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Electrospun poly (methyl methacrylate) decorated Titanium dioxide, reduced graphene oxide composite nanofiber for dye and perovskite sensitized solar cell applications

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Abstract:
Poly (methyl methacrylate) (PMMA) - Titanium dio-xide (TiO2) and PMMA-TiO2- reduced graphene oxide (rGO) nanofibers (Nfs) have been prepared by an electrospinning method. In addition, the Inorganic cesium lead iodide (CsPbI3) perovskite sensitizer material by a two-step solution process also prepared. The prepared all the Nfs examined by HR-SEM, EDAX analysis, x-ray diffraction pattern, FT-IR spectroscopy, UV-visible NIR spectra,AC impedance spectroscopy and the I-V characterizations. The perovskite solar cell device gave the 10.03% and 11.38% of the better power conversion efficiency than the other PMMA based materials.

1. Introduction

Dye-sensitized solar cells (DSSCs) and perovskite solar cells (PSCs) based research more emerging field in the many countries, due to their less-expensive, easy to fabricate and clean, renewable energy source [1-2].The DSSC, nanocrystalline semiconducting metal oxide immersed in the dye solutions, the injected dye molecules absorbing the sunlight then passes the electrons through the valence band to the conduction band. The accepted electrons by conduction band give the electrolyte solutions of iodide to tri-iodide redox mediator. Then, the platinum counter electrode is collecting the electrons from the I^-/I^{3-} redox mediator [3]. Based on the mechanism, the DSSC has several advantages, including very good color and optically transparent. However,efficiency-based fabrication of dye-sensitized solar cells has some limitation. So that, many studies are currently focused, have to improve their efficiency and stability of the DSSCs. The main scope of this work, we have to prepare the composite of TiO_2-reduced graphene oxide Nfs photo-anode for dye and perovskite sensitized solar cells. The composite nanofiber based materials is enhanced the dye absorption, excellent flexibility, higher surface area, electrical conductivity, better stability, and higher power conversion efficiency.

2. Experimental Details

2.1. The preparation of reduced graphene oxide (rGO)

The graphene oxide prepared by Hammers method [4]. The graphite powder (2 gm) was kept mixed with 75 ml of Sulphuric acid in a 250 ml of round bottom flask keep in an ice bath around at the 0-5 ºC temperature condition and continues stirring for 4 h. Followed by the some workup, the reduced graphene oxide (rGO) product was obtained. The PMMA-TiO2-rGONfs, the preparation of cesium lead iodide, Fabrication of dye sensitized solar cells and Characterized.

2.2. Fabrication of perovskite solar cells

As-synthesized 20 uL perovskite solutions was spin coated on photo-anode of PMMA-TiO_2-rGO Nfs at rate of 2000 rpm for 40s and then annealed in air at 100°C for 30 min. The hole transport material solution of 40 mM Spiro-OMeTAD was deposited onto the perovskite-sensitized PMMA-TiO_2-rGO Nfs photo-anode and left stationary for 1 min in order to penetrate the HTM solution into PMMA-TiO_2-rGO Nfs pores prior to spin coating. Then, the substrate was spun up to 2500 rpm for 40s, followed by heating on a hot plate set at 100°C for 20 min under N_2 atmosphere. Finally, 50 nm Au layer was thermally evaporated on the HTM as counter electrode.

3. Results and Discussion

3.1 XRD, FT-IR analysis, UV-Visible NIR and Tauc plot analysis

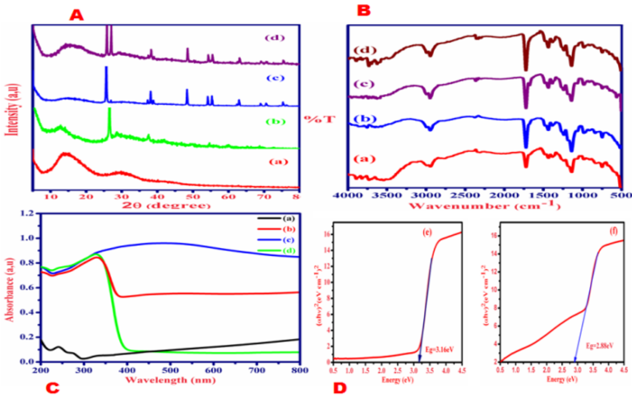

Fig. 1 XRD(A),FT-IR(B), UV-Visible NIR(C) and Tauc plot(D) analysis of (a) PMMA, (b) PMMA-rGO, (c) PMMA-TiO_2, and (d) PMMA-TiO_2-rGO Nfs.

XRD pattern analysis was used to determine the crystalline nature of PMMA, PMMA-rGO PMMA-TiO_2, PMMA-TiO_2-rGO Nfs. PMMA, PMMA-rGO Nfs XRD pattern was represented in Fig.1A (a, b). The 2θ value at 11.09°, 20.23°, 24.02°, and 28.17°, which is corresponding to the semicrystalline nature of PMMA and PMMA-rGO [41]. Fig.1A (c) was revealed that the 2θ values at 24.5°, 48.3°, and 53.6°, which is corresponding to the PMMA-TiO2 Nf crystalline plane of (101), (200) and (105). Fig.1A (d) is the PMMA-TiO2-rGO Nf , 2θ value is 11.09, 25.2°, 48.4°, and 53.2°. And, these crystalline planes view on the (001), (101) and (002).

Fig.1B is the FT-IR spectrum of PMMA nanofiber stretching and bending vibration of an O-CH_3 group appeared at 988 and 1453cm^{-1}. The carbonyl group (C-O) stretching vibration of PMMA Nfs appeared at 1726cm^{-1}. PMMA-rGO Nfs peak at 3240, 1730 and 1080cm^{-1} was corresponding to the hydroxide stretching vibration. The peak at 3450, 2988, 1726, 1450, 1328 and 650 cm^{-1}, which is assigned to the stretching vibration of hydroxide group, a methylene group, a carbonyl group, a cyano group and the titanium hydroxide group. Further, the peak observed at 3450, 2890, 1720, and 1423 cm^{-1} is the corresponding to the PMMA-TiO2-rGO Nfs.

Fig.1C is the UV-Visible-NIR spectra of these nanofibres, particularly peak values of PMMA and PMMA-rGO Nfs appeared at 242nm and 330nm (a,b), it's due to the, $\pi \longrightarrow \pi^*$ and $n \longrightarrow \pi^*$ transitions of the methylene and carbonyl groups present in the PMMA, PMMA-rGO Nfs. The PMMA-TiO2 Nfs Fig.1C (c) observed the absorption peak at 290nm. PMMA-TiO_2-rGO nanofiber appear in the maxima at 335nm(d). Tauc plot used to measure that the optical band gap energy of PMMA-TiO_2 and PMMA-TiO_2-rGO Nfs. PMMA-TiO_2-rGO Nfs has achieved the better band gap energy value of 2.88eV compared with PMMA-TiO_2 Nfs optical band gap energy value of 3.16Ev (Fig1D).

The surface morphology of the PMMA-TiO_2 and PMMA-TiO_2-rGO Nf photo-anodes were analyzed by high resolution-scanning electron microscopy (HR-SEM).

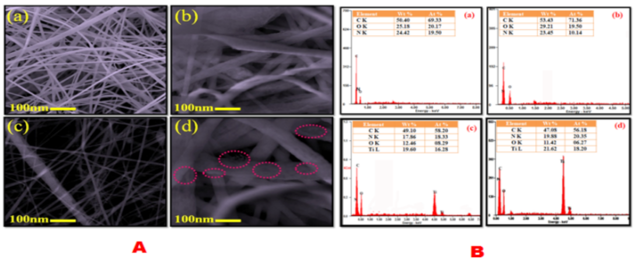

Fig. 2 HR-SEM images and EDAX spectra of (a) PMMA, (b)PMMA-rGO,(c)PMMA-TiO_2,and(d)PMMA-TiO_2-rGO Nfs.

Pristine PMMA and PMMA-rGO Nf surface appeared in the uniform fiber distribution, better surface smoothness and this result was mention in Fig.2A. The surface morphology of the PMMA-TiO_2-rGO was better fiber distribution, smooth surface area compared with PMMA-TiO_2. EDAX spectra of these Nfs were present in the Fig.2B. These spectra was clearly indicated that the composition of the nanofibers.

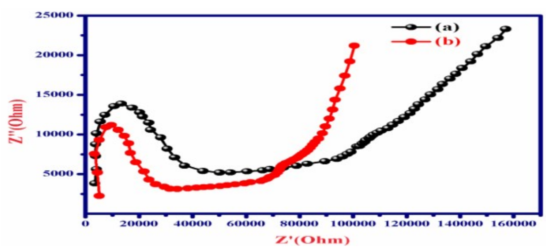

Fig.3 AC impedance spectra of (a) PMMA-TiO_2 and (b) PMMA-TiO_2-rGO Nfs.

AC impedance studies of PMMA-TiO_2-rGO Nfs were the determination of the electrical conductivity. Here, PMMA-TiO_2-rGO Nfs has the lower the charge transport resistance, lower the charge transport resistance was achieved higher electrical conductivity. The higher electrical conductivity of the photo-anode (PMMA-TiO_2-rGO) gives the higher short circuit current and higher open circuit voltage as well as improves the power conversion efficiency of the device.

I-V characterization of PMMA-TiO_2-rGO

I-V characterization of the PMMA-TiO_2 and PMMA-TiO_2-rGO were used as the photo-anode for dye and perovskite sensitized solar cells and thus help of the composite electrolyte membrane for dye sensitized solar cell. The DSSC devices, PMMA, PMMA-rGO, PMMA-TiO_2, PMMA-TiO_2-rGO all the Nfs electrolyte membrane was achieved better sunlight into energy conversion efficiency. Because. The nanofiber used as the photo-anode for inorganic perovskite solar cell device, the power conversion efficiency, and their I-V curve values is mention in Table 1

Table 1.

I-V characterizations of PMMA-TiO_2 and PMMA-TiO_2-rGO Nfs were used as photo-anode for perovskite solar cell.

Photo-anode for PSC	Jsc (mAcm^{-2})	Voc (V)	FF (%)	η (%)
PMMA-TiO_2 Nfs	18.49	0.87	0.63	10.13
PMMA-TiO_2-rGO Nfs	19.54	0.91	0.64	11.38

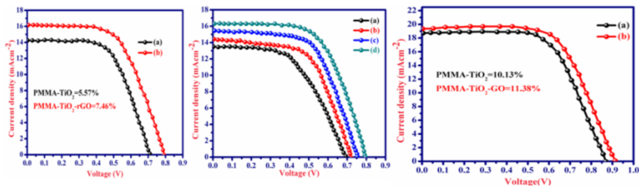

Fig.4. I-V curve of DSSC and Pervoskite Nfs for PSC.

4. Conclusions

FT-IR,XRD,UV-NIR analysis useful analytical tool to study the functional group of these nanofibres. PMMA-TiO_2-rGO HR-SEM images were confirmed that the formation of the PMMA-TiO_2 and PMMA-TiO_2-rGO Nfs photo-anodes. From the EIS studies, to measure the higher ionic conductivity value of the PMMA-TiO_2-GO Nfs photo-anode materials was achieved the 2.49 x 10^{-3} Scm^{-1}. Overall, PMMA-TiO_2-rGO Nfs used as photo-anode for inorganic perovskite solar cell was give better sunlight energy into electrical energy conversion efficiency of 11.38%.

Acknowledgements

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