Stability of Photoactive Oxide Semiconductors

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One-Dimensional nanofibrous semiconductor oxides offer great potential for solar energy conversion because of the reduced grain boundaries and increased surface area. They provide direct electrical pathway for the rapid collection of carriers generated within the surface, thus minimizing the charge recombination rate [1]. Numerous reports have been devoted to photovoltaic technology, but there are still certain trade-offs in the current state of research. Relevant aspects include lower photoconversion efficiency, use of potentially hazardous materials, high cost and low stability. In order to minimize these limitations, semiconductor oxides are coupled with suitable sensitizers to harvest the visible region of solar spectrum. Semiconductor QDs are considered as excellent sensitizers because of their unique material properties such as tunable band gaps, multi-exciton generation (MEG), and large intrinsic dipole moments [2]. Although stability is a very critical parameter for photoactive films, there have been relatively fewer reports on the systematic study of the influence of growth parameters on the stability of oxide films. This study reports on the stability of various semiconductor oxide films.

Ti foils (2 cm x1 cm) were polished and degreased with sonication in 1:1 isopropanol and acetone solution for 10 minutes. Highly ordered TiO_2 nanotube arrays were grown by potentiostatic anodization in two electrode electrochemical cell with coiled Pt wire cathode. Constant voltage of 30V was applied for 2 hrs. The electrolyte consisted of 0.5 wt% NH_4F dissolved in ethylene glycol solution with 3 wt% H_2OThe distance between working and counter electrode was about 2-3 cm [3]. The as-prepared TiO_2 NT films were annealed at 450^oC under air atmosphere for 2 hrs. Annealed TiO_2 NTs were sensitized with binary and ternary quantum dots employing Succesive ionic layer absorption and reaction (SILAR) technique [4]. After sensitization, films were washed with DI water and dried under N_2 atmosphere at 300^oC for 1 hr.

Surface morphology of the films (before and after sensitization) was examined by SEM technique. Elemental composition of substrate and oxidation state of elements was analyzed with X-ray photoelectron spectroscopy (XPS). Photoelectrochemical measurements (photocurrent/ photovoltage versus time and I-V characteristics) were carried out to depict the photoconversion efficiency of designed photoanodes. Electrochemical impedence spectroscopy (EIS) and incident photon to current conversion efficiency (IPCE) results were also obtained. The correlation of morphological changes with photoelectrochemical response of sensitized-TiO_2 nanostructures will be discussed. Stability studies of TiO_2 films and various other semiconductor oxides using ICP-MS technique will be presented.

Acknowledgements: This study was supported by the Department of Energy, under Contract DE-FG36-06GO86066.

References

1. P. Sudhagar, J. H. Jung, S. Park, Y.-G. Lee, R. Sathyamoorthy, Y. S Kang and H. Ahn. "The performance of coupled (CdS:CdSe) quantum dot-sensitized TiO_2 nanofibrous solar cells." Electrochemistry Communications 11 (2009): 2220–2224.

2. Z.-X. Li, Y.-L. Xie, H. Xu, T.-M. Wang, Z.-G. Xu and H.-L. Zhang. "Expanding the photoresponse range of TiO_2 nanotube arrays by CdS/CdSe/ZnS quantum dots co modification." *Journal of Photochemistry and Photobiology A: Chemistry* 224 (2011): 25– 30.

3. J. Wana, X. Yan, Junjie Ding, M. Wang and K. Hu. "Self-organized highly ordered TiO_2 nanotubes in organic aqueous system." Materials Characterization" 60 (2009): 1534 – 154.

4. S.D. Sartale andC.D. Lokhande. "Growth of copper sulphide thin films by successive ionic layer adsorption and reaction (SILAR) method." *Materials Chemistry and Physics* 65 (2000): 63–67.