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Refractive Index of SIC Nano Composite

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ABSTRACT

Graphene and silicene are currently attracting the interest of many researchers in the field of material science due to some unique material properties [1]. Graphene is also very advantageous in the field of electronics and telecommunication industries but zero band gap of graphene is really a problem to use it in electronic devices [2]. In this paper, we calculate the refractive index of silicon carbide (SiC) nanocomposite (a composite prepared by combining graphene and silicene). Since SiC nanocomposite possesses band gap and it has higher mechanical stability than existing silicon, it can be used in electronic devices.

Keywords: *Graphene, silicene, silicon-carbide nanocomposites, zero bandgap*

1. INTRODUCTION

The structure of graphene consists of parallel layers of carbon atoms of two-dimensional sheets. sp^2 hybridization joins each of the carbon atoms of a given layer to its three adjacent carbon atoms in the same layer. So to form hexagons each carbon atoms use three other carbon atoms to form three sigma (σ) bonds, the fourth electron of each carbon atom is used to form Pi (π) bond. The distance between two adjacent layers is 3.35 Å and the C-C bond distance in a layer is 1.42 Å. Since these structures are loosely linked with each other by weak Vander Waal force, they can easily slide over each other and results in their slippery nature and lubricating property. The electricity and heat conductive property is due to the presence of Pi (π) electrons [3].

A single layered 2D structure of silicon is silicene. It is analogous to graphene in many respects such as structure, hexagonal arrangements of atoms, monolayer, etc. [4, 5]. But the C-C bond distances in graphene much less than Si-Si bond distance in silicene which is 2.28 Å. Both sp^2 and sp^3 hybridizations are observed in silicene [5-7]. Silicene also have sigma ( ) as well as pi (π) bonds like graphene but the pi bond is very weak in nature. This is the cause for its large bond distance compared to graphene [7]. Graphene possesses mass less Dirac electrons [8-10] but silicene don't. Graphene has no band gap [11] but a band gap of 2 meV is noted in silicene [2, 6].

This paper is organized as follows: In Sec. 2, we discuss briefly about the advantages of the use of graphene in electronic devices. In Sec. 3, we calculate the refractive index of silicon-carbide nanocomposite. In Sec. 4, we present our conclusions.

2. GRAPHENE IN ELECTRONIC DEVICES

Reddy et al. [11] have studied the graphene based transistor in the field of cloud computing. They have found that as the size of the device decreases; electron flow increases by using graphene as transistor material. The electron mobility in graphene is about 1000 times more than silicon. This property will increase the data transfer rate thus resulting faster operation. The reaction time in graphene is very short about 2.1 picoseconds and it has the ability to absorb 60% of the visible light spectrum. Graphene based sensors allow a frequency of 262 GHz, and a data transfer rate over 30 GB/Sec range of wavelengths when compared with the current commercial networks with a rate of 1.2 GB/Sec. This kind of performance is based on short lifetime of charge carriers in graphene. Graphene's ability to increase internet speed is confirmed by its property electroluminescence due to radioactive recombination. The power required for off-on of a device made of graphene will be about 70% less than existing one [11]. Thus operation cost of devices can be reduced. But a key disadvantage of graphene to be used as transistor is the absence of band gap. The I_{on}/I_{off} ratios for graphene based field effect transistors (GFETs) are less than 100, while any successor to the Si MOSFET should have excellent switching capabilities in the range 10^4-10^7 [2, 11].

3. CALCULATION OF REFRACTIVE INDEX OF SILICON CARBIDE NANOCOMPOSITE

Laser beam ablation technique used for preparation of metal nanocomposite might be utilized for preparation of SiC nanocomposite. Refractive index of nanocomposite can be calculated the formula given below [12]

$$\mathbf{n_{nc} = (1-c) n_m + c n_{np}} \qquad (1)$$

Where, n_{nc} = refractive index of nanocomposite; n_m = refractive index of matrix; n_{nc} = refractive index of nanoparticle and c = volume fraction of the nanoparticles. Under same conditions of temperature and pressure atomic weight of silicon and graphene are 14 and 6 respectively. So c for the nanoparticle (graphene) is 0.3. We also know $n_m = n_{silicon} = 3.78$ and $_{np} = n_{graphene} = 2.4$ at

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532 nm wavelength of light. Putting these values in the above equation we get $n_{nc} = n_{silicon\text{-}carbide} = 3.366$. Hence, the refractive index of the nanocomposite is much higher than graphene itself. Silicon have a Young's modulus of 130 to 185 GPA where as the value of the same parameter for silicon carbide is 450 GPa [13]. Thermal conductivity of silicon is 149 W m^{-1} K^{-1} but of silicon-carbide nanocomposite is 500 W m^{-1} K^{-1}.

4. CONCLUSION

The silicon-carbide nanocomposite has higher refractive index than graphene. Mechanically it is much stronger than existing silicon with much more thermal conductivity. Despite of the absence of band gap graphene is used as electronic power off on device. The I_{on}/I_{off} ratios for graphene based field effect transistors (GFETs) are less than 100, while any successor to the Si MOSFET should have excellent switching capabilities in the range 10^4-10^7 [2, 11]. Silicon-carbide nanocomposite also opens a band gap of 2.36, 3.23 and 3.05 eV for (β) 3C cubic, 4H hexagonal and (α) 6H hexagonal structure respectively. So theoretically, proposed silicon-carbide nanocomposite can be used as a new material for telecommunication industries but practically still the parameters are to be verified.

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