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# Investigation of ZnO-based nanostructured dye-sensitized solar cell electrodes

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*In the name of God*

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# INVESTIGATION OF ZnO-BASED NANOSTRUCTURED DYE-SENSITIZED SOLAR CELL ELECTRODES

**BY**

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# ABSTRACT


## INVESTIGATION OF ZnO-BASED NANOSTRUCTURED DYE-SENSITIZED SOLAR CELL ELECTRODES

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With increasing consumption of energy, non-fossil energy sources such as solar energy are being considered intensely. In this study several different morphologies of nanostructured ZnO arrays were produced as photo-anode electrodes of dye-sensitized solar cells. Fluorine-doped tin oxide (FTO) substrate was pre-modified with a ZnO thin film as a seed layer by Sol-Gel coating. Then, well-aligned ZnO nanorod arrays with high aspect ratio have been grown on the substrate by hydrothermal process. $TiO_2$ thin shells with different thickness were grown on the ZnO nanorods by chemical vapor deposition (CVD) method, which improved the cell efficiency. Also flower like ZnO nanosheets, and globular ZnO, which it was a novel structure, were grown on FTO substrates by chemical bath deposition (CBD). Dendritic structures were produced by growing the ZnO nanorods on flower like ZnO nanosheets which it was different from others. Sample characterization was performed by X-ray diffraction (XRD), electron microscopy (SEM, FESEM, TEM, and SAD), X-ray photoelectron spectroscopy (XPS), and UV-vis Spectroscopy. The nanorod diameter distribution was obtained from SEM and FESEM images. The diameter of the ZnO nanorods ranged from about 30nm to more than 100nm and their lengths were about 6μm for 12 hours hydrothermal process. XRD and TEM analysis indicated a wurtzite structure with high crystallinity and confirmed that each individual ZnO nanorod was a single crystal. XPS and TEM results confirmed the formation of a $TiO_2$ film on the ZnO nanorods. UV-vis Spectroscopy showed that the transmittance of ZnO nanosheets layers was more than ZnO nanorods sample with the same thickness in the visible range. The photoelectrochemical experiments were performed in a sandwich type

two-electrode cell and *J-V* curves were obtained. Results of the test of ZnO nanorods based solar cells, showed that by increasing the thickness of ZnO nanorods layer, efficiency improved slightly and then decreased for higher thickness values. The results of solar cell testing showed that coating of $TiO_2$ shells on ZnO nanorod significantly increased the short circuit current ($J_{SC}$), open circuit voltage ($V_{OC}$), fill factor and efficiency relative to devices without $TiO_2$ shells. Overall cell efficiency jumped from 0.45% for bare ZnO nanorode array to 0.92% for 14 nm thick $TiO_2$ shells on ZnO which showed a two fold increase. The fill factor increased from 0.37 to 0.60, showing a 62% improvement. For a $TiO_2$ shell 21 nm thick, $V_{OC}$ increased from 0.53V, to 0.68 V. The results showed that it is possible to fabricate core-shell cells of higher efficiency by using nanorod arrays. Using ZnO nanosheets and globular ZnO electrodes instead of ZnO nanorods, improved the $J_{SC}$, $V_{OC,}$ fill factor and solar cell efficiency. Using ZnO nanosheets electrodes instead of ZnO nanorods, increased the cell efficiency from 0.45% to 2.9%, which showed a several fold increase. Overall conversion efficiency about 3.8% was obtained for globular ZnO electrodes. Also by using dendritic structures of ZnO the cell efficiency and other parameters were improved, which was due to the high surface area. Increased thickness of ZnO nanosheets and globular structures layers improved the efficiency several times, which was not possible for ZnO nanorod. Design of experiments via Taguchi methods was done and the optimum condition was obtained. The results of solar cell tests showed that sensitization time was an important parameter in the ZnO based dye-sensitized solar cell efficiency and the highest efficiency was obtained for 30 minutes sensitization time.

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