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Highly Efficient Ca-Doped CuS Counter Electrodes for Quantum Dot Sensitized Solar Cells

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Abstract : The present study reports the incorporation of calcium ions into the CuS counter electrodes (CEs) in order to modify the photovoltaic performance of quantum dot-sensitized solar cells (QDSSCs). Metal ion-doped CuS thin film was prepared by the chemical bath deposition (CBD) method on FTO substrate and used directly as counter electrodes for TiO_2/CdS/CdSe/ZnS photoanodes based QDSSCs. For the Ca-doped CuS thin films, copper nitrate and thioacetamide were used as anionic and cationic precursors. Calcium nitrate tetrahydrate was used as doping material. The surface morphology of Ca-doped CuS CEs indicates that the fragments are uniformly distributed, and the structure is densely packed with high crystallinity. The changes observed in the diffraction patterns suggest that Ca dopant can introduce increased disorder into CuS material structure. EDX analysis was employed to determine the elemental identification, and the results confirmed the presence of Cu, S, and Ca on the FTO glass substrate. The photovoltaic current density – voltage characteristics of Ca-doped CuS CEs shows the specific improvements in open circuit voltage decay (Voc) and short-circuit current density (Jsc). Electrochemical impedance spectroscopy results display that Ca-doped CuS CEs have greater electrocatalytic activity and charge transport capacity than bare CuS. All the experimental results indicate that 20% Ca-doped CuS CE based QDSSCs exhibit high power conversion efficiency (η) of 4.92%, short circuit current density of 15.47 mA cm^{-2}, open circuit photovoltage of 0.611 V, and fill factor (FF) of 0.521 under illumination of one sun.

Keywords : Ca-doped CuS counter electrodes, surface morphology, chemical bath deposition method, electrocatalytic activity
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