versus temperature, we derived a thermo-optic coefficient K = 4.58 x 10^{-5} °C^{-1} (x 3 times higher than Si_3N_4).

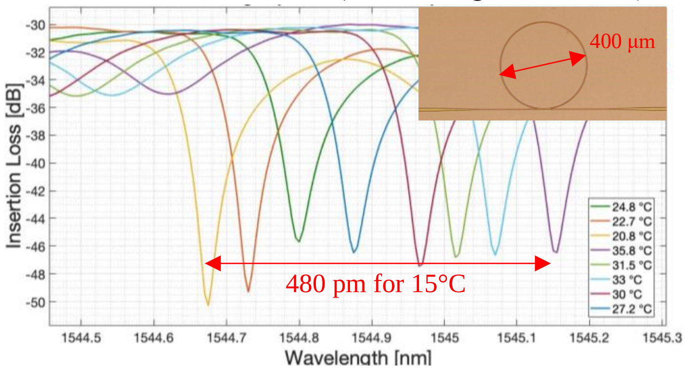

Fig. 2. Wavelength shift of a SiOC microring resonator (top view photo in the inset) versus temperature .

Preliminary high power measurements also reveal a two photon absorption (TPA) threshold of 4.456 x 10^{-2} GW/cm^2 (x 2 times higher than silicon waveguides) and a nonlinear refractive index n_2=3.29 x 10^{-14} cm^2/W (x 13 times higher than Si_3N_4 waveguides [2]), thus making SiOC a promising material for nonlinear applications. A detailed comparison between the optical properties of sputtered and CVD SiOC films and waveguide will be provided.

The work was mainly performed at Polifab, the micro- and nanofabrication facility of Politecnico di Milano.

1. F.A Memon., et al., High Thermo-Optic Coefficient of Silicon Oxycarbide Photonic Waveguides, *ACS Photonics* 2018.
2. Kazuhiro Ikeda, et al., Thermal and Kerr nonlinear properties of plasma-deposited silicon nitride/ silicon dioxide waveguides, *Optics Express* 2008.