Material and Structural Design for High Efficiency Dye-Sensitized Solar Cell

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We report here (part 1) the size-dependent scattering efficiency and (part 2) the bi-functional material of nano-embossing hollow spherical (NeHS) TiO_2 for high efficiency dye-sensitized solar cell. Part 1. Effect of scattering particle size on light scattering efficiency in dye-sensitized solar cell has been investigated using two different rutile TiO_2 particles of 0.3 μm (G1) and 0.5 μm (G2). The conversion efficiency of 7.55% for the thin nano TiO_2 underlayer film is improved to 8.94% and 8.78% when G1 and G2 particulate overlayer is introduced, respectively, corresponding to 18.4% and 16.3% increases. Significant improvement and strong size-dependence are associated with the quantity and wavelength of transmitted light and the difference in reflectivity of G1 and G2 scattering particles. Part 2. Nano-embossing hollow sphere (NeHS) TiO_2 was prepared without the aid of template or surfactant. TEM study for the sliced NeHS confirms that the wall of hollow sphere is composed of ~18 nm anatase TiO_2 particles with mesoporous structure. Photovoltaic property is studied using a bilayer structured film having the NeHS TiO_2 overlayer. Upon deposition of the NeHS TiO_2 particulate film on the 6 μm-thick nanocrystalline TiO_2 film, the conversion efficiency is improved remarkably from 7.79% to 9.43%, corresponding to 21% increase. The NeHS TiO_2 overlayer film exhibits even better conversion efficiency than the films consisting of the mainly nanocrystalline TiO_2 and the light scattering overlayer with large TiO_2 particles having flat surface. Studies of incident photon-to-current conversion efficiency (IPCE) and UV-Vis reflectance suggest that such superior photovoltaic performance is attributed to the efficient light scattering and photocurrent generation characteristics by NeHS TiO_2. Using the bi-functional property of NeHS TiO_2 and adjusting layer thickness, the conversion efficiency as high as 10.34% has been achieved under AM-1.5G one sun light intensity.