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Bismuth as efficient sintering aid for TiO_2-based low temperature dye sensitized solar cell

Hazim Khir [a], A.K. Pandey [a,b,*], R. Saidur [a], Muhammad Shakeel Ahmad [c,**], M. Samykano [d], Nasrudin Abd Rahim [c]

[a] *Research Centre for Nanomaterials and Energy Technology (RCNMET), School of Engineering & Technology, Sunway University, No. 5, Jalan Universiti, Bandar Sunway, Petaling Jaya, 47500, Selangor Darul Ehsan, Malaysia*
[b] *Center for Transdisciplinary Research (CFTR), Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India*
[c] *Higher Institution Centre of Excellence (HICoE), UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D, University of Malaya, Jalan Pantai Baharu, 59990, Kuala Lumpur, Malaysia*
[d] *Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26600, Pekan, Pahang, Malaysia*

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ABSTRACT

Flexible dye sensitized solar cell (DSSC) developed at low temperature with low conversion efficiency due to the poor interparticle contact and charge transfer has limited their further development. In this research, bismuth (Bi) nanoparticles were implemented as titanium dioxide (TiO_2) photoanode sintering aid to combat this issue. By utilising the liquid phase sintering theory, interparticle contact of photoanode was improved due to neck formation at the TiO_2–Bi matrix. This feat was achieved even at low temperature (150 °C and 200 °C) because Bi have a low melting point of 271.5 °C. The charge transfer was also found to have increased while the resistance lowered with the implementation of Bi from the plasmonic effects of Bi nanoparticles. The highest conversion efficiency was obtained at 7.93 % for the TiO_2-5wt% Bi sample sintered at 200 °C. The efficiency was 2%–16 % higher than controlled DSSC samples prepared at high temperature (450 °C). The improvement in interparticle contact due to neck formation and enhanced charge transfer with reduced recombination reactions was attributed as the reason for the superior performance. Increasing the Bi composition even further caused reduction in the efficiency due to layer cracking and electron trapping sites from high amount of Bi.

1. Introduction

A typical dye sensitized solar cell (DSSC) device is consist of several components that include the photoanode, counter electrode, conductive substrate, sensitizing dye and liquid electrolyte. As a third-generation and emerging solar cell technology, DSSC has been growing rapidly due to their low cost from material abundance as well as having cheap and simple fabrication process [1]. Conductive glass substrate including fluorine-doped tin oxide (FTO) glass and indium-doped tin oxide (ITO) glass is typically used in DSSC development, giving the device a rigid structure [2]. Semiconducting metal oxide material such as titanium dioxide (TiO_2) with appropriate band position and large surface area is typically coated onto the glass substrate and underwent sintering process at high temperature of 450 °C to construct the photoanode component [3]. Sintering the photoanode at high temperature was conducted to remove organic additives present in the photoanode material, enhance the interparticle connection, improve charge transport and collection [4]. DSSC counter electrode meanwhile is typically made up of conductive substrate coated with catalyst such as platinum (Pt) [5]. However, DSSC still suffers from the issue of low conversion efficiency compared to other third-generation solar cell such as perovskite and organic solar cells that yielded conversion efficiency of 25.5 % [6] and 20.6 % [7] respectively. Meanwhile, the highest recorded efficiency for DSSC so far stands at 15.2 % [8]. Thus, flexible DSSCs have been developed in order to lower the manufacturing cost and widen DSSCs' application as another way to address the issue limiting the device

* Corresponding author. Research Centre for Nanomaterials and Energy Technology (RCNMET), School of Engineering & Technology, Sunway University, No. 5, Jalan Universiti, Bandar Sunway, Petaling Jaya, 47500, Selangor Darul Ehsan, Malaysia.
** Corresponding author. Higher Institution Centre of Excellence (HICoE), UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D, University of Malaya, Jalan Pantai Baharu, 59990, Kuala Lumpur, Malaysia.
E-mail addresses: adarsh.889@gmail.com, adarshp@sunway.edu.my (A.K. Pandey), shakeelalpha@gmail.com (M.S. Ahmad).

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