



3rd International Nanotechnology Conference & Expo

May 7-9, 2018 Rome, Italy

The Semiconductor Compound $\text{Cu}_2\text{Zn}_{1-x}\text{Cd}_x\text{SnS}_4$ for Solar Cells

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The semiconductor compound $\text{Cu}_2\text{Zn}_{1-x}\text{Cd}_x\text{SnS}_4$ (CZCTS) is considered as one of the ideal photovoltaic absorber layer materials for low-cost thin film solar cells, since CZCTS has a large absorption coefficient and all the constituent elements are naturally abundant. A $\text{Cu}_2\text{Zn}_{1-x}\text{Cd}_x\text{SnS}_4$ (CZCTS) thin films system (where $x = 0$ and 0.2) are deposited using chemical bath deposition method on the aluminium and ITO glass substrates. The films deposited onto ITO-glass slides were first cleaned with detergent water and then dipped in acetone. Solution were prepared by mixing 0.2 M aqueous solutions of CuCl_2 , ZnCl_2 , CdCl_2 , SnCl_4 , and thiourea $[\text{CS}(\text{NH}_2)_2]$ at ratio of $2x:1-x: x: 1: 4$ (Cu, Zn, Cd, Sn, S) using a magnetic stirrer. The films had a uniform thickness of (800) nm. The structural properties were determined by X-ray diffraction (XRD; Shimadzu) with $\text{CuK}\alpha$ radiation ($\lambda = 1.5406 \text{ \AA}$). Film morphology was analyzed by atomic force microscope (AFM)- type (CSPM). The optical absorption and transmission spectra were obtained using a UV-vis spectrophotometer within the wavelength range of 300 nm to 1100 nm. The XRD patterns show the major diffraction peaks at $2\theta = (28.59)$ and (28.4) for CZTS at $x = 0$ and for CZCTS at $x = 0.2$. The increase in cadmium (Cd) as shown by the shift in the main diffraction peak to a lower value of 2θ is attributed to the increase in lattice spacing of the longer Zn atom (1.71 \AA) substitution for smaller Cd atoms (1.53 \AA). Furthermore, an increase in the main peak intensity is observed in the presence of cadmium. A comparison with ASTM card JSPDS 26-0575 reveals that the CZTS ($x = 0$) thin film exhibits a crystal structure tetragonal type of kestrits phase with a preferred orientation (112) and other planes, i.e., (220) and (312) . For $2\theta = (28.59, 47.5, 56.1)$ The CZCTS film at $x=0.2$ has a tetragonal phase.

The absorbance layers of CZCTS were measured from 300 nm to 1100 nm. Shows the plot of α (cm^{-1}) versus the wave length λ , which suggests that the two Film exhibits high absorption coefficient ($> 10^4 \text{ cm}^{-1}$). Thus a very thin layer of film ($1-2 \mu\text{m}$) can absorb over 90% of photons over the spectrum, with higher photon energy in the bandgap. The optical properties of the CZTS layer can be improved with a substitution of Zn atoms by Cd atoms to give lower energy gap gap, because since ZnS has a direct optical band near 3.6 eV that gives a higher energy gap of CZTS. The absorption edge shifts to the NIR region with increased x . The obtained optical gap for CZTS is $(1.7)\text{eV}$ which agrees with the CZTS bandgap and 1.66 eV for CZCTS at $x = 0.2$. Eg decreases with increased cadmium content.

The CZCTS films coated on Al substrates were applied to the preparation of CZCTS solar cells. The CZCTS solar cells with a structure of $\text{Al}/\text{ZnO}/\text{CdS}/\text{CZCTS}/\text{In}$ lime glass were fabricated. The performance of the solar cells was evaluated under standard AM 1.5 ($100 \text{ mW}/\text{cm}^2$) illumination. The solar cell with the CZCTS absorber layer annealed at $300 \text{ }^\circ\text{C}$, exhibited a relatively high efficiency of 9.2% ($V_{oc} - 0, 520 \text{ V}$, $J_{sc} - 22, 4 \text{ mA}/\text{cm}^2$, $\text{FF} - 0, 65$). It confirms the effect of preventing the decomposition of CZCTS phase by the addition of Sn during the annealing process.

In conclusion, a simple and relatively safe approach for the fabrication of CZCTS nanoparticles has been developed. To the best of our knowledge, this is the first time that this low-temperature colloid approach has been applied to the fabrication of CZCTS nanoparticles. We found that the use of different chalcogenide sources resulted in different products of synthesis. The annealing temperature and special ambient effect on the properties of CZCTS films were investigated.