2D material on 1D Photonic Crystal (PhC) Nanowires

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***Abstract*—Graphene has gained much attention since 2004 due to its excellent properties in electronics and photonics applications. With the smallest density footprint as only a small fraction in nanoscale range is required for a wide application; the material is predicted to overcome the limitation of other bulk semiconductor materials. A single layer of graphene can absorb 2.3% of light and as the number of layer increased, the light absorption will increased additively. We report the FDTD simulation of a single layer of graphene together with the 1D Photonic Crystal (PhC) nanowires for future optical interconnect development. The PhC nanowire is constructed by using Silicon with a series of nanoholes inside with a cavity of 330 nm to guide the C-band wavelength. The photonic band-gap is being designed to be from 1250 nm to 1750 nm. The resonance wavelength obtained is at 1553.26 nm and with a single layer of graphene applied on top of the PhC nanowire, the shift in wavelength of 0.32 nm is obtained. It is observed that the transmission performance also deteriorates where the peak obtained shows a reduction of 0.001.**

Keywords—Graphene; Photonic Crystal; Optical Interconnect; cavity; FDTD .

I. INTRODUCTION

The limitation of data microprocessing speed at a small scale has nearly comes to its bottleneck [1]. The limitation is due to the quantum tunneling effect and other fundamental aspect at the small scale of existing material and device technology [2]. Another approach to overcome this problem has resurfaced where photonics technology has been predicted to be used for a smaller size of device with higher performances in data processing. Photonic Crystal (PhC) nanowires has come into the attention of researchers to overcome the limitation of electrical interconnect in microprocessors.

PhC nanowires can be tailored to act as a filter to only allow the specific wavelength by introducing a set of nanoholes in the waveguide structure. By introducing the holes, and with a proper 1D arrangement, the resonance wavelength and the transmission value can be varied accordingly [3].

2D materials has come to the attention of many researchers due to their phenomenal electrical and optical properties. Graphene has been intensively researched since it first isolation by Novoselov *et. al* in 2004 [4]. The absorption coefficient of graphene is 2.3% but with short interaction length [5]. The absorption coefficient will increased additively with the number of layers [6].

II. DEVICE SIMULATION MODEL

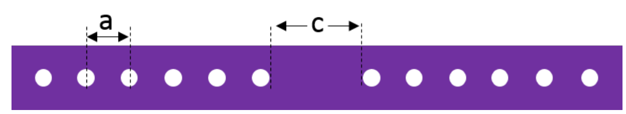

Fig. 1. Single cavity nanowire with a width W: 500 nm, length: 7 µm, depth of 260 nm and six periodic mirror with lattice constant a: 320 nm, cavity 330 nm and radius r: 75 nm

The PhC nanowire is designed with a width W of 500 nm, length L of 7 µm and thickness depth of 260 nm Silicon guiding layer consisting of 12 periodic holes with a, 320 nm. Fig. 1 shows the splitting of 6 periodic holes (mirror) with a cavity of 330 nm in between for light confinement at C-band wavelength region. The model was simulated using 3D-FDTD. The light source is a continuous wave (CW) broadband light. The light source was injected into the nanowire at one end and then measured at the other end of the device for the transmission performance.

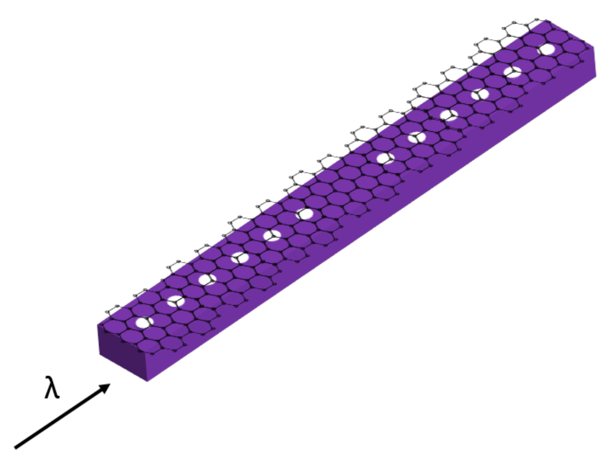

Fig. 2. Single cavity nanowire with a width W: 500 nm, length: 7 µm, depth of 260 nm and six periodic mirror with lattice constant a: 320 nm, cavity 330 nm and radius r: 75 nm and with single layer graphene on top of the waveguide

The simulation was repeated with the addition of single layer graphene (SLG) on top of the waveguide as shown in Fig. 2.

III. RESULTS AND DISCUSSION

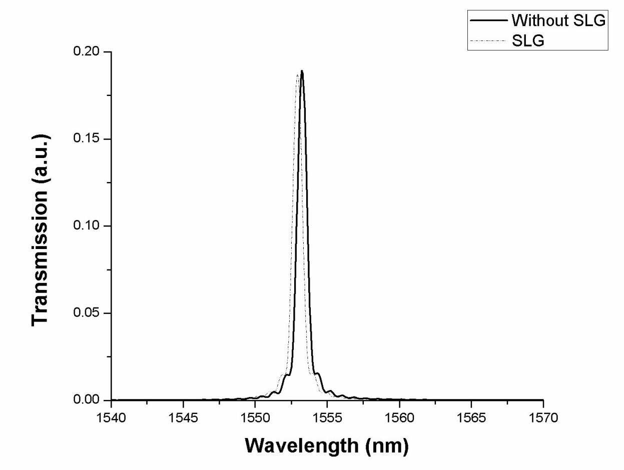

Fig. 3. The resonances of the simulated device without and with SLG at C-band wavelength

Fig. 3 shows the resonance wavelength obtained for simulated PhC nanowire without SLG is 1553.26 nm with the transmission value of 0.189. The values obtained is due to the confinement of the desired wavelength in the respective designed holes diameter and length of cavity. The transmission obtained is less than 50% due to the number of holes introduced where the more holes introduced in the nanowire, the lossier the waveguide will become. This can be prevented by reducing the number of holes with a taper holes so that there will be a mode match in the transmission to obtain a balance of good confinement and transmission.

With the introduction of graphene layer, the transmission value is reduced to 0.188. This is due to some of the light is being absorbed in the graphene layer. It is noted that the resonance wavelength is shifted by 0.32 nm. The shifted in wavelength is due to the changes in the effective index of the nanowire due to the different refractive index introduced by the graphene layer.

IV. CONCLUSION

The designed nanowires can be utilized for future interconnect to overcome the limitation of existing interconnect application. With the massive data transmission in photonics application with a smaller dimension of wire, a small footprint of devices can be achieved. The performance of the devices can be tailored to a very precise wavelength selection and not only limited to C-band application but other band of wavelengths as well. With the aid of 2D materials such as graphene, the application of this devices can be broaden not limited to interconnect but also for other applications such as modulators and photodetectors.

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