Dye Aggregation Influence on Dye Sensitized Solar Cell Performance in Nanocoral ZnO-Based Thin Film Cells Sensitized With N-719 and Rose Bengal Dyes

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Dye sensitized solar cells are regarded as a relevant class of photovoltaic devices offering significant efficiencies at a relatively low cost. One of the main challenges in the area lies in finding novel electrode materials and sensitizers. The goal of this work was to apply instead of the commonly used TiO_2 electrode a nanoporous ZnO material fabricated using the large throughput technique of sputtering and to evaluate its performance as a function of the material properties. Furthermore, a direct comparison of two dyes in one structure is performed leading to the assessment of a double-dye cell.

The electrodes were formed on fluorine-doped indium tin oxide (FTO) covered glass. The photoelectrode was fabricated through deposition of a nanocoral Zn film by magnetron sputtering with subsequent annealing in an oxygen flow at 400 °C for 5 minutes. To increase its conductivity, it was doped with hydrogen by annealing in an Ar/H_2 flow at 350 °C for 30 seconds. The photoelectrodes were sensitized by soaking in 0.25 mM ethanol solutions of the N-719 and RB dyes. A 0.5 mM solution was also prepared for the N-719 dye for comparison. The soaking times were in the range of 0.5 h to 100 hours. The counter electrode was a 5 nm thin Pt film on the FTO-covered glass. Holes were drilled for electrolyte filling in the counter electrode and the cell was assembled by gluing the two electrodes together using a 25 µm – thick adhesive gasket. Finally, the structure was filled with a iodide/tri-iodide acetonitrile-based electrolyte and sealed. Cell testing was performed using a solar simulator by measuring dark and illuminated J-V characteristics. A photodiode model was fitted to the data, yielding the series and shunt resistivities as well as diode ideality factors. Structural studies of the electrode material was performed by means of scanning (SEM) and transmission electron microscopy (TEM) with energy dispersive x-ray spectroscopy (EDX). The obtained data are discussed to relate the cell performance to the material structures.

We found that the optimum electrode sensitization time was 5 hours for N-719, yielding η = 1.37%. For longer times, an amorphous scale formed on top of the electrode film, deteriorating performance by blocking free electrolyte flow. By TEM imaging the structure and nanometer-scale thickness of these N-719 shells was determined. On the other hand, for the RB dye, sensitization times of the order of 100 hours are optimal but the efficiencies are significantly limited to fractions of the N-719 value. This dye covered the ZnO nanocrystals less effectively by forming a much thinner shell than the N-719 dye, which we believe to be the main reason for lowered efficiency.

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