Preparation by Hydrothermal Method of TiO_2-RGO Nanocomposite and Using as Photoanode of Dye-Sensitized Solar Cell

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Abstract

We explored the photoanode properties of DSSCs by used RGO and TiO_2 nanoparticles as an optical electrode (we used the doctor's blade method). Using the hydrothermal process, we prepared a nanocomposite of TiO_2/RGO. SEM and XRD, tests were used to study the structural properties of TiO_2 and TiO_2/RGO. When compared the J-V properties of the integrated devices made to those made, the J-V properties of the integrated devices came out on top of used TiO_2/RGO as the photoanode in a solar cell for TiO_2/RGO, which increased the PCE (8.674±0.063%). We were able to improve the short circuit current density (Jsc) and the power conversion efficiency (PCE) for the effective region by adding RGO to the TiO_2. The PCE has improved due to better electron transport, improved electron collection in photoanode, and increased light-harvesting performance. As a result, RGO with distinct structural and optical properties is a viable choice in DSSC.

Key Words: Hydrothermal, DSSCs, RGO, TiO_2/RGO and Photoanode.

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Introduction

Nanotechnology is one of the most promising technologies of the 21st century (Mansoori and Soelaiman, 2005). The National Nanotechnology Initiative (NNI) in the United States defines nanotechnology as the "nanoscale science, engineering, and technology, where unique phenomenon's permit new uses in a variety, ranging from chemical, physical and biological fields to medicines, technical and electronic engineering fields (Choi *et al.*, 2009). Nanotechnology and Nanoscience have widened the field of research, which includes structures devices, and systems where nanotechnologies play a role in practically every scientific discipline (Bayda *et al.*, 2020). One of the uses of Nanotechnology is the production of electrical energy through solar cells. It has become a solution to energy problems today by providing clean, safe, and environmentally friendly energy(Zafar, Yun and Kim, 2017).

Recently, many efforts have been devoted to developing and improving the performance of solar cells with a common mission to obtain greater efficiency to compete with old traditional energy resources(Javed *et al.*, 2020). Among the efforts are the process of generating electrical energy using organic dyes when exposed to light (Yan *et al.*, 2013). After their discovery by researchers Brian Origen and Michael Grazel in 1991 (Chen *et al.*, 2019). The process of light absorption and transport of cargo carriers is done by several different elements of DSSCs. This is unlike conventional cells that perform these functions through semiconductors.

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DSSCs are characterized by low manufacturing prices because they are made of low-cost, easy-to-manufacture, and good-performance materials. This is the most important thing that distinguishes it from traditional cells (Choi *et al.*, 2013; Hussein *et. al.* 2019; Abd *et. al* 2020). However, their main problem is their relatively low stability and efficiency compared to silicon cells. Therefore, many researchers went to study its mechanism of action and change its basic components and manufacturing methods to obtain better results (Yum *et al.*, 2013). There are many studies and researches that specialize in using nanocomposites with titanium dioxide to enhance the efficiency of DSSCs. In 2019 M. Younasa et al. When the nanocomposite of 0.06 percent -MWCNT- TiO_2 was used as a photoanode in the suggested DSSC structure, a photovoltaic efficiency of 7.15 percent was reached. In addition to delivering a 13 percent increase in photovoltaic efficiency over the widely used [TiO_2/N3/Pt] DSSC configuration, the [MWCNT- TiO_2/N3/MWCNT] DSSC ensures the proposed design's cost-effectiveness by replacing Pt with affordable MWCNT (Younas *et al.*, 2019).In 2020 researcher Farhad Jahantigh et al. Added quantum monolayer graphene points (SLGQDs, average size ~ 9 nm) in N719 / TiO_2 nanoparticles (prepared using the physician's blade method). A low-cost, high-yield SLGQDs solution was manufactured using only glucose and Deionized water as precursors using the aqueous heat treatment method(Jahantigh, Ghorashi and Bayat, 2020).

The hydrothermal approach was used to generate a TiO_2 / RGO nanocomposite in the presence of glucose in this research. The usage of nanocomposite as a photoanode film material for DSSC, which demonstrates the DSSC's comparative photoelectric performance compared to the photoanode TiO_2 film.

Experimental Section

Materials

The basic materials used in this research are FTO glass (Fluorine doped conducting tin oxide SnO2/F) thickness 2.2 mm, TiO_2 (Titanium dioxide) density 4.23 g/m3 at 25C°, the nano-graphene powder was purchased from the company VCN and has 99.5% purity, 1-20 nm diameter and dye Ruthenium N719 Purity 97%, Platinum Wire (diameter: 100 µm) used in the manufactured counter electrode (CE).

Preparation of photoanode TiO_2 Film for Device1

The FTO glass was cut into slices (2.5 × 2) cm, and the FTO slices were cleaned by dipping them in a detergent solution for 15 min, then placed in a digital ultrasonic cleaner device for 15 min each time in ethanol and distilled water. TiO_2 paste was prepared using the sol-gel method, by adding 1g of TiO_2 nanoparticles powder in a glass beaker contains (8ml) pure ethanol (99.9%) using a magnetic stirrer, and after 10 min was added (0.2ml) of citric acid (99%), then (0.5 g) of Ethyl Cellulose(99.7%), and the ingredients were mixed for 36 hours at room temperature.

A paste of TiO_2 with an effective area of 1cm2 was deposited on clean FTO glass using the doctor blade technique. After leaving it for 10 min until it dries. We put it in a heated oven at 450 C° for 30min for surface treatment. After that, the TiO_2 film was immersed in dye solutions of ruthenium (N719) at room temperature to allow for sufficient dye absorption for 24 hours away from light. The film was rinsed with pure ethanol to remove the remaining or excess dye on the TiO_2 film.

Preparation of photoanode TiO_2-RGO Film for Device 2

To Preparation of photoanode TiO_2/RGO film, we weigh 0.02 grams of RGO with 99.5% purity and placed it in a beaker by an ultrasonic device, and added 4ml of pure ethanol to it for 15 minutes. Then we add 1 g of TiO_2 for 30 min of stirring, after which we add 50 ml of deionized water to the beaker. The as-prepared precursor solution has been put to an autoclave after an hour of ultrasonic stirring and then heated at 160 Co for 72 hours. After being cooled down to room temperature, the suspension has been filtered and cleaned by ethanol several times before being dried at 50 Co. now we have dry TiO_2 / RGO nanocomposite, we grind it well and take 1 gram of it and put it in a glass beaker (magnetic stirrer), and repeat the same steps when making the TiO_2 film in device1.

Preparation of Counter Electrode (CE)

Preparation of thin-film of platinum (Pt) for counter electrode was prepared in thermal evaporation in vacuum method (TEV), where Platinum metal was placed on a boat made of tungsten, then put FTO glass at 9 cm from the heating source. Where platinum metal vaporization was carried out by using the pressure of its amount (10 mbar), where the thickness of film Pt was

100(μm) and effective area (1 cm2). The thickness of the film was calculated using the gravimetric method according to the (Al-bahrani and Qassim, 2020).

The thickness of the membrane (T) $=\frac{M}{2\pi\rho R^2}$ (1)

Where R the distance between the heating source and the FTO, ρ is the density of the material (Pt) ρ =21.45 3mg/cm³ and m the mass of the material (g)=0.27±0.0002g.

After preparation of the photoanode and counter electrode we combine the two electrodes in a sandwich manner, then (I^-/I^-_3) was injected between them

Characterization

X-ray diffraction (XRD) patterns were used to investigate the structures of TiO_2 and TiO_2/RGO nanocomposites. A scanning electron microscope was used to examine the surface morphology of TiO_2/RGO and the cross-sectional morphology of TiO_2/RGO nanocomposite (SEM). The cell efficiency (PCE) and fill factor (FF) equations can be used to calculate the DSSC parameters:

$$FF = \frac{V_{max}\ x\ J_{max}}{V_{OC}\ x\ J_{SC}} \quad (2)$$

$$PCE = \frac{V_{oc}\ x\ J_{SC}\ x\ FF}{Pin}\ x\ 100\% \quad (3)$$

Results and Discussion

X-ray Diffraction (XRD)

TiO_2, TiO_2/RGO composites structures crystalline was examined by X-ray diffraction (XRD) as shown in Fig. 1 outside. The XRD patterns show the characteristic peaks of TiO_2 diffraction. TiO_2 anatase phase crystal planes may index to (101), (004), (200), (105), (211), (204), (116), (220) and (215) respectively the maximal values for the tablets of 25.3, 37.8, 48.0, 53.9, 55.1, 62.7, 68.8, 70.3, and 75°. Moreover, there is no sign that the RGO loaded nanoparticles have a characteristic diffraction peak and no peak change there is. The principal RGO characteristic peak at 24.5°, which is obscured by the main TiO_2 anatase peak at 25.3°, could explain (Pan *et al.*, 2012), implying that RGO nanoparticles are only deposited on the surface of TiO_2 rather than incorporating into the lattice.

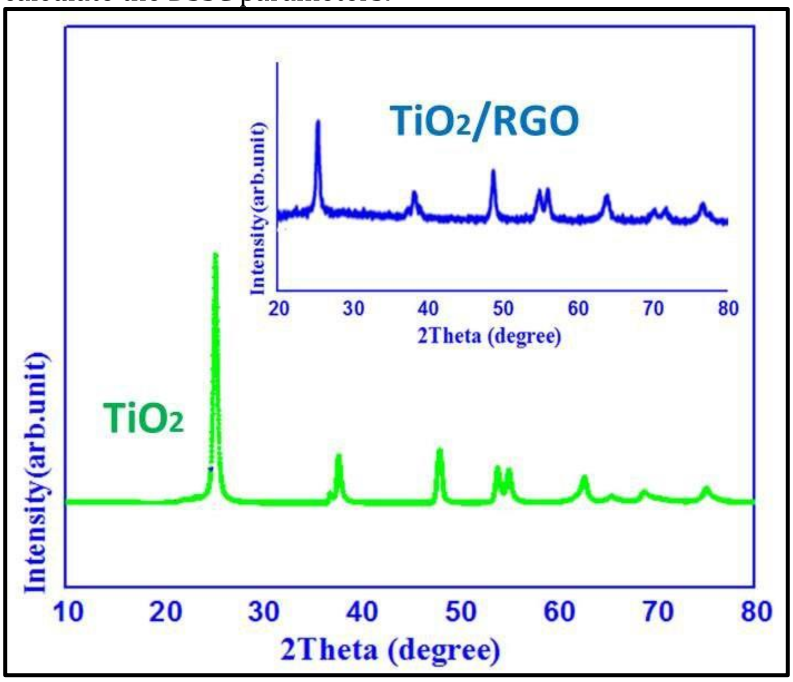

Fig. 1. X-ray diffraction patterns of pure TiO_2 and TiO_2/RGO

SEM Analysis

The morphology of TiO_2 and RGO nanoparticles studied using a scanning electron microscope (SEM) as shown in Fig.2 (a and b), respectively. The results are displayed has displayed in Fig. 2 a has evaluated the morphological structure of TiO_2. The photos show thick agglomerates of TiO_2 NPs (20-50 nm). Fig. 2 b shows the SEM picture of RGO. It was found, due to the oxygenated functional groups on the surface, that might operate as an anchoring point for both nanoparticles. TiO_2 NPs have significant attachments to RGO sheets.

Fig 3 show the morphology of TiO_2/RGO nanocomposite analyzed via scanning electronic microscopy (SEM) the rounded TiO_2 nanoparticles aggregating over the RGO sheets can be seen in the micrographs, clarifying the production of TiO_2/RGO nanocomposites and confirming that RGO reduction and TiO_2 crystallization were achieved by hydrothermal reaction at the same time.

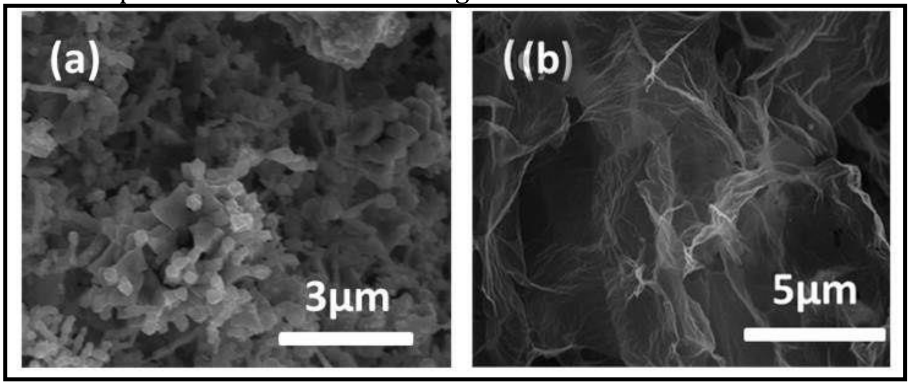

Fig. 2. SEM images of (a) pure TiO_2 and (b) RGO

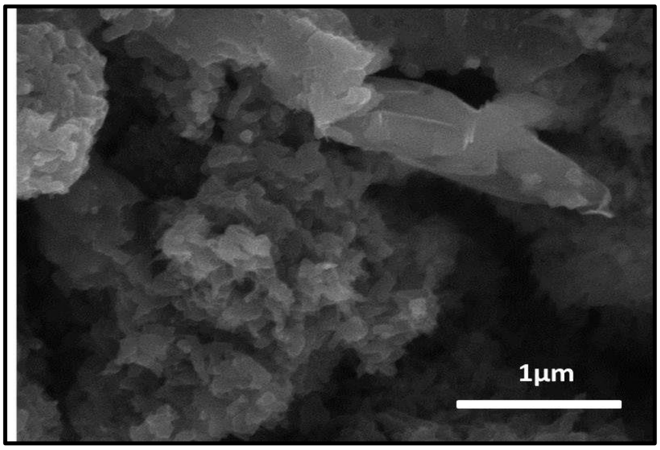

Fig. 3. SEM image of TiO_2/RGO nanocomposite

The J-V characteristics of the dye-sensitized solar cells are seen in Fig. (4) and also the photovoltaic parameters we got it by J-V curves as described in Table1. The results we obtained from these curves resulting in higher values of (Jsc= 18.79 mA/cm2) and (Voc=0,677V) comparative than when nanocomposite TiO_2 were present alone, bringing this increased the PCE of the cell containing the photoanode TiO_2/RGO to 8.674 %. We conclude that the presence of finely dispersed reduced graphene oxide facilitates electron transport and reduces electron-hole recombination resulting in a better performance from TiO_2 photoanode.

The Photovoltaic Performance (PV) of DSSC Devices

Table 1. Photovoltaic parameters of pure TiO_2 and TiO_2 /RGO

Cell	Photo Electrode	Counter Electrode	Dye	J_{sc} (mA/cm^2)	V_{oc}(v)	FF	PCE(%)
Device1	TiO_2	Pt film	N719	17.90±0.01	0.661±0.003	0.681±0.003	8.057±0.077
Device2	TiO_2 /RGO	Pt film	N719	18.68±0.01	0.673±0.001	0.690±0.004	8.674±0.063

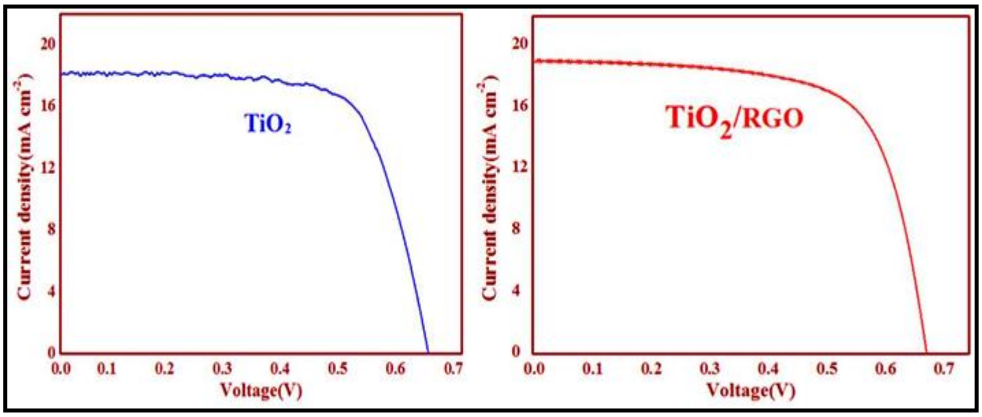

Fig. 4. Shown the J-V curves of the DSSC for TiO_2 and TiO_2/RGO

Conclusions

A reproducible simple one-step synthesis technique has been used successfully to create TiO_2/RGO composites in water and ethanol (4:1) solvent mixture using the hydrothermal treatment process. The heterojunction displayed by TiO_2/RGO and the ability to reduce the recombination rate of electron-hole pairs, to speed up the transmission of the charge, and to produce visible light absorption were studied.

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