Efficiency Enhancement in Dye-Sensitized Solar Cells Using Hierarchical TiO_2 Microspheres as a Scattering Layer

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Abstract

Dye-sensitized solar cells (DSCs) have emerged as a viable alternative to the conventional silicon-based solar cells due to simple fabrication, low cost and tunable aesthetic features, such as colour and transparency. The photoanode of DSCs, usually TiO_2 layer, plays a crucial role in the overall power conversion efficiency as it influences in both photon absorption and electron transport. The efficient photoanode should have large surface area, well-connected internal pores and efficient light scattering property. In order to further enhance the efficiencies of DSCs, different light scattering techniques are used. Typically, this is achieved by employing another layer of TiO_2 containing larger size spheres on top of the smaller size particle layer of TiO_2. In this work, we have succeeded in designing a hierarchically structured TiO_2 scattering layer consisting of sub-micron size TiO_2 spheres composed of aggregates of TiO_2 nanoparticles of size around 10 nm. The DSCs with hierarchical TiO_2 sphere scattering layer sensitized with N719 dye outperform the DSCs having TiO_2 nanofiber and TiO_2 nanotube scattering layers. The highest current density of 14.80 $mAcm^{-2}$ was achieved with TiO_2 sphere scattering layer compared with TiO_2 nanofiber and TiO_2 nanotube scattering layers. The power conversion efficiency of DSC with hierarchical TiO_2 sphere scattering layer was 7.38 % under standard AM 1.5 illumination conditions, whereas the efficiency of DSC without scattering layer was 6.68 % and the efficiency of DSC with TiO_2 nanofiber scattering layer and TiO_2 nanotube scattering layer was 6.47 % and 7.03 % respectively. The diffuse reflectance measurements reveals that the better performance of DSC with hierarchical TiO_2 sphere scattering layer is mainly due to the improved light harvesting by scattering of long wavelength radiation by the sub-micron size TiO_2 spheres.