UNIVERSITI TEKNOLOGI MARA

FABRICATION AND CHARACTERISATION OF GRADED INDEX NANOSTRUCTURED TiO_2 COMPACT LAYERS FOR DYE-SENSITIZED SOLAR CELL

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the result of my work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any other degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, University Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

A novel graded index nanostructured TiO_2 compact layer (arc-TiO_2) had been successfully deposited on Indium tin oxide (ITO) substrate by long-throw radio-frequency (RF) magnetron sputtering. The main aims of the arc-TiO_2 compact layer were to serve as an antireflective compact layer that could reduce reflection losses, improve the photo-response of dye molecules, and prevent electron recombination in a dye-sensitized solar cell (DSSC) application. The employment of the TiO_2 compact layer in the DSSC was carefully optimised in term of RF power and thickness of the arc-TiO_2 film. Meanwhile, the desired characteristics were systematically investigated by means of UV-absorption spectra, incident photon to current efficiency (IPCE), open-circuit voltage decay (OCVD) and electrochemical impedance spectroscopy (EIS). The average transmittance of the ITO/arc-TiO_2 conducting substrate in the region from 400 nm to 1000 nm was approximately 85%. Corresponding average reflectance difference that was recorded in comparison to the bare ITO was 2.5 %. The red-shift behaviour of the transmittance peak was actually due to the formation of a new hybrid band energy structure of 3.1 eV resulting from the tin (Sn) diffusion in the ITO film that shifted the absorption edge of the substrate. This had favoured the absorption characteristics and photo-response of N719 dye. Hence, the consistency of peaks between the transmittance spectra of the substrate with the corresponding IPCE spectra of the DSSC cell was improved. Additionally, the arc-TiO_2 compact layer preserved the higher conductivity of the ITO films from oxygen-related defects during the annealing process. The resistivity of the ITO/arc-TiO_2 substrate was conserved at 2.05×10^{-4} Ω cm even at this high temperature. The preserved conductivity had consequently decreased the charge interfacial resistance (R1) in the EIS measurement and facilitated the charge transport from the nanocrystalline-TiO_2 to the ITO. In later investigations, it was revealed that the 100 nm thickness of arc-TiO_2 compact layer prepared using 100W RF power become the optimal deposition parameters for preparing the compact layer. At this stage, the reduced interfacial resistance R1 observed under EIS measurement was 2.36 Ω and the highest IPCE peak of 58% was achieved at 550 nm wavelengths. The higher IPCE had contributed to 8.93 mA/cm^2 of the cell's short-circuit photocurrent, J_{SC} and 0.67 V to the associated open circuit voltage, V_{OC}. The photo-generated electron lifetime, τ_n of 1.1 orders of magnitude higher than bare ITO was achieved. As a result, the overall conversion efficiency of 3.45% was recorded for the optimized DSSC device. This record was actually 50% improved compared to that of bare ITO cell. Therefore, the combined effects (i.e., reduced reflection losses and interfacial resistance with better photo-response) owed to the arc-TiO_2 compact layer prepared at their optimal condition was found to be important as it had originated the remarkable improvement in this arc-TiO_2 based DSSC.

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