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ORIGINAL RESEARCH ARTICLE

Electrodeposition of ZnS Thin Films by Complexing Agent-Free Electrolyte Containing Sodium Thiosulfate as the Sulfur Precursor

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Abstract

Thin films of zinc sulphide (ZnS) were prepared by a facile, economical, and scalable electrochemical method as a buffer layer for a CdS/CdTe based solar cell. Herein, a three-electrode cell in a complexing agent-free electrolyte containing 0.1 mol/L $Na_2S_2O_3$ and 0.1 mol/L $ZnSO_4$ was employed for the deposition of ZnS. The electrodeposition conditions (temperature: 30°C, pH: 4.2, cathodic potential: −1.10 V and deposition time: 90 min) were identified to grow an ideal thin film of ZnS on fluorine-doped tin oxide (FTO)-coated glass substrate, applying moderate stirring of 60 rpm. In material characterization of heat-treated samples (300°C, 10 min), the optical absorption measurement depicted a direct energy bandgap of 3.64 eV with low light absorbance and a blueshift from bulk ZnS. Scanning electron microscopy and atomic force microscopy studies demonstrated the uniform distribution of ZnS grains over the FTO glass substrate, and x-ray diffraction analysis revealed an amorphous structural nature of ZnS. The charge carrier density and flat-band potential of the ZnS material were determined as 1.19×10^{-19} cm^{-3} and −0.59 V, respectively, by Mott–Schottky analysis.

Keywords Buffer layer · complexing agent free · electrodeposition · sodium thiosulfate · zinc sulfide

Introduction

Zinc sulphide (ZnS) has been recognized as a II-VI semiconductor material due to its wide bandgap of (3.5–3.8) eV[1–4] at room temperature, allowing the band to be tuned in the ultraviolet (UV) region. Also, it has a direct transition,[5] high transparency,[2] and refractive index of 2.35,[6] while it is non-toxic, cheap, and abundant.[7] These properties make ZnS a potential candidate in applications such as decorative coatings, UV light-emitting diodes, field effect transistors, sensors, and buffer/window layers in photovoltaic solar cells.[2,6,8,9] Pertaining to the photovoltaic solar cells, the wider bandgap and high transparency of ZnS thin films may effectively decrease the absorption losses in the window layer and increase the short-circuit current density of the cells.[1,2,6,10] Therefore, ZnS may be considered a great replacement for cadmium sulphide (CdS) window material in single-junction CdS/CdTe- and CdS/$CuInGaSe_2$-based solar cells.[1,11–13]

Several techniques including chemical bath deposition (CBD), electrochemical atomic layer epitaxy (EC-ALE), molecular beam epitaxy (MBE), metal organic chemical vapor deposition (MOCVD), thermal evaporation, spray pyrolysis, successive ionic layer adsorption and reaction (SILAR), electrodeposition (ED), magnetron sputtering, and screen printing[2,6,7,13–17] have been used to develop ZnS thin layers on different substrates. Physical techniques are expensive but more reliable, whereas the chemical techniques are cost-effective and scalable. Since the electrodeposition (ED) technique possesses the latter attributes,[2,6,7,13,17] the focus herein is on an electrochemical study for developing thin films of ZnS by varying the electrolytic bath temperature, pH, and the deposition potential and time to control its electrical, optical, morphological and structural properties.

Reports of electrodeposition of ZnS thin layers without binding/complexing agents are scarce. Ammonia (NH_3), hydrazine (N_2H_4), trisodium citrate ($Na_3C_6H_5O_7$), glycerol ($C_3H_8O_3$), and ethylenediaminetetraacetic acid (EDTA) have often been used as complexing agents in the preparation of ZnS thin films.[2,5,7,9,13,18] This report is based on a complexing agent-free cathodic electrodeposition technique

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