Investigation of properties of Recombination Inhibiting Barrier Layer for Dye Sensitized Solar Cell

Abstract

Dye Sensitized Solar Cells (DSSCs) represent a type of solar cell ideal for various low-power applications that harness solar energy. Unlike traditional silicon-based photovoltaic devices, DSSCs are notable for their simple assembly and cost-effective fabrication process. These cells comprise three main components: an anode (also known as a photoanode or working electrode), a redox electrolyte, and a counter electrode.

In Dye Sensitized Solar Cells (DSSCs), one of the primary challenges is the issue of interfacial charge recombination. This phenomenon occurs when the electrons generated by light exposure at the anode recombine with the oxidized species in the redox electrolyte or with holes in the dye molecules instead of being transferred to the external circuit. This recombination process significantly reduces the number of electrons available to contribute to the electrical current, thereby diminishing the overall efficiency of the solar cell.

Applying a barrier layer in Dye Sensitized Solar Cells (DSSCs) is an effective strategy to arrest interfacial charge recombination. This layer acts as a physical and electronic shield, preventing electrons from recombining with the oxidized species in the redox electrolyte as well as a path enabling the flow of electrons, if the right material is chosen for the barrier layer. By improving charge separation and enhancing electron transport, the barrier layer significantly boosts the overall efficiency of DSSCs. To achieve this, various layers of materials were applied in different combinations onto a conducting glass substrate. The selection and deposition of these materials were guided by their respective Highest Occupied Molecular Orbital (HOMO) and Lowest Unoccupied Molecular Orbital (LUMO) band level values, primarily the later one. These values are crucial in ensuring efficient charge transfer and minimizing energy losses. By carefully matching the HOMO and LUMO levels of the materials, it is possible to enhance the overall performance and efficiency of the Dye Sensitized Solar Cells (DSSCs). This strategic selection optimizes the alignment of energy levels, facilitating better electron flow and reducing recombination.

Various materials, including ZnO, TiO_2, CdS, CeO_2, CuO, ZrO_2, TiO_2-ZrO_2 composite and Eu-doped TiO_2-ZrO_2 composite, have been synthesized for their potential application in Dye-Sensitized Solar Cells (DSSCs) and characterized by standard techniques. The XRD results confirmed the creation of pure crystalline phases for almost all the

materials. The average crystallite sizes of the prepared materials were determined using the Scherrer formula, which correlates the broadening of the peaks with the size of the crystallites. The calculated crystallite sizes ranged from 6.47 nm to 23.94 nm. The UV-Vis spectra revealed good absorption across a wide wavelength range for all samples. The refractive index of the materials, which varied from 2.03 to 3.04, is another critical parameter for DSSCs. Simple and inexpensive dye-sensitized solar cells (DSSCs) were fabricated using the synthesized materials. Expensive Ruthenium dye was replaced with Anthocyanin dye which was extracted from pomegranate juice, and the platinum counter electrode was substituted with a graphite coating. The barrier layers of different material in different combinations were introduced between two electrodes.

Dye-Sensitized Solar Cells (DSSCs) were fabricated through the application of multilayer coatings, resulting in significant efficiency enhancements. Notably, the DSSC featuring a ZnO/CdS/CuO combination demonstrated the highest efficiency of 9.93%. It was observed that the efficiency of DSSCs increased with the integration of barrier layers, up to a certain threshold. However, beyond the addition of two barrier layers, efficiency began to decline. This decrease in power conversion efficiency is attributed to the increased thickness of the multilayer structure, which can hinder electron transport due to higher resistance and diminish overall performance.