

Integrated waveguide and micro-ring resonator polarizers via integrated 2D graphene oxide films

David Moss ¹

¹swinburne university of technology

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Abstract

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Yang Qu^a, Jiayang Wu^a, Yunyi Yang^b, Xingyuan Xu^a, Yao Liang^a, Sai T. Chu^c, Brent E. Little^d, Roberto Morandotti^e, Baohua Jia,^b and David J. Moss^{a,*}

^aOptical Sciences Centre, Swinburne University of Technology, Hawthorn, VIC 3122, Australia

^bCentre for Translational Atomaterials, Swinburne University of Technology, Hawthorn, VIC 3122, Australia

^cCity University of Hong Kong, Tat Chee Avenue, Hong Kong, China

^dXi'an Institute of Optics and Precision Mechanics Precision Mechanics of CAS, Xi'an, China

^eINRS –Énergie, Matériaux et Télécommunications, 1650 Boulevard Lionel-Boulet, Varennes, Québec, Canada

Abstract: We experimentally demonstrate integrated waveguide and micro-ring resonator polarizers incorporating two-dimensional layered graphene oxide films, with a high polarization dependent loss of 53.8 dB and a high polarization extinction ratio of 8.3 dB, respectively.

1. Introduction

Polarization control is a fundamental requirement in many optical technologies [1-3]. Integrated polarization selective devices based on complementary metal-oxide-semiconductor (CMOS) compatible integrated platforms [4,5] offer competitive advantages of compact footprint, high stability, mass producibility and high scalability as functional building blocks for photonic integrated circuits [2]. Recently, the huge optical anisotropy and broadband response of two dimensional (2D) materials such as graphene and transition metal dichalcogenides have been widely recognized and exploited to implement polarization-selective devices [6-9]. However, none of these demonstrations were based on CMOS compatible platforms. Generally, the integration of 2D materials on CMOS compatible platforms requires layer transfer processes. Despite its widespread implementation, the transfer approach itself is complex, which makes it difficult to achieve precise patterning, as well as flexible placement and large-area continuous coating on integrated devices.

Owing to its ease of preparation as well as the tunability of its material properties [10], graphene oxide (GO) has become a highly promising member of the 2D family. Recently [10], we reported large-area, transfer-free, and high-quality GO film coating on integrated waveguides using a solution-based method with layer-by-layer deposition of GO films. Here, we use these techniques to demonstrate GO-coated integrated waveguide and micro-ring resonator (MRR) polarizers on a CMOS compatible doped silica platform [11]. We achieve highly precise control of the placement, thickness, and length of the GO films coated on integrated photonic devices by using our layer-by-layer GO coating method followed by photolithography and lift-off processes. We measure the performance of the waveguide polarizer for different GO film thicknesses and lengths versus polarization, wavelength, and power, achieving a very high polarization dependent loss (PDL) of ~ 53.8 dB. For GO-coated integrated MRRs, we achieve an 8.3-dB polarization extinction ratio between the TE and TM resonances. These results confirm the high-performance of integrated polarization selective devices incorporated with GO films.

2. Device fabrication and experimental results

Figure 1 (a) shows a schematic of a uniformly GO-coated waveguide polarizer. The waveguides were fabricated from high-index doped silica glass core ($\sim 2 \mu\text{m}$ wide $\times \sim 1.5 \mu\text{m}$ high) surrounded by silica. 1 to 10 layers of GO were uniformly coated on doped silica waveguides. Fig. 1(b) shows the measured Raman spectra of the waveguides without GO and with 2 layers of GO, confirming the integration of GO onto the top surface by the presence of the D (1345 cm^{-1}) and G (1590 cm^{-1}) peaks of GO. Fig. 1(c) is a microscope image of the integrated MRR patterned with 50 layers of GO. The combination of patterning and deposition control of GO films along with large area coating capability is critical for large-scale integrated devices incorporated with GO.

Figure 2 shows the polarization dependent (TE (in-plane) and TM (out-of-plane)) performance for both the 1.5-cm-long uniformly coated waveguides (0-10 layers), left side (i), and the patterned 2-mm-long devices (10-100 layers), right side (ii). Figure 2(a) shows the polarization dependent insertion loss. Figure 2(b) presents the

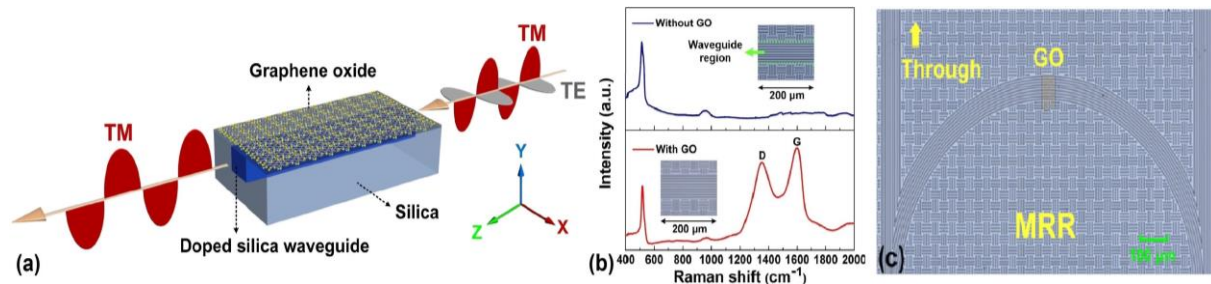


Fig. 1 (a) Schematic illustration of GO-coated integrated waveguide polarizer. (b) Raman spectra of the integrated chip without GO and with 2 layers of GO. Insets show the corresponding microscope images. (c) Microscope images of an MRR patterned with 50 layers of GO.

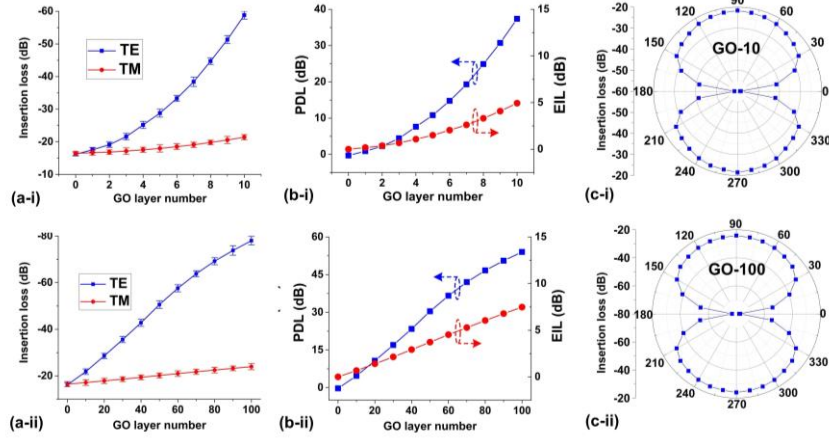


Fig. 2 (a) Measured TE and TM polarized insertion loss. (b) Extracted polarization dependent loss (PDL) and excess insertion loss (EIL). (c) Polar diagrams for the insertion loss. In (a) – (c), (i) shows the results for 1.5-cm-long uniformly coated waveguides (0, 1, 2, ..., 10 layers of GO) and (ii) shows the results for 1.5-cm-long waveguides with 2-mm-long patterned GO (0, 10, 20, ..., 100 layers of GO). The input CW power and wavelength in (a) are 0 dBm and 1550 nm.

polarization dependent loss (PDL), which defined as the ratio of the maximum to minimum insertion losses, and excess insertion loss (EIL), the insertion loss induced by the GO film over the uncoated waveguide. Figures 2(c-i) and 2(c-ii) are the polar diagrams for the insertion loss, respectively. The TE insertion loss increases much more strongly than TM with layer number, thus forming the basis for high-performance polarization dependent devices.

The measured TE and TM polarized transmission spectra of the uniformly GO-coated MRR are shown in Figs. 3(a) and (b), respectively, while the transmission spectra of the patterned MRR are shown in Figs. 3(c) and (d), all measured with the same doped silica MRR at a continuous wave power of ~0 dBm. For the patterned MRR with 50 layers of GO, a maximum polarization extinction ratio (defined as the difference between the extinction ratios of the TE and TM polarized resonances) of ~8.3 dB was achieved. For nonlinear applications[12], compared

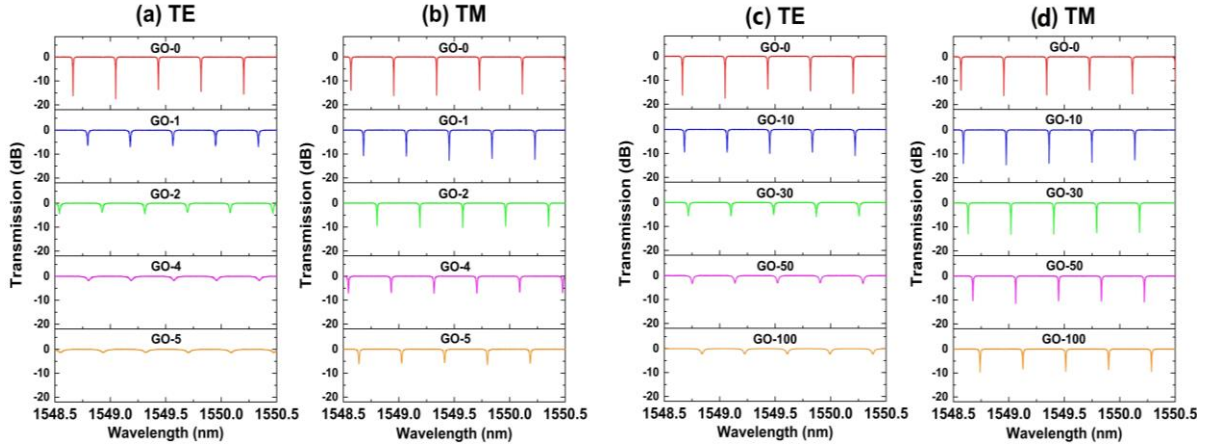


Fig. 3. (a) – (b) Measured TE and TM polarized transmission spectra of the MRR uniformly coated with 0–5 layers of GO. (c)–(d) Measured TE and TM polarized transmission spectra of the MRR patterned with 10–100 layers of GO.

with other 2D materials, n_2 for GO is lower than graphene but still two orders of magnitude higher than bulk silicon [13,14], which demonstrates the high potential of GO as a new optical material for nonlinear photonic applications. Further, like Si-Ge heterostructures, [15, 16] GO may also offer interesting possibilities for both 2nd and 3rd order nonlinear effects courtesy of its complex anisotropic nonlinear optical characteristics.

3. Conclusion

Integrated waveguide and MRR polarizers incorporating 2D layered GO films are experimentally demonstrated with a high polarization dependent loss of 53.8 dB and a high polarization extinction ratio of 8.3 dB, respectively.

4. References

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