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Improved electron transfer of TiO_2 based dye sensitized solar cells using Ge as sintering aid

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ABSTRACT

Low electron mobility of TiO_2 semi-conductor and inferior inter-particle contact facilitate recombination reactions that leads to low performance of dye sensitized solar cells (DSSCs). To improve electron mobility at relatively low sintering temperatures, doping of germanium (Ge) nanoparticles with TiO_2 have been trailed due to its excellent optoelectronic and low temperature sintering properties. Anatase TiO_2-Ge nanocomposites have been prepared by using colloidal suspension process and deposited on conducting glass using doctor blade technique. Four types of nanocomposites i.e. (1) TiO_2–0.5 wt%Ge, (2) TiO_2–2 wt%Ge, (3) TiO_2–5 wt%Ge and (4) TiO_2–10 wt%Ge have been prepared and sintered at 400 °C with a control specimen fabricated using pure TiO_2 nanoparticles (sintered at 450 °C) for comparison purpose. To investigate the morphological and structural characteristics, SEM and XRD have been employed. The UV-vis and impedance spectroscopy have been performed to observe light absorption and electron transfer characteristics respectively. Finally, specimens were tested for their photo conversion efficiency. An increase in electron transfer ability and conversion efficiency have been recorded with increase in Ge nanoparticles even at 400 °C sinter temperature compared to reference TiO_2 photoanodessintered at 450 °C.

1. Introduction

Electron recombination reactions and light scattering ability along with dye pick up capacity are the main parameters to improve the performance of electrochemical dye sensitized solar cells (DSSCs) [1,2]. Efficient charge carrier transport (electrons) from the semiconductor nanostructure to the external load through transparent conducting oxide layer without recombining with electrolyte or dye guarantee the suppression of recombination reactions which is still one of the main reasons of less efficiency of DSSC device [3]. For efficient electron transfer, it is of utmost importance that the semiconductor nanoparticles should be sintered to coble initial sintering stage where inter-particle contact area increases by neck growth from 0 to ∼0.2%. Sintering temperatures which are restricted to 400 and 450 °C cannot provide this much vibrational energy to increase the thermal entropy (ST) to the extent necessary to lower the surface/boundary energy (γ_{gb}) of nanoparticles by 2/3 compared to solid/vapor surface energy (γ_{sv}) of the system. Without enough heat energy the Gibbs free energy of surfaces will not allow the formation of necks and diffusion of surfaces for proper inter-particle contact [4].

Various approaches have been trialled to improve the incident photon conversion efficiency (IPCE) of DSSCs, such as size quantization [5–7], development of different nano-architectures [8–11] and doping with different cations and anions

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