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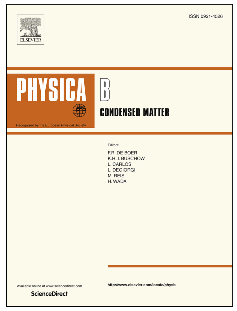

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Modeling the strain impact on refractive index and optical transmission rate

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Abstract

We propose a new and simple modeling approach for strain impact on the transmission and reflection rate of semiconductor devices. The model is applied to graphene or carbon nanotubes deposited on substrates. Any change in transmission rate by strain can directly impact on the short-circuit current density of an electronic device. The nanolayers of graphene and nanotubes are often used as the excellent replacement for the conventional metallic contacts. However, these nanolayers are sensitive to in-plain and out-plain strain. It is shown that the transmission rate is significantly reduced by the strain. We have also calculated the change in the refractive index under in-plain strain and the consequent change in reflection rate. The modeling can be extended to calculate the change in the refractive index under out-plain strain. Furthermore, one can calculate the change in short-circuit current density of the full device (i.e. solar cell) under in-plain or out-plain strains. A practical outcome of our modeling approach is to optimize the thickness or concentration of graphene and carbon nanotube to en extent which is less sensitive to any thermo-mechanical strain. This leads the reader to strain tuning techniques which are rarely applied to sensors, solar cells or photodetector devices through fabrication and characterization process.

Keywords: Strain, refractive index, optical transmission, reflection, graphene, nanotube.

1. Introduction

Graphene and nanotubes were often proposed as the environment friendly and cost-effective materials for the conventional metallic back contacts in solar cells [1, 2]. Various optoelectronic devices are now using nanostructures of graphene and nanotubes as the front, back, or buffer layer in solar cells, light sensors, potodetectors, etc. [3, 4]. High light transparency for a wide range of wavelengths, good thermal conduction, excellent electrical conduction and simple deposition has attracted the attention to this materials for optoelectronic applications. Higher light transparency will increase the transmission rate which will directly impact on the short circuit current density of the device. We have already applied this concept on CdTe and CIGS thin film solar cells [5, 6]. Nevertheless, the atomically thin nature of graphene and nanotubes makes them vulnerable against strain and stress. Guinea has proposed that graphene shows unique feature in responding to strain which is the influence of long range strains on it's electronic properties [7] Strain is induced on nanolayers during normal operation or through electrical characterization and heat dissipation process. Levy et al. have proposed theoretical calculation showing that strain can be used to engineer graphene electronic states through the creation of a pseudo–magnetic field due to massless Dirac fermion-like band structure and particular lattice symmetry of graphene [8]. Nevertheless, the effect of strain on optical properties of these layers has not been widely investigated via semi-classical modeling approaches though mostly by finite element simulation analysis [9]. Especially in photovoltaic devices, the dependence of exciton de-bounding on film morphology and lattice strain has yet to be modeled and further explored. McDaniels et al., have shown that both offset on bandgap and lattice strain have a ignificant impact on charge transfer dynamics [10]. The refractive index is very useful parameter to design the anti-reflection coating on the surface of solar cells or photodetectors thus the proposed modeling provides a handy approach for designing optoelectronic devices with less vulnerable design but also with robust absorption of shining light. Tran et al. have proposed a modeling approach to calculate the impact of refractive index and bandgap of GeSn alloys for the wavelength range of 1500 to 2500 nm [11]. Vazinishayan et al. have performed Finite Element simulation analysis to calculate the mechanical strain effect on the optical properties of ZnO nanowire (NW) before and after embedding ZnS nanowire into ZnO nanowire [9]. They have shown that increasing the strain caused by external load (i.e. by applying external electrodes) changes the light reflection, transmission and absorption. We have already developed a quantitative approach for the modeling of optical loss in thin film solar cells by connecting the transmission/reflection rate to short-circuit current density [6, 12]. The optical transmission rate is obtained only from optical constants such as refractive index and extinction coefficients which promises a simple approach to optimize the absorption capability of a device only by calculating the reflec-

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