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RESEARCH

Investigation of the mixed cation effect and the irradiance level dependence on the efficiency of dye-sensitized solar cells

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Abstract

The development of photoelectrochemical energy conversion devices holds immense significance in addressing the escalating demand for renewable and environmentally benign energy. By harnessing the synergistic effects of salt mixtures that encompass both large and small counter ions, notable advancements in dye-sensitized solar cell (DSSC) performance have been realized. The investigated DSSCs with a novel organic electrolyte complex that contains LiI and (tetrahexylammonium) Hex_4NI exhibited significant efficiency enhancement compared to that of their individual salt end components. The ionic conductivity variations and frequency-dependent AC conductivity in the electrolyte and dielectric properties were analyzed using complex impedance data. The conductivity in the electrolyte at room temperature is 11.44 mS cm^{-1}. The investigated DSSCs are comprised of improved TiO_2 multilayer photoelectrodes and Pt counter electrodes. Under an irradiance of 1000 W m^{-2}, the energy conversion efficiency of the mixed salt system reached 8.37%, marking an impressive enhancement of 86.83% and 76.21% compared to the Hex_4NI and LiI-based single salt counterparts, respectively. Additionally, an impressive efficiency of 10.57% is shown when the light intensity drops to 400 W m^{-2}. The cells exhibited commendable short-term stability, likely attributed to the elimination of volatile solvents in the electrolyte. This study underscores the pivotal role played by mixed counter ions in the electrolyte, as they elicit synergistic effects that amplify DSSC performance enhancements, effectively overshadowing the effects imposed by conductivity variation.

Keywords Dye-sensitized solar cell · Mixed salt electrolyte · Electrolyte · Multilayer electrode · Low light

Introduction

It is crucial to conduct research on photoelectrochemical (PEC) energy conversion devices to address the rising demand for energy and the dwindling supply of nonrenewable energy sources. Due to their reduced manufacturing cost and ease of fabrication, dye-sensitized solar cells (DSSCs) are a prospective alternative to conventional silicon-based solar cells [1, 2]. DSSCs technology has attained promising development after the development of nanostructured TiO_2-based devices [3]. The DSSCs have exhibited maximum power conversion efficiency (PCE) of around 15% [4]. However, their stability is an issue [5, 6]. The electrolyte is responsible for the charge transport between the photoanode and counter electrode, which is vital to the performance of DSSCs. In DSSCs, organic solvent-derived electrolytes are prevalent, and their conductivity and other properties are highly advantageous for device performance [1]. In addition, when volatile solvents are excluded from the electrolyte in a DSSC, better cell performance stability can be expected, but their efficiency suffers.

There are several types of electrolytes, including solid-state electrolytes, gel electrolytes, and liquid electrolytes suitable for DSSCs. Each type has advantages and disadvantages, and their viability is dependent on the application. Solid-state electrolytes, for example, are utilized frequently because of their thermal dependability, chemical stability, and low risk of leakage [7]. However, they are difficult to manufacture and have poor mechanical properties, resulting

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