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The annealing temperature effects on the synthesis of n-TiO_2/dye/p-CuI solid state solar cells

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Dye sensitized systems have aroused much attention as a cheap alternative source for regenerative power sources. The dye-sensitization process on wide band gap semiconductors was investigated in the 1960s [1]. The n-TiO_2|Dye|p-CuI dye-sensitized solid states solar cells by using cheap materials have been fabricated. The optically transparent and electrically conducting CuI of about 100 nm thickness films have been prepared by pulsed laser deposition using a CuI target. For preparation of the titanium dioxide (TiO_2) films, the glacial acetic acid (5.5 ml), 5 ml of tetraisopropyl titanate $[(CH_3)_2CHO]_4$ (Aldrich) and 1 drop of triton X-100 (Sigma) were mixed with 10 ml of 2 propanol. Water (3 ml) was added to the above solution drop wise while vigorously stirring the solution. Degusa P-25 TiO_2 powder (0.65 g, Nihon Aerisol) was added to the above mixture and was kept under vigorous stirring for 2-3 hours. The resulting semi-colloidal suspension was used as the stock solution. A small amount of the stock was spread on preheated (at about 150 ^oC) fluorine doped conduction ITO coated glass plate (1 x 2.5 cm^2) by plastic dropper and was allowed to dry for few minutes. TiO_2 coated glass plate was fired at annealing temperature from 450 to 800 ^oC for 6 hours.

Fig. 1 shows the XRD spectra of TiO_2 films. Curves a and b illustrate the XRD spectra of TiO_2 films prepared at 450 ^oC and 800 ^oC, respectively. The peak at 25.3^o (curve a) corresponds to (101) plane of the anatase phase of TiO_2, indicating that the TiO_2 film deposited at 450 ^oC is composed of anatase structure. This peak is decreased with simultaneous increase in the intensity of new peak at 28.3^o for the samples prepared at higher temperature (800 ^oC). This new peak corresponds to (110) plane of TiO_2. Only the rutile phase (curve b) was observed for the film prepared at 800 ^oC, indicating that the TiO_2 film is only composed of rutile structure.

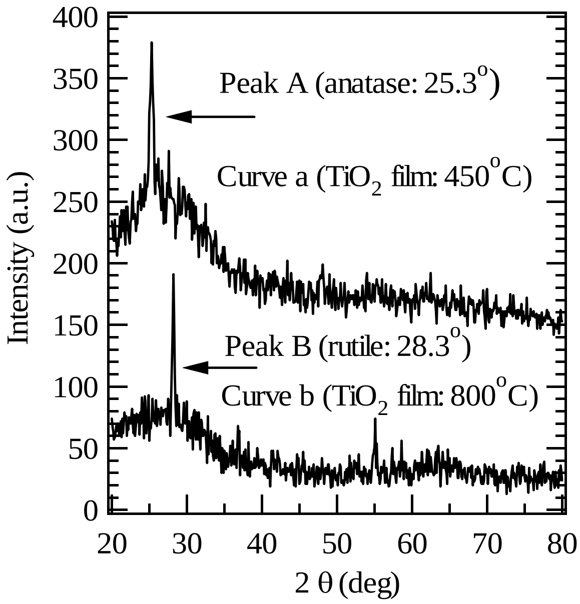

Fig. 1: X-ray diffraction for the (a) TiO_2 on glass, prepared at 450 ^oC, and (b) TiO_2 on silicon, prepared at 800 ^oC.

Fig. 2 shows the transmission spectra of TiO_2 film prepared at 450 and 800 ^oC for 6 hours, respectively. The transmittance spectrum shows the TiO_2 film prepared at 450 ^oC exhibited optical transmittance over 70% in the wavelength region in range 450 - 900 nm. TiO_2 films prepared as described above exhibited high degree of porosity and transparency to visible light. The transmittance spectra for both films (a) 450 ^oC and (b) 800 ^oC show a sharp decrease in the transmittance at around 390 - 410 nm (3.18 - 3.02 eV) of light wavelength, almost matching with the band edge of anatase (3.15

eV) and rutile (3.00 eV) phase of TiO_2 [2]. The reflectance spectra show an increase in reflectance while the transmittance spectra show a decrease in transmittance with increase of preparation temperature. This decrease in transmittance is considered partly due to higher reflectance and also partly due to higher absorption at higher preparation temperature (800 ^{o}C).

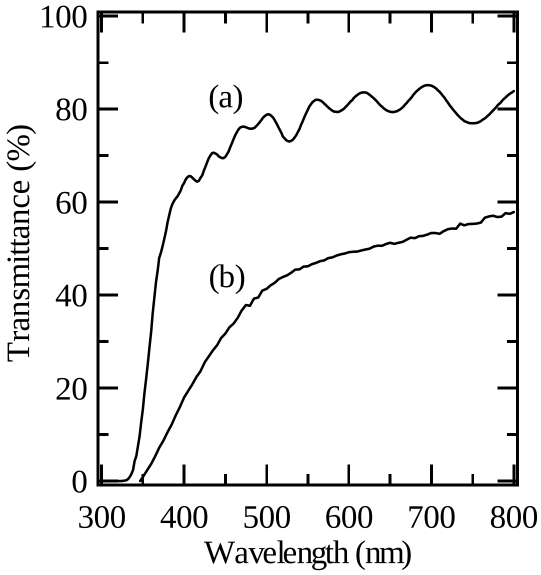

Fig. 2: Transmittance spectra of TiO_2 film prepared at (a) 450 ^{o}C and (b) 800 ^{o}C.

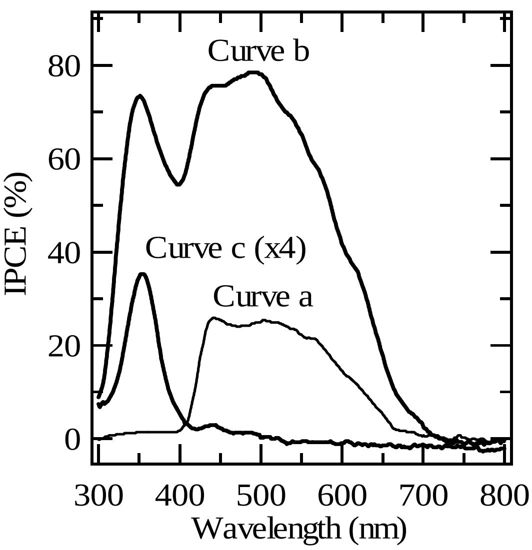

Fig. 3: Variation of IPCE with wavelength of p-CuI|Dye|n-TiO_2 for illumination through (a) CuI and (b) TiO_2 films, and (c) IPCE spectrum of TiO_2 electrode in aqueous 0.1 M NaOH under illumination.

A high incident photon to current conversion efficiency (IPCE) was observed under illumination through TiO_2 layer compared to that of through CuI layer. Dye molecules exhibited a relay effect under illumination through TiO_2 layer at wavelengths shorter than 400 nm. Significantly enhanced photocurrent was observed under illumination. Action spectra of the n-TiO_2|Dye|p-CuI cell is shown in Fig. 3. High incident photon to current conversion efficiency over 70% was observed under illumination. In addition to the sensitization process, band gap excitation of TiO_2 was observed only under illumination through TiO_2 layer, as shown by curve b in figure 3. For comparison, the IPCE action spectrum of TiO_2 electrode is shown by curve c in the same figure.

The cells performances have been given in the current-voltage working curve under illumination when exposed to AM 1.5 illumination condition (100 mW/cm^2, 25 ^{o}C). The maximum short circuit current density (J_{sc}) of about 12.2 mA/cm^2 and open circuit voltage (V_{oc}) of about 480 mV were obtained for the CuI|Dye|TiO_2 solid states photovoltaic solar cells with good reproducibility. The fill factor (FF) and power conversion efficiency (η) were about 47.8% and 2.8%, respectively.

Acknowledments

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References

[1] H. Gerischer and H. Tributsch, Ber. Bunsenges. Phys. Chem. 72 (1968) 437.

[2] H.O. Finklea, Semiconductor Electrodes, H.O. Finklea (eds), Elsevier Science Publishers B.V., Amsterdam, The Netherlands (1988) 49, and references therein.