

Study of Photoelectrochemical Cells for Hydrogen Production by Water Splitting Using CIGS2/CdS Heterojunction

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Polycrystalline, p-type semiconducting of nearly stoichiometric, slightly Cu-poor, large-grain, chalcopyrite $\sim 2.75 \mu\text{m}$ $\text{CuIn}_{1-x}\text{Ga}_x\text{S}_2$ (CIGS2) thin films were prepared on Mo-coated glass, with Ga content, x , of 0.3–0.5. Heterojunction CdS layer was deposited on CIGS2 by chemical bath deposition (CBD) using CdSO_4 or Cd-acetate buffer solution.

Counter electrode (anode) of sputter-deposited platinum film on Mo-coated glass substrate used for initial PEC measurements showed poor adhesion and failed due to Mo oxidation. Hence a platinum foil was used. PEC measurements under illumination for $\text{CuIn}_{0.6}\text{Ga}_{0.4}\text{S}_2/\text{Pt}$ and $\text{CuIn}_{0.5}\text{Ga}_{0.5}\text{S}_2/\text{Pt}$ showed maximum negative (cathodic) photocurrent of -6.3 mA and -10.5 mA at -1.2 V and -1.9 mA and -3.2 mA at -0.8 V respectively (Figure 1). Negative values of photocurrent signify cathodic behavior (p-type material) and reduction of water to hydrogen.

In a heterojunction, the semiconductor with the lower band gap determines the maximum cell efficiency. Voltammograms of heterojunction $\text{CuIn}_{0.6}\text{Ga}_{0.4}\text{S}_2/\text{CdS}/\text{Pt}$ and $\text{CuIn}_{0.5}\text{Ga}_{0.5}\text{S}_2/\text{CdS}/\text{Pt}$ by CdSO_4 route showed promising results with maximum negative photocurrent of -11.5 mA and -14.8 mA at -1.2 V and -5.6 mA and -6.3 mA at -0.8 V (Figure 2). Excellent results were obtained with $\text{CuIn}_{0.6}\text{Ga}_{0.4}\text{S}_2/\text{CdS}/\text{Pt}$ and $\text{CuIn}_{0.5}\text{Ga}_{0.5}\text{S}_2/\text{CdS}/\text{Pt}$ by Cd-acetate route, the measured photocurrent under illumination are -15.6 mA and -14.5 mA at -1.2 V and -7.6 mA and -4.3 mA at -0.8 V respectively (Figure 3). The notable feature of the voltammograms was that substantial photocurrent was observed already starting at -0.2 V . The results for samples with CdS coating by Cd-acetate buffer solution route were better, because it deposits a thicker and more crystalline CdS layer as opposed to a thin layer by CdSO_4 route. PEC response returned to its original behavior under dark conditions after the illumination was switched off. The excellent performance of the CIGS2/CdS heterojunction is attributed to the superior quality of the junction for effective charge separation instead relying on the semiconductor-electrolyte interface. Preliminary results for $\text{CuIn}_{0.6}\text{Ga}_{0.4}\text{S}_2/\text{CdS}/\text{ZnO}/\text{ZnO}:\text{Al}/\text{Pt}$ by CdSO_4 route were not promising probably due to poor quality of ZnO and ZnO: Al layer and also possible reactions at the ZnO/ZnO: Al layer.

With further optimization, CIGS2/CdS heterojunction could be utilized as a photocathode for hydrogen production by water splitting using solar radiation.

