Design and Optimization of Graphene based polymer filled Silicon Slot Waveguide

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1. Abstract

A Graphene-caped polymer filled silicon slot waveguide is proposed to enhance the interaction between Graphene layer and propagating optical mode. This is achieved by field intensity enhancement in slot region and consequent optical absorption by Graphene layer. The proposed design is optimized to achieve a low half wave voltage-interaction length product ($V_\pi \times L_\pi$) of 0.05 V-cm, low energy consumption (0.61 pJ/bit), 90 micron length, wide 3-dB modulation bandwidth of approximately 197 GHz and a drive voltage in the range of 2.2 V to 7.8 V. This design is compatible with Complementary metal-oxide-semiconductor (CMOS) fabrication standard.

2. Device Structure and Methodology

The electro optic (EO) phase modulator is designed at 1550 nm on commercially available silicon on insulator (SOI) wafer with two equally and oppositely doped silicon wire waveguides of height H_g (220 nm) forming a slot of width W_S . The charge carriers responds faster to the external bias voltage compared to the confined electric field in slot which improves the modulation speed. One of the silicon wire waveguides is connected to the Pd/Au electrode using silicon slab of height H_S. The slot is filled with non-linear electro-optic polymer (AJSP-100, n_{poly}=1.54 with pockels coefficient r_{33}=65 pm/V) [3] which improves the modulation efficiency and shows instantaneous response to electric field. Graphene (Gr) monolayer of thickness h_{gr} is isolated and positioned on top of silicon slot waveguide by a dielectric spacer hBN of thickness h_{diel}. The proposed structure is simulated in COMSOL multiphysics software and its electrical characteristics are predicted using physically based device simulator ATLAS.

Figures

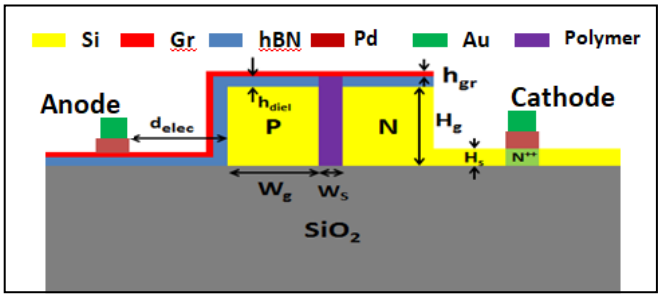

Figure 1: Schematic of Graphene based polymer filled silicon slot waveguide

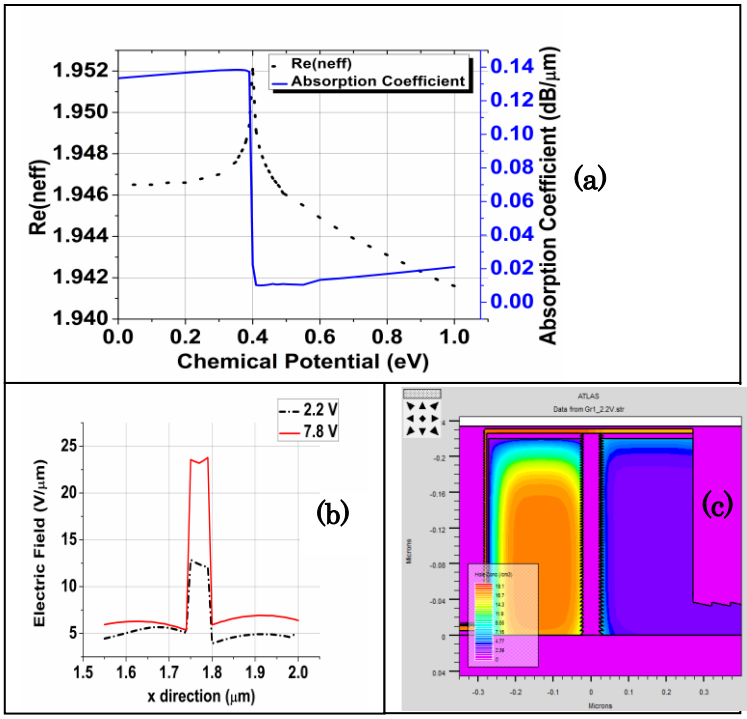

Figure 2: (a) Real parts of effective modal index (neff) and absorption coefficient as a function of chemical potential of Graphene (b) Surface plot of Electric field distribution along x direction at 2.2 V and 7.8 V applied to anode while grounding cathode (c) Hole concentration profile within silicon wire and formation of depletion region between silicon wire and Graphene layer at 2.2 Volt applied to anode while grounding cathode.

3. Conclusions

A Graphene-caped EO phase modulator can be realized using Mach-zehnder interferometer. The proposed design shows a high efficiency of 0.05 V-cm and 3-dB modulation bandwidth of 197 GHz due to strong interaction between propagating optical mode and Graphene monolayer. In future, by further reducing the contact resistance of metal electrode with Graphene as well as by reducing the capacitance between Graphene and silicon wires, the 3 dB modulation bandwidth can be increased manifolds and energy consumption can be reduced. Such designs can successfully contribute to the idea of 'Green photonics'.

References

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