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Zns/Cu_2ZnSnS_4/Cdte/In Thin Film Structure for Solar Cells

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Zinc sulfide (ZnS) is a wide direct band gap, high optical absorption coefficient, reasonable work function. It has attracted considerable attention due to its excellent electrical and optical properties with its distinct properties has become the potential candidate for many applications[1-2].

ZnS layers were electrodeposited from an aqueous electrolyte containing 0.3 M $ZnCl_2$ and 0.03 M $(NH_4)_2S_2O_3$ in 800 mL of de-ionized water. Electropurification of the $ZnCl_2$ was carried out for 48 h prior to the addition of $(NH_4)_2S_2O_3$ in order to remove any possible impurity ions present in the solution. Finally, the pH of the electrolyte containing both precursors was adjusted to 3.00 ± 0.02. The temperature of the electrolyte was 30 °C. Uniform and transparent ZnS layers were cathodically deposited on cleaned glass/İTO substrates using a simple two-electrode deposition system at a cathodic potential of 1550 mV established using a cyclic voltammogram. The deposited layers using an average deposition current density of ~65 $\mu A \cdot cm^{-2}$ and deposition time of 60 min have thickness of ~150 nm. These were then annealed in air at 350 °C for 10 min.

Prior to the deposition of Cu_2ZnSnS_4, the glass/İTO/ZnS substrates were cleaned with methanol and deionised water. The deposition of Cu_2ZnSnS_4 layers was also done using a two-electrode system at a cathodic deposition potential of 1450 mV also established using a cyclic voltammogram. The Cu_2ZnSnS_4 deposited on glass/İTO had a thickness ~300 nm while that deposited on glass/İTO/ZnS had a thickness ~150 nm. This therefore brings the total thickness of the ZnS/Cu_2ZnSnS_4 bi-layer to ~250 nm comparable to the ~300 nm of Cu_2ZnSnS_4 grown on glass/İTO. The CdTe deposition electrolyte contained 1 M $CdSO_4$ (99.0%) and 1 mM TeO_2 (99.999%) in 800 mL of de-ionized water. To do this, a cyclic voltammogram was recorded using the two-electrode system, to determine the reduction potential of Cd^{2+}. The TeO_2 was first dissolved in H_2SO_4 and then added into the bath after the electro-purification of $CdSO_4$, and the pH of the electrolyte adjusted to 2.00 ± 0.02. After depositing and characterizing few CdTe samples on glass/İTO substrates, the final cathodic deposition potential for CdTe was taken as 2038 mV. CdTe thin layers with thickness of ~1.70 μm were then deposited on annealed glass/İTO/CdS and glass/İTO/ZnS/CdS substrates previously cleaned with methanol and de-ionised water. Typical deposition time for the CdTe used in this work was 4 h, with an average deposition current density of ~176 $\mu A \cdot cm^{-2}$. To complete the solar cell fabrication, the annealed glass/İTO/Cu_2ZnSnS_4/p-CdTe 2-layer structure and glass/İTO/n-ZnS/n-Cu_2ZnSnS_4/p-CdTe 3-layer structure were etched for 5 s in aqueous solution of 1.0 g of $K_2Cr_2O_7$ acidified with 10 mL of dilute H_2SO_4 in 10 mL of deionised water, rinsed in deionized water and then etched in a warm solution containing 0.5 g each of NaOH and $Na_2S_2O_3$ in 50 mL of deionised water for 2 min. The thickness of the gold contacts was ~100 nm each with a diameter of 2 mm. This makes ZnS a suitable candidate for use as effective buffer/window layer in CdTe-based multilayer graded bandgap solar cells. It is important to note what happens to the ZnS/Cu_2ZnSnS_4/CdTe structure in the annealing process. The glass/ITO/ZnS/Cu_2ZnSnS_4/CdTe/In solar cell is also similar to the glass/ITO/ZnS/Cu_2ZnSnS_4/CdTe/In counterpart in structure and is used as a control experiment in this work to compare the advantages of the architecture with ZnS as wide bandgap buffer/window layer. The result of using ZnS as the buffer/window layer is directly reflected in the improved high short-circuit current density (*J*sc) as well as improved open-circuit voltage (*V*oc), fill factor (*FF*) and ultimately, the conversion efficiency (η) of the 3-layer device, are compared to the device.

However, to ensure that the observed high *J*sc values are genuine, the diodes producing them were isolated by carefully removing the CdTe material around them and repeating the I-V measurements. It is therefore possible in these solar cells for photons with energy lower than the energy bandgap of CdTe to create useful electron-hole pairs that contribute to photo-generated current.

Keywords: Solar cells, 3-layer device

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