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Photovoltaic Properties of Graphene-TiO_2 Nanocomposite

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Abstract: Nanocrystals of TiO_2 was synthesized by aqueous chemical route. Whereas, the graphene used in this work was synthesized by electrochemical exfoliation. The ex-situ approach was adopted for the preparation of composites. The composites was prepared by mixing 1.6 wt.% of graphene into TiO_2 nanocrystals. The photovoltaic device was fabricated by using as-synthesized composite on indium tin oxide (ITO) coated glass substrate by using a doctor blade technique. Current-Voltage (IV) measurement has been done on the photovoltaic cell using incandescent light bulb. Light intensity dependent current–voltage measurements of graphene-TiO_2 thin film shows photovoltaic effect. Various diode properties determined from IV measurements, such as open circuit voltage (V_{oc}), short circuit current (I_{sc}), fill factor (FF), and conversion efficiency (η).

Keywords– Photovoltaic; Graphene-TiO_2; Nanocomposites.

Introduction:

Pristine monolayer graphene has zero band gap [1]. The gapless energy dispersion allows electron–hole pairs to be created over a bandwidth from UV to THz [2]. Peining et al report the fabrication of one-dimensional TiO_2–graphene nanocomposite by a facile and one-step method of electrospinning for the photovoltaic and photocatalytic properties [3]. Wang et al reported the synthesis of reduced graphene oxide-anatase TiO_2 nanocomposite and studied the photo-induced charge transfer properties [4]. Zhang et al investigated the effects of TiO_2 film thickness on photovoltaic properties of dye-sensitized solar cell and its enhanced performance by graphene combination [5]. Meng et al synthesized the Ag_2Se-graphene/TiO_2 nanocomposites by sonochemical synthesis and enhanced photocatalytic properties under visible light [6]. Shu et al reported the synthesis and photovoltaic performance of reduced graphene oxide–TiO_2 nanoparticles composites by solvothermal method [7].

In the present work, we investigate the photovoltaic response of graphene-TiO_2 nanocomposite. The prepared composite material was characterized by X-ray diffraction and scanning electron microscope. Different photovoltaic parameter of fabricated cell was determined.

Experimental:

The graphene sample used in this investigation was synthesized by a previously reported method [8]. The TiO_2 was used in this study was synthesized by aqueous chemical route by taking starting chemical $TiCl_4$ and NaOH in 1:1 M quantity. The nanocomposite was prepared ex-situ approach. Firstly, 1.6 wt.% graphene was mixed in 2 g TiO_2 powder in acetone medium under constant stirring of 1 h at room temperature (300 K). As-prepared composite was dried at room temperature for complete night and then sintered at 120 °C for 5 h. The XRD pattern was recorded on Rigaku (Miniflex II) diffractometer. To analyse the morphology, SEM image was acquired using JEOL JSM-7500F. The photovoltaic cell fabrication was done through doctor blade technique on ITO glass substrate. The aluminium foil was used as a metallic electrode.

Results and Discussion:

Figure 1 shows XRD patterns of the graphene, TiO_2 and graphene-TiO_2 nanocomposite. From XRD patterns, it is clearly observed the formation of graphene (JCPDS No. 01-0646) and TiO_2 (JCPDS, No. 76-1940), as it exactly indexed to respective JCPDS cards. In addition, it can be seen that the intensities of the XRD peaks of the TiO_2 weakened in composite state. By using Scherrer's relation, the average grain size was found to be 7.9 nm. The shoulder peak emerge at 2θ=27° is characteristic peak of TiO_2.

The SEM image of nanocomposite is depicted in Figure 2. This image clearly shows that TiO_2 was attached on the graphene sheets. This attachments graphene and TiO_2 may become graphene sheets defects rich [9, 10].

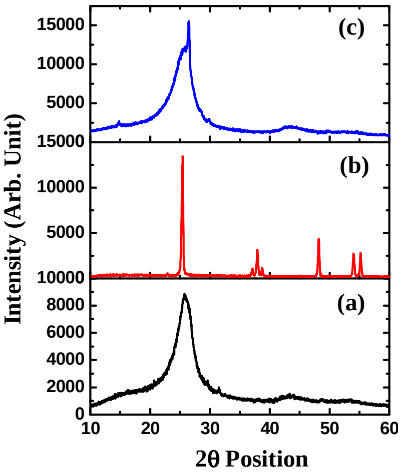

Figure 1. XRD pattern of (a) graphene, (b) TiO_2 and (c) graphene-TiO_2 nanocomposite.

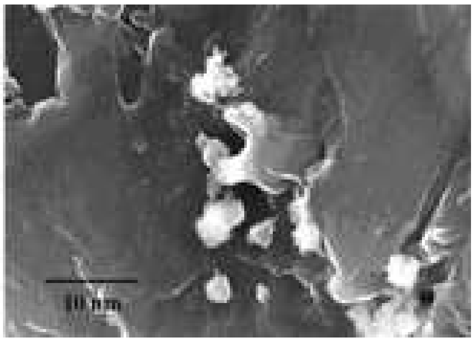

Figure 2. SEM image of graphene-TiO_2 nanocomposites.

The different photovoltaic parameters like open circuit voltage (V_{oc}), short circuit current (I_{sc}), fill factor (FF), maximum current output (I_m), maximum voltage output (V_{max}) and conversion efficiency (η) are determined for graphene-TiO_2 nanocomposite. The fill factor and efficiency are calculated using the relation [11].

The measurement was done using the 100W bulb radiating light power of 0.0207 Watt/m^2 and room temperature of 300 K. The power of light from the bulb was determined by a luxmeter. The bulb-photovoltaic cell separation distance was 25 cm. The current-voltage curve for as-synthesized photovoltaic material is displayed in Figure 3. The diode parameters V_{oc}, I_{sc}, I_{max}, V_{max} and η for the photovoltaic cell listed in Table 1.

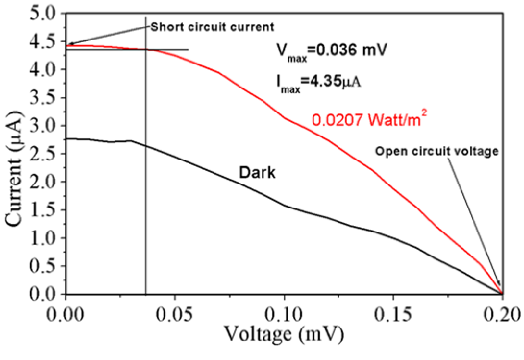

Figure 3. Current-voltage plot of the photovoltaic cell.

Table 1 Photovoltaic parameters V_{oc}, I_{sc}, I_{max}, V_{max} and η for the graphene-TiO_2 nanocomposite.

V_{oc}	I_{sc}	I_{max}	V_{max}	FF	η
0.20 mV	4.48 μA	4.35 μA	0.036 mV	0.174	7.56

Conclusions:

Fabrication of photovoltaic cell using doctor blade technique is very straight forward method. The photovoltaic cell had Voc of 0.20 mV, Isc of 4.48 μA, FF of 0.174 and efficiency of 7.56. Yet the efficiency of the fabricated photovoltaic cells was low, the availability and low cost of the materials makes it relatively inexpensive as compared to other cell devices.

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