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Optimizing concentration of titanium dioxide nano-fillers in PEO gel-polymer electrolytes for enhanced performance of dye-sensitized solar cells

Chandrika R. P.[1*], Liyanage J. P.[1,2], Wijayaratne W. M. K. B. N.[1,2] and Bandara T. M. W. J.[1,2]

[1]Postgraduate Institute of Science, University of Peradeniya, Sri Lanka.
[2]Department of Physics, Faculty of Science, University of Peradeniya, Sri Lanka.
pathma.chandrika@gmail.com*

The influence of nano-composite gel-polymer electrolytes on the performance of dye-sensitized solar cells (DSSCs) has attracted significant attention recently. In this study, titanium dioxide nanoparticles (TiO_2) with varying percentages were incorporated into a gel-polymer electrolyte in order to determine the optimal nanofiller (NF) concentration as well as to study the effect of NFs composition on conductivity in the polymer electrolyte and light to current conversion efficiency of DSSCs. For these purposes, TiO_2 NFs with an average particle size of 13 nm were incorporated into polyethylene oxide (PEO) based gel-polymer electrolyte. The TiO_2 nano-composite electrolyte series were prepared by varying the TiO_2 NF composition from 0.0 to 25.0 wt.% relative to the PEO weight. The DSSCs were assembled by sandwiching NF incorporated polymer electrolyte between a multilayer photoanode sensitized with N719 dye and platinum electrode. The conductivity and light to current conversion efficiency depend on the NF composition in the polymer electrolyte. The electrical conductivity of the electrolyte and efficiency of DSSCs containing nano-composite electrolytes increases with the increase in TiO_2 content up to 17.5 wt.% and then decreases with any further increase in TiO_2 percentage. Temperature-dependent electrical conductivity of the prepared nanocomposite gel-polymer electrolytes was investigated by gradually increasing the temperature from 20 °C to 80 °C increments of 10 °C. The conductivity increased with rising temperature within this range, and the temperature dependence exhibited VTF (non-Arrhenius) behavior. The optimum TiO_2 composition was found to be 17.5 wt.%, with a conductivity of 5.18 mS cm^{-1} at 20 °C, which increased to 10.43 mS cm^{-1} when the temperature was raised to 80 °C. Thus the highest recorded conductivity was observed at the temperature of 80 °C, testing temperature was not raised further as higher temperatures cause the release of I_2 from the electrolyte. The conductivity enhancement with added TiO_2 can be attributed to the change in the morphology of the polymer network. TiO_2 NFs contribute to this process by inducing electrostatic interactions/Lewis acid-base interactions between O atoms of the PEO and hydroxyl group of the TiO_2 particles. DSSC assembled with the polymer electrolyte containing 17.5 wt.% of TiO_2 NFs (the highest conducting electrolyte) exhibited the highest photoelectric conversion efficiency of 7.30%, representing a 28.1% enhancement compared to the reference DSSCs assembled with a filler-free gel-polymer electrolyte, which had an efficiency of (5.70%).

Keywords: Dye sensitized solar cells, Ionic conductivity, Nano fillers, Photoelectric conversion efficiency

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