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The role of ascorbic acid in optimizing optoelectronic performances of CdS thin films

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Cadmium sulfide (CdS), a widely studied (II-VI) group semiconductor, has long captivated the scientific community due to its potential applications in photovoltaic (PV) devices. However, optoelectrical properties of n-CdS, such as flat band potential, and optical band gap, are crucial for enhancing solar cell efficiency. This study explores the tunability of these properties in CdS thin films through chemical bath deposition (CBD) with a mild reducing agent ascorbic acid ($C_6H_8O_6$). A series of CdS thin films were deposited on fluorine-doped tin oxide (FTO) glass substrates by using various concentrations of ascorbic acid (0, 0.1, 0.01, and 0.001 mol.dm^{-3}). The deposition chemical bath consisted of 0.1 mol.dm^{-3} cadmium sulfate ($CdSO_4$) and 0.2 mol.dm^{-3} thiourea ($CS(NH_2)_2$) as cadmium and sulfur sources, respectively. The deposition process was conducted at 80 °C for one hour at a pH of 11. Post-deposition, the CdS films were etched in the non-conductive side of the FTO with diluted hydrochloric acid (HCl), followed by annealing at 300 °C for one hour in air. All the electrical measurements were performed in a photoelectrochemical cell comprising a CdS/0.1 mol.dm^{-3} $Na_2S_2O_3$/Pt half-cell with an active area of 1 cm². An Ag/AgCl electrode served as the reference for all characterizations. The short-circuit current density (J_{SC}) has shown a significant increase with decreasing ascorbic acid concentration, achieving a 155.6% enhancement with a concentration of 0.001 mol.dm^{-3} compared to untreated CdS. Conversely, with increasing ascorbic acid concentration the open-circuit voltage (V_{OC}) and the flat band potential (V_{FB}) decreased. The highest reported photocurrent power ($V_{OC}\times I_{SC}$) was observed in films deposited with 0.001 mol.dm^{-3} ascorbic acid, showing a 150.2% improvement over untreated CdS. Scanning electron microscopy (SEM) analysis revealed that ascorbic acid-treated CdS films exhibited aggregated nanoscale particles, whereas untreated films displayed larger clusters. Consequently, the photocurrent enhancement is attributed to these morphological changes that cause higher effective surface area in the ascorbic-treated CdS thin films compared to the untreated CdS. Furthermore, Mott-Schottky analysis confirmed that all deposited films retained n-type characteristics. This study demonstrates that the electronic properties of n-CdS can be finely tuned through ascorbic acid treatment, making it a promising approach for fabricating thin film solar cells with high light-to-current conversion efficiency. The ability to control and enhance these properties is invaluable for advancing PV applications and achieving higher solar cell performances.

Keywords: CdS, Thin films, Chemical bath deposition (CBD), Ascorbic acid

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