Physical properties of novel $Cu_{1-x}Cd_xS_2$ thin films by chemical bath deposition method for low cost solar cell

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Introduction

Ternary and quaternary compound/alloy semiconductors, having tuneable physical properties owing to their composition of constituent elements, plays vital role in electronic, optoelectronic, photovoltaic and thermo-photovoltaic applications [1]. For energy harvesting by means of solar power, ternary and quaternary metal chalcogenides play assuring role emanating from their tuneable physical properties by simply varying the composition of its constituent elements. The highest efficiency in thin film solar cells has been achieved using CdS as window layer and copper based absorber materials [2]. We have synthesized a novel material $Cu_{1-x}Cd_xS_2$ by simple solution process at low temperature in single step. The suitability of this material as a novel absorber and window layer for the fabrication of thin film solar cells at low cost is analysed.

Experimental method

Thin films of $Cu_{1-x}Cd_xS_2$ were prepared with various compositions by chemical bath deposition method in single step at room temperature. The precursor solutions were prepared by dissolving various ratios of $CuSO_4.5H_2O$, $CdSO_4.8H_2O$ and $CS(NH_2)_2$ as cation (Cu^{2+}, Cd^{2+}) and anion (S^{2-}) sources. The concentration of anion was fixed for all reactions and only the cationic concentration (Cu^{2+} and Cd^{2+}) was varied. All the samples were prepared simultaneously in different beakers under same conditions at room temperature and their physical properties were analysed by X-ray diffraction (XRD), scanning electron microscopy (SEM), electron probe micro analysis (EPMA), X-ray photo electron spectroscopy (XPS), UV-Vis, Raman spectroscopy and Hall effect measurement studies.

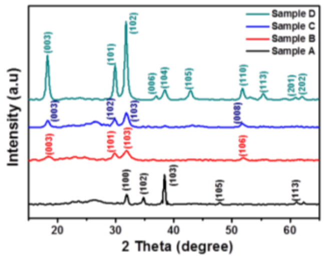

Figure 1. XRD patterns of $Cu_{1-x}Cd_xS_2$ thin films

Table 1. Electrical properties of deposited $Cu_{1-x}Cd_xS_2$ thin films

S. No.	Sample	Carrier Concentration (cm-3)	Resistivity (Ωcm)	Mobility (cm^2/Vs)	Type of charge carriers
1	A	3.48×10^{18}	0.16	10.6	p-type
2	B	1.57×10^{14}	2.41×10^4	1.64	n-type
3	C	4.07×10^{13}	5.66×10^4	2.7	n-type
4	D	1.8×10^{12}	3.5×10^5	15.06	n-type

Results and discussion

The recorded XRD patterns (Fig. 1) revealed the hexagonal structure of deposited films and increase of unit cell volume upon varying Cd composition. The material had wider absorption (300 – 1300 nm) with red shift in absorption edge and band gap of $Cu_{1-x}Cd_xS_2$ thin film increased from 1.46 eV to 1.85 eV for Cu to Cd rich composition. SEM image showed continuous coating of thin films with morphology changed from spherical to sheet-like structure. EPMA measurement showed the composition of S remained same and cation compositions were changed. Relative variations in the Cd composition of deposited films were observed as the precursor concentration varied. Increase in binding energies of Cu 2p, Cd 3d and S 2p levels were observed as the composition of cadmium increased. Carrier concentration of $Cu_{1-x}Cd_xS_2$ thin films decreased as the composition of Cd increased in deposited thin films (Table 1). The $Cu_{1-x}Cd_xS_2$ thin films exhibited two different type conductivities, p and n-type owing to composition of cations. Physical properties of $Cu_{1-x}Cd_xS_2$ thin films can be tuned between Cu_xS and CdS to get desired properties. $Cu_{1-x}Cd_xS_2$ thin films with Cu and Cd rich compositions had wider absorption region, p and n-type conductivities, higher carrier concentration and tuneable band gap between Cu_2S and CdS. Therefore this material is suitable for photovoltaic applications and it can perform the role of both p-type and n-type semiconductor based on their composition.

Reference

1. S. Adachi, Properties of semiconductor alloys: Group IV, III-V, II-VI Semiconductors, Wiley, (2009)
2. P. Jackson, D. Hariskos, E. Lotter, S. Paetel, R. Wuerz, R. Menner, W. Wischmann, M. Powalla, Prog. Photovolt: Res. Appl. **19** (2011) 894