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Solar Energy Materials & Solar Cells
ELSEVIER
Solar Energy Materials & Solar Cells 87 (2005) 77–86
www.elsevier.com/locate/solmat

Performance of dye-sensitized solar cell based on nanocrystals TiO_2 film prepared with mixed template method

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Received 18 May 2004; received in revised form 15 June 2004; accepted 18 June 2004
Available online 21 November 2004

Abstract

Highly efficient dye-sensitized solar cells were produced using high-crystalline TiO_2 nanoparticles as a thin-film semiconductor prepared with a mixed template of copolymer F127 (poly(ethylene oxide)$_{106}$-poly(propylene oxide)$_{70}$-poly(ethylene oxide)$_{106}$) and surfactant CTAB (cetyltrimethylammonium bromide) which allows access to larger surface area, smaller size and higher crystallinity TiO_2 particles. The light-to-electricity conversion of the TiO_2 film composed of nanocrystals with the size of 3~5 nm, which carry out perfect electrical contiguity between film and conducting glass and between every TiO_2 coating, was over 6% with a film of 5.5 μm thickness. Over 8% conversion efficiency has been obtained with a double-layer film composed by the TiO_2 layer and the scattering layer.

Keywords: Dye-sensitized solar cell; TiO_2 nanocrystal; Block copolymer

1. Introduction

Dye-sensitized solar cell (DSC) is currently attracting widespread academic and intense commercial investigation and interest for the conversion of sunlight into

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doi:10.1016/j.solmat.2004.06.011

electricity because of their low-cost and environment friendly photovoltaics with good efficiencies comparable to that of silicon cell [1]. These cells consist of a nanoporous anode formed by a sintered film of anatase TiO_2, which serves as electron acceptor and transport layer coated with a monolayer of a sensitizer dye for light absorption and electron injection into the TiO_2 conduction band. A liquid electrolyte generally consists of an organic solvent such as acetonitrile and a redox couple I^-/I_3^- that serves as the redox medium to regenerate the photoexcited dye molecules by reduction. In the cells, undoubtedly, the mesoporous titania films and the dyes are two of the key components for high-power conversion efficiencies. Research efforts have focused on improving this system by altering the particle size and morphology of TiO_2 [2], optimizing the fabrication and structure of the TiO_2 film [3–5], developing new sensitizers [6], suppressing charge recombination [7] and improving interfacial energetics [8]. A high performance of DSC required the nanocrystalline TiO_2 electrode with large surface area, high crystalline and without crack and cavities, and favorable electrical contiguity with the conducting glass substrate, so that the dyes can be sufficiently adsorbed and the electron can be quickly transferred. So far, the most common TiO_2 films electrode has been prepared from colloids with the doctor blade technique, which make it possible to achieve porous electrodes with high surface areas. However, the method is needed to disperse TiO_2 colloid nanoparticles in water with surfactant dispersants and specialized and complicated equipments and techniques in order to improve the electrical contiguity with the conducting glass substrate and increase the pore volume in the film. Hence, the incompletely dispersion and aggregation of particles is difficult to overcome, resulting in a film with cracks, cavities and bad electrical contiguity between the conducting glass and TiO_2 film, which cause low energy conversion efficiency in DSC. The aims of this report are, therefore, to establish a chemical technique by making a gel composed by nanocrystals TiO_2 and organic compound, which is mixed with TiO_2 in the molecular scale. The method would replace the conventional physical mechanical dispersion methods and make it much easier to fabricate the DSC and overcome the defect of the traditional method. The gel can be freely and easily coated on the surface of substrates to form transparent TiO_2 film electrodes with various thickness, diverse shapes, perfect electrical contiguity and high efficiency.

There are many routes for the creation of inorganic/organic complex: among those, the template synthesis method is considered prospective, based on the advantages of homogeneity, purity, and novel morphologies, structure and properties [9]. Here, TiO_2 gel with anatase phases was prepared by using a mixed template and directly used to fabricate the DSC. In our work, the mixed template agents play not only a role of template, which formed the porous structure, but also are responsible for the fabrication of homogeneous TiO_2 gel, which is crucial for the preparation of films with uniform and crack-free structure and perfect electrical contiguity. So it is very important to select suitable templates for making high-performance TiO_2 film and improving the efficiency of the DSC. Taking into account all these considerations, we select copolymer F127 produced by BASF company, an excellent gelation and coating agent, as our template which benefits for