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Photovoltaic performance photodiodes based on reduced graphene Oxide-Fe_3O_4 and carbon nanotube-Fe_3O_4 nanocomposites

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Abstract

We have studied photovoltaic performance photodiodes based on reduced graphene oxide-iron oxide (RGO-Fe_3O_4) and multi-wall carbon nanotube-iron oxide (MWCNT-Fe_3O_4) nanocomposites. Characterization of the RGO-Fe_3O_4 and the CNT-Fe_3O_4 nanostructures is investigated in detail by X-ray diffraction (XRD), FT-IR spectroscopy and scanning electron microscope (SEM). RGO is synthesized using modified Hummers' method oxidation of graphite powder. The photovoltaic properties of the RGO-Fe_3O_4/p-Si/Al and the MWCNT-Fe_3O_4/p-Si/Al photodiodes are analyzed. The maximum electrical power values of devices were found to be 12.9 μW and 10.4 μW under 100 mW/cm^2 illumination, respectively. The devices exhibit photovoltaic behaviors with open circuit voltages (V_{oc}) and short circuit currents (I_{sc}). The diodes with MWCNT- Fe_3O_4 and RGO- Fe_3O_4 nanocomposites may be used as a photodiode in optoelectronic applications.

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Keywords: Reduced graphene oxide, Carbon nanotube, Photovoltaic device, Diode

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1. Introduction

Carbon is a group IV element that is very active in producing many molecular compounds and crystalline solids. Many new crystalline forms of carbon have only recently been experimentally discovered in the last few decades. These newer crystalline forms include buckyballs, carbon nanotubes (CNTs), and graphene. In addition, CNTs and graphene occupy a reduced amount of space compared with their older siblings. Hence, they are often referred to as reduced-dimensional or low-dimensional solids or nanomaterials. There are two families of CNTs, namely single-wall CNTs and multi-wall CNTs (MWCNT) [1]. CNTs have drawn great attention, for their high aspect ratios, predominant electrical and mechanical properties [2]. In the meantime, graphene, a free standing two dimensional crystal with one atom thickness, has attracted much attention because of its unique properties, such as remarkable electronic properties, superlative mechanical strength, surface properties [3] and has been extensively applied to prepare various hybrid nanomaterials [4-6].

In this work, attempts have been made to synthesize graphene oxide by improving the Hummers' method and to synthesize RGO-Fe_3O_4 and MWCNT-Fe_3O_4 nanocomposites. We have studied photovoltaic performance of photodiodes based on RGO-Fe_3O_4 and MWCNT-Fe_3O_4 nanocomposites. The photovoltaic properties of the RGO-Fe_3O_4/p-Si/Al and the MWCNT-Fe_3O_4/p-Si/Al photodiodes are analyzed.

2. Materials and Methods

2.1. Synthesis of graphene oxide

Graphene oxide (GO) was prepared from extra pure graphite powder (Sigma Adrich, 99.99%) according to improved Hummers' method. The graphene oxide was synthesized as powder and more details are available in our previous study [7].

2.2. Synthesis of RGO-Fe_3O_4 and MWCNT-Fe_3O_4 nanocomposites

0.5 gr GO and MWCNT in two flask separately were dispersed in Ethanol:H_2O (1:1) solution and ultrasonicated for 10 min. 80 mmol $FeCl_3$-$6H_2O$ and 40 mmol $FeCl_2$-$4H_2O$ were dissolved with deionized water in N_2 atmosphere and 3.5 ml oleic acid was added to this solution and pH was adjusted about 4 using NH_3(%14) solution in another flask with GO and MWCNT dispersions respectively. Solutions were mixed slowly and stirred for 8 h. Then, the solutions were filtered and washed with Ethanol:H_2O (1:1) and dried at 50 °C in oven for 12 h. Finally, the RGO-Fe_3O_4 and MWCNT-Fe_3O_4 nanocomposites were obtained as powders.

2.3. Preparation of the photodiodes

The RGO-Fe_3O_4/p-Si/Al and the MWCNT-Fe_3O_4/p-Si/Al photodiodes devices have been prepared using *p*-type Si (100) wafer with 380 μm thickness and 1-10 Ωcm resistivity as substrate. The wafer, *p*-type Si was cut into pieces of 1.0 cm length by 1.0 cm breadth. The *p*-type Si substrates were ultrasonically cleaned in acetone for 15 min. followed each by using ultrasonic cleaner and later cleaned with deionized water. The *p*-type Si substrates were then exposed to oxygen plasma cleaner in order to make the surface hydrophilic and dried. The ohmic back contact has been made by evaporating Al on the back surface of the substrate, followed by a temperature treatment at 580 °C for 3 min. in N_2 atmosphere. Then, we used the spin coating method to form the RGO-Fe_3O_4/p-Si/Al and the MWCNT-Fe_3O_4/p-Si/Al structures. The RGO-Fe_3O_4 and MWCNT-Fe_3O_4 aqueous suspensions with a concentration of 0.4 mg/ml of nanocomposites was suspended in deionized water. The prepared nanocomposites aqueous suspensions were stirred at 50 °C for 2 hours to yield clear and homogenous suspensions. In order to prepare RGO-Fe_3O_4 and MWCNT-Fe_3O_4 films on the *p*-Si substrates were spin coated at 4,000 rpm for 40 s. This is followed by annealing the film at 50°C for 1 hour in N_2 atmosphere. The thickness of the films was measured using profilometer and observed to be about 100 nm. In addition, the front contacts have been formed by sputtering silver (Ag) as dots with diameter of about 1.0 mm on the front surface of the RGO-Fe_3O_4/p-Si/Al and the MWCNT-Fe_3O_4/p-Si/Al through a shadow mask. Fig. 1 shows the schematic structure of RGO-Fe_3O_4/p-Si/Al and MWCNT-Fe_3O_4/p-Si/Al structures used in this study.

2.4. Characterization tools of GO, nanocomposites and photodiodes

The structures of GO, GO-Fe_3O_4 and MWCNT- Fe_3O_4 nanocomposites were examined by XRD using Philips X`Pert PRO diffractometer with CuK_α radiation (λ=0.154nm) at 40 kV and 30 mA. The nanocomposite powders were examined by means of scanning electron microscope (Zeiss EVO 10LS-SEM) due to small nanosize of