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Improved charge transfer through the minimal addition of Pb as a sintering aid to TiO_2-based low-temperature dye sensitised solar cell

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ABSTRACT

The poor interparticle connectivity between the nanoparticles architecture of photoanode due to insufficient sintering temperature has been an issue for developing flexible dye sensitised solar cell (DSSC). This issue has led flexible DSSC to yield low conversion efficiency. This research aims to implement lead (Pb) as sintering aid to improve the interparticle connection of the photoanode by using the concept of liquid phase sintering. With low melting point of Pb (327.5 °C), necks were formed at the titanium dioxide (TiO_2)–Pb interface that improved the connection and lowered the electronic resistance even at low sintering temperature of 150–250 °C. Morphological studies showed the formation of these necks, while phase analysis indicated the more desirable TiO_2 anatase phase was present. Specimens containing 5 wt% Pb in the TiO_2 matrix showed the highest efficiency value of 8.73% at 250 °C, which is even higher compared to their high-temperature (450 °C) counterpart by 12.21%. This is due to surface fusion of Pb at a lower temperature, leading to enhanced interparticle contact and reduction in recombination reactions. Further increase in Pb did not improve the conversion efficiency which can be due to high charge trapping sites and layer cracking due to high amounts of Pb in TiO_2 matrix.

1. Introduction

Dye sensitised solar cells (DSSCs) are a third-generation solar cell that have been growing in popularity due to their low cost of production with readily available materials, easy fabrication process, ability to operate under low-light conditions, good stability, and nice aesthetics [1,2]. DSSC is a sandwich structure comprised of components including the conductive substrate, photoanode, counter electrode, sensitiser/dye and electrolyte. Typically, the conductive substrate is made up of conductive glass materials such as fluorine tin oxide (FTO) glass with one substrate coated with semiconducting materials such as titanium dioxide (TiO_2) nanoparticles that are sensitised with dyes (ruthenium-based) [3]. Meanwhile, the other substrate is coated with counter electrode catalysts, typically platinum or other materials such as MXene (Ti_3C_2) flakes [4] and tungsten disulfide (WS_2) nanosheets [5]. The two electrodes are then joined together with some iodide-triiodide liquid electrolyte is usually deposited in between them to complete the device. Due to the device's simplicity, DSSC have been under intensive research, with the highest efficiency recorded at 14.2% in the year 2020 [6], a slight increase from the previous record of 12.3% in 2011 [7]. The lack of significant improvement in the efficiency of DSSC highlights their main issue, especially when compared to some other third-generation solar cells, such as perovskite and organic solar cells with conversion efficiency of 25.5% and 19%, respectively [8,9]. Therefore, researchers have been taking a different approach by reducing the cost of DSSC manufacturing instead while still producing good or comparable

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