THE USE OF SILICON CARBIDE AS SCATTERING LAYER IN DYE SENSITIZED SOLAR CELL (DSSC)

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Thin titaniumdioxide (TiO_2) semiconductor layer with different scattering layers was investigated in dye-sensitized solar cells (DSSC). Since the cost of the photoactive dye in the DSSC is relatively high, it is reasonable to assume that the price of the dye could be one of the decisive factors in determining the price of the DSSC modules. Using a thin layer of nanocrystalline TiO_2 would imply reduction in the amount of dye coverage, however, lower amount of dye in the thin films would imply fewer electron generation upon illumination. Thus, it becomes necessary to include a light scattering layer such that the lower photon conversion due to thin layer could be compensated. In the present study, up to 80% increase in current density was observed due to SiC scattering layers. Diffuse Reflectance, J-V curve and IPCE measurements were employed in order to study the optical properties of these scattering and shows parameters of cell improved after use of SiC layer and the efficiencies increased from 4.72 to 5.43.

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1. Introduction

Having four electrons in (Si and C) final orbital and the half of full capacity layer have created properties such as crystal formation and a unique combination for these elements. The ion lattice in carbon is as a transparent crystal, but as a silver color solid form in silicon [1]. The basic physical properties of significant inorganic nanostructures compared with silicon carbide (SiC) shows that silicon has an ideal characteristic due to the working function and band gap [2].

The process of SiC powder preparation using sol-gel method is employed because of its high purity**.** Despite the good conductivity of SiC layers, their transparency is not acceptable. Opaque layers, form due to the weak oxidation, so in order to increase the efficiency of light absorption, SiC is used as light scattering layers in dye sensitized solar cells. It is increasing the optical path using light scattering particles. Therefore light path length in the active layer consisting of TiO_2/SiC is increased. Here in this study, SiC nano-particles are used as light scattering layers in Dye sensitized solar cells.

2. Materials and method

SiC powder preparation using Sol-Gel method [3,4]. When drying procedure is complete, samples are powdered and are annealed at 1000 °C. The process of annealing samples was done in Chemical vapor deposition (CVD) furnace, in air atmosphere with a thermal gradient of 5 °C per minute. In high temperature, agglomeration of particles increases. Therefore the layer would gain an acceptable specific surface, and would become capable of massive light absorption.

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For using SiC powder in DSSC, we dispersed it in ethanol and then added ethyl cellulose (30–50mPas, Fluka) and terpineol (Merck) to the solution under stirring at 45 °C for 30 min to evaporate ethanol by rotary evaporator. The final pastes correspond to 18 wt.% SiC, 9 wt.% ethyl cellulose and 73 wt.% terpineol. We used obtained paste as scattering paste in photo anode for DSSC. Photo anode containing 20 nm sized TiO_2 anatase particles and SiC nanoparticles witch deposited by doctor blade method.

The photo anode were sintered at 325 °C for 5min, at 375 °C for 10 min, and at 450 °C for 15min, and finally, at 500 °C for 30 min [5]. An active area of 0.25cm^2 was selected from sintered electrode and the electrodes were immersed in dye (N719) solution (0.4mM in ethanol) at room temperature for 20 hours. Pt catalyst was deposited on the FTO glass by coating with a drop of H_2PtCl_6 solution (5mM in isopropyl alcohol) with repetition of the heat treatment at 460 °C for 15 min. The dye-covered electrode and Pt-counter electrode were assembled into a sandwich type cell and sealed with 30 μm-thick spacer at 120 ºC for a few seconds. The redox electrolyte (I^-/I^-_3), was then introduced into the cell.

The morphology of the products was characterized with using of scanning electron microscopy (SEM, Philips, XL30). Diffused reflectance spectroscopy (DRS, AvaSpec-2048TEC) and incident photon-to-current efficiencies (IPCE) were measured with mono-chromatic incident light of $1*10^{16}$ photon/cm^2 under 100mW/ cm^2 with bias light in DC mode (Jarrel Ash monochromator, using a 100 W halogen lamp) and a Calibrated photodiode (Thorlabs) to study the optical properties of layers. Current density–voltage measurements were performed using simulated AM 1.5 sunlight with an output power of 100 mW cm^{-2} using computer-controlled potentiostate/galvanostate (IVIUM, Compactstat).

3. Results and discussion

Fig. 1 shows the scanning electron microscopy (SEM) image of SiC powder.

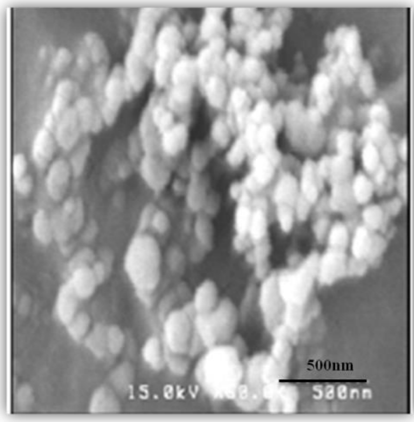

Fig.1: SEM images of the SiC Nano-powder samples, annealed at 1000°C.

The XRD pattern of the annealed SiC powders, at 1000°C shows that the main peak of the SiC powder has formed in scattering angles of 36.00, 60.330, and 72.40 (Figure 2). These angles all belong to the β -SiC phase. The Extra peak in the scattering angle of 21.1, is because of the formation of Si or silicon phase.

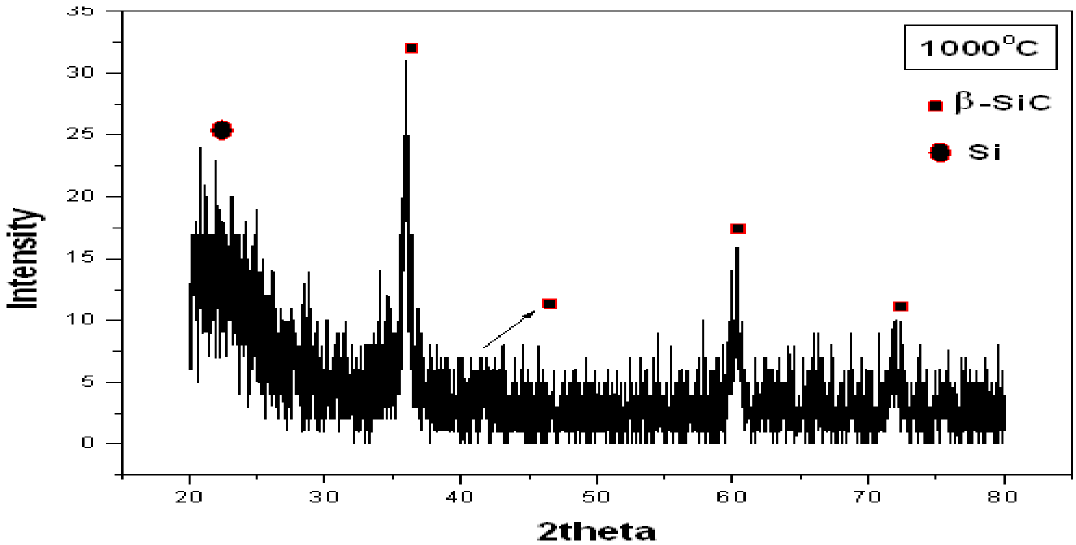

Fig.2: XRD spectrum of SiC nano powder at annealing temperature of 1000.

Figure 3 shows the diffuse reflectance spectra (DRS) of TiO_2 and TiO_2/SiC layers. Diffused reflectance is improved over 50 % when SiC is used as scattering layer. It shows that light reflection to the solar cell and more light absorbtion by dye causes more photo electorn generating.

Figure 4 shows the current density–voltage (J–V) curves of the TiO_2 and TiO_2/SiC-based DSSC under AM1.5 light illumination. The photoelectrode chemical properties of these electrodes are listed in Table 1; FF, V_{OC}, and J_{SC} are fill factor, open circuit photovoltage, and short-circuit photocurrent, respectively. For the TiO_2-based DSSC, J_{SC} and η were 10.57mAcm^{-2}, 4.72% respectively. After using SiC as scattering layer in photoanode the performance of DSSC is improved greatly. J_{SC} and η were reached to 12.81mAcm^{-2} and 5.43% respectively.

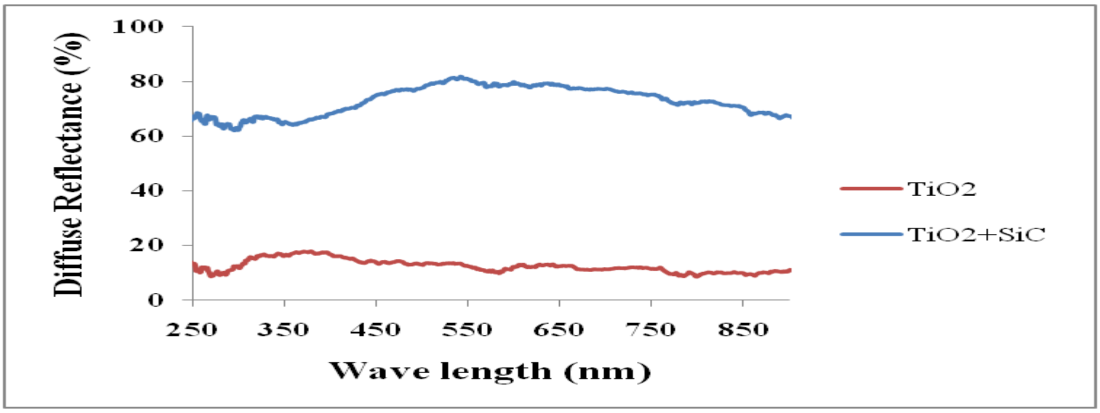

Fig.3: Diffuse Reflectance Spectrum (DRS) of TiO_2 and TiO_2/SiC layers

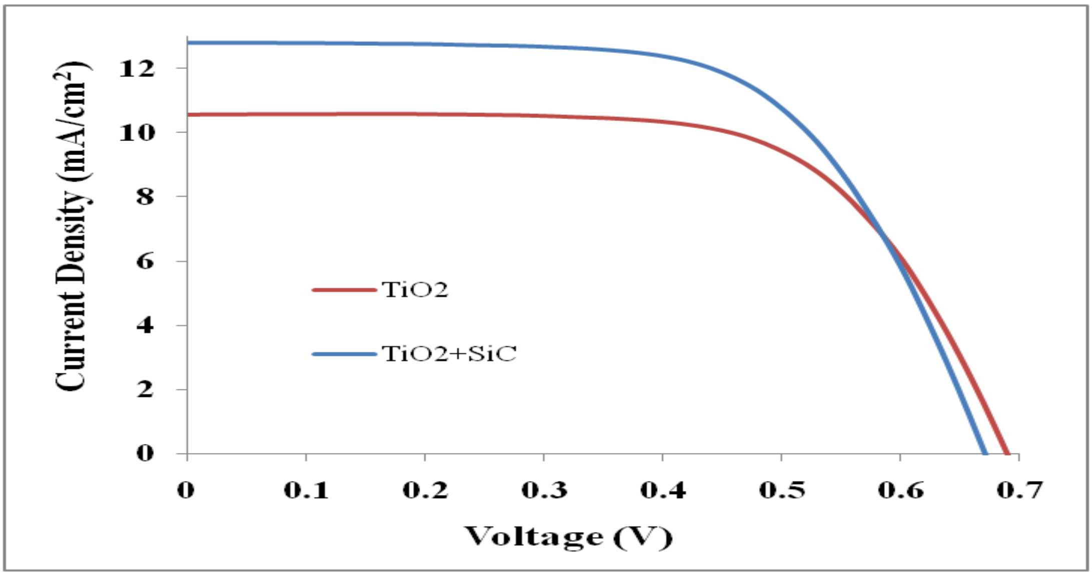

Fig.4: J-V characteristics of cells based on TiO_2 and TiO_2/SiC

Table1: Parameters of TiO_2 and TiO_2/SiC as photoanode of DSSC

Samples	J_{SC} (mA cm^{-2})	V_{OC} (V)	FF	η (%)
TiO_2	10.57	0.69	0.64	4.72
TiO_2/SiC	12.81	0.67	0.63	5.43

The incident-photon-to-current conversion efficiency (IPCE) spectra (Figure 5) provides more evidence on the scattering effect. TiO_2/SiC cell show higher IPCE than that of TiO_2 cell over the entire wavelength region, which is in agreement with the observed higher Jsc due to light scattering and DRS spectrum of layers.

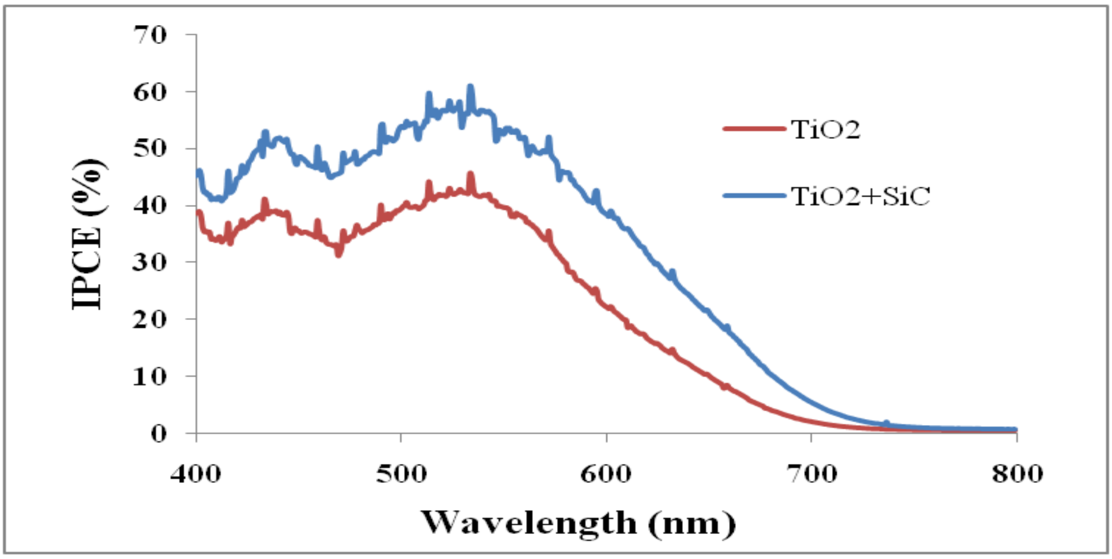

Fig.5: IPCE spectra of cells

4. Conclusions

The use of SiC nano-particles as light scattering layers in DSSC results in an increase of the current density and efficiency. With adding SiC, the percentage of reflectance distribution of light scattering layers, increases by 55 percents. Also this scattering power of SiC, improves diffused reflectance of layer and IPCE in solar cells.

References

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