Design of Novel Hierarchical TiO_2 Photoanode Material for Optimum Performance in Dye-Sensitized Solar Cell

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Abstract

The dye-sensitized solar cell (DSC, Graetzel cell) presents an attractive alternative to solid-state photovoltaics at competitive cost[1]. Morphological engineering of a TiO_2 photoanode aims at preparation of perfectly crystalline transparent layers with high surface area and represents one of the key issues in optimization of DSCs. Due to obvious incompatibility of these properties, combined hierarchical layers were designed to meet both requirements. The solar performance of multilayer mesoporous TiO_2 films sensitized with N-945 dye scales linearly for 1 – 3 layer films, but reaches plateau value for more than 8 layers[2, 3]. The solar conversion efficiency of 5.05 % was found for a 2.3 μm thick mesoporous TiO_2 film consisting of 10 layers[4]. To eliminate problem of electron capturing and recombination with dye/electrolyte within extremely open mesoporous structure, which probably hinders the increase of solar conversion efficiency for 8 and more mesoporous TiO_2 layers, electrospun nanocrystalline fibrous TiO_2 was incorporated into mesoporous TiO_2 thin film. TiO_2 with fibrous morphology was found to be beneficial for the performance of corresponding photoanode in dye-sensitized solar cell (DSC). Obviously, its wirelike structure suitably interconnects mesoporous network and thus increases the electron collection efficiency from the TiO_2 layer to the F-doped SnO_2 (FTO) electrode. Performance of the DSC with 2.5 μm bimodal TiO_2 photoanode reached 5.35%. Among others, the performances of DSCs are limited by the charge recombination taking place mainly at the FTO/TiO_2 interface. Due to the porous structure of TiO_2 films the electrolyte solution easy penetrates to the FTO. The physical contact between the electrolyte and the FTO surface causes the charge recombination resulting in a considerable loss of photoelectron conversion efficiency in DSCs. Therefore, the recapture of the photoinjected electrons with the I_3^- ions should be avoided. FTO coverage with a thin compact TiO_2 underlayer was found to be the effective way to reduce the contact surface area for the bare FTO substrate and the redox electrolyte (so-called blocking effect). Besides the blocking effect, the compact layer can improve the adhesion of the FTO/TiO_2 interface as well and creates more electron pathways from the porous layer to FTO and subsequently increases the electron transfer efficiency. Compact non-porous TiO_2 films were prepared by means of dip-coating from precursor sol containing poly(hexafluorobutyl methacrylate) as the structure directing agent[5]. The roughness factor is lower than 20 even for approximately 1 μm thick film. Films were grown on glass and FTO and cover even rough surfaces of the substrates perfectly, which proves the presence of thixotropic properties in the Ti-precursor gel.

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