COLLOIDAL CHEMICAL SYNTHESIS OF QUATERNARY CHALCOGENIDE BASED $Cu_2M_xSn_{(1-x)}S_4$ (M= Ni AND Fe) SEMICONDUCTOR NANOPARTICLES: POTENTIAL ABSORBANCE LAYER MATERIALS FOR PHOTOVOLTAIC APPLICATION

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Chapter 10

CHAPTER 10

SUMMARY OF THE PRESENT WORK AND FUTURE PROSPECTS

This work is an extensive study of the synthesis of relatively new quaternary semiconductor materials, $Cu_2Ni_xSn_{(1-x)}S_4$ (CNTS) and $Cu_2Fe_xSn_{(1-x)}S_4$ (CFTS) nanoparticles of different precursor ratios via the precipitate and hydrothermal synthesis methods for photovoltaic applications. The synthesized nanoparticles have been characterized by different techniques and their utilization as potential absorbance layers in thin film solar cells investigated. In this study, CNTS and CFTS solar cells have been fabricated through the spin coating technique. The solar cell was fabricated with the structure FTO/ZnO/CdS/CNTS (and CFTS)/Ag and the performance studied under AM 1.5 illumination. The device architecture consisted of a window layer, buffer layer and CNTS and CFTS absorbance layer.

10.1 SUMMARY OF THE PRESENT STUDY

This thesis work was mainly focused on the synthesis of new functional quaternary semiconducting nanoparticles and analyzing their physical, chemical, optical and electrical properties for next-generation solar cell applications. The main objective of the present thesis was to identify suitable chalcogenide semiconductor nanoparticles, which work as potential absorber layer materials in the second-generation thin film applications.

An effort was made to optimize the concentration of CNTS and CFTS nanoparticles. $Cu_2Ni_xSn_{(1-x)}S_4$ (CNTS) and $Cu_2Fe_xSn_{(1-x)}S_4$ (CFTS) nanoparticles were successfully synthesized by the precipitate and hydrothermal methods. The synthesized nanoparticles were characterized by using various analytical techniques. The incorporation of transition metals in the quaternary system helps to tune and influence the optical properties of the parent system. In the present study this was successfully achieved by Ni and Fe incorporation in CTS to form $Cu_2Ni_xSn_{(1-x)}S_4$ (CNTS) and $Cu_2Fe_xSn_{(1-x)}S_4$ (CFTS) nanoparticles of different compositions (x= 0, 0.2, 0.4, 0.6, 0.8 and 1 M), by facile chemical techniques such as chemical precipitation and hydrothermal method. The reason for the different crystallite size may be the reaction kinetics during the formation of different transition metal sulfides $Cu_2M_xSn_{(1-x)}S_4$ (M= Ni and Fe). In general, each transition metal has a different affinity to control the size of the nanoparticles during the nucleation and growth process. In addition to this, the hydrothermal reaction parameters help to obtain stannite phase when the reaction concentration gets changed. The band gap energy of the prepared compounds was found to be suitable for solar cell applications. Figure 10.1 shows an comparison of the optical band gaps of $Cu_2Ni_xSn_{(1-x)}S_4$ (CNTS (x=0.8)) and $Cu_2Fe_xSn_{(1-x)}S_4$ (CFTS (x=0.8)) nanoparticles prepared by the precipitate and hydrothermal methods.

Table 10.1 provides an overview of the characteristics of $Cu_2Ni_xSn_{(1-x)}S_4$ (CNTS(x=0.8)) and $Cu_2Fe_xSn_{(1-x)}S_4$ (CFTS(x=0.8)) nanoparticles.

On the whole, the chalcogenide quaternary semiconductor nanoparticles have been successfully synthesized and their structural, optical and electrical properties show that these materials can be used as absorbers materials in thin film solar cells.

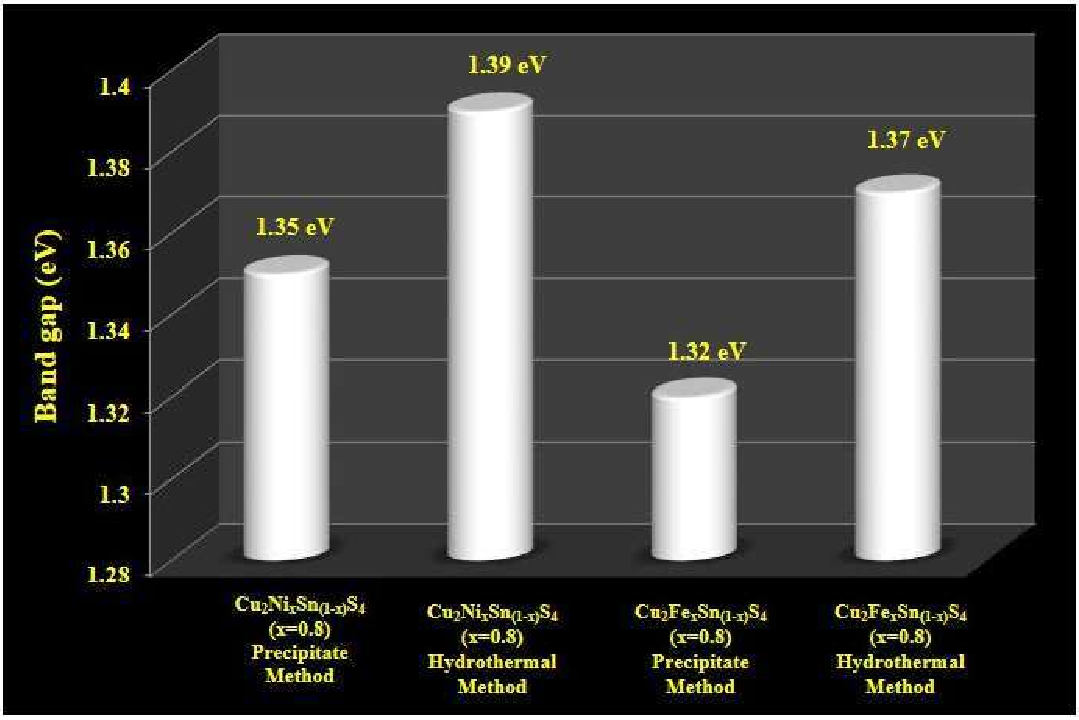

Figure 10.1 Comparison of the optical band gaps of $Cu_2Ni_xSn_{(1-x)}S_4$ (CNTS (x=0.8)) and $Cu_2Fe_xSn_{(1-x)}S_4$ (CFTS (x=0.8)) nanoparticles prepared by the precipitate and hydrothermal methods

Table 10.1 An overview of the characteristics of $Cu_2Ni_xSn_{(1-x)}S_4$ (CNTS(x=0.8)) and $Cu_2Fe_xSn_{(1-x)}S_4$ (CFTS(x=0.8)) nanoparticles

Compound name and Method	Crystallite size (nm)	Structural and Phase	Optical band gap (eV)	Morphology	Electrolyte	Specific capacitance (Areal) ($mFcm^{-2}$)	(η) (%)
Cu_2NiSnS_4 - Precipitate method	10.9	Cubic	1.31	Clusters with Flake like morphology	0.1 M of Phosphate buffer solution	-	-
$Cu_2Ni_xSn_{(1-x)}S4$ CNTS (x=0.8) - Precipitate method	**15-20**	**Cubic with stannite phase**	**1.35**	**Dispersed Flake-like-Agglomerated clusters**	**0.1 M NaOH**	**1173**	**1.65**
$Cu_2Ni_xSn_{(1-x)}S4$ CNTS (x=0.8) - Hydrothermal method	**12**	**Cubic with stannite phase**	**1.39**	**Flake-like-slightly Agglomerated clusters**	**0.1 M NaOH**	**2214.85**	**2.37**
Cu_2FeSnS_4 - Hydrothermal method	8-30	Tetragonal	1.39	Irregular sphere like morphology	0.1 M NaOH	-	-
$Cu_2Fe_xSn_{(1-x)}S4$ CFTS (x=0.8) - Precipitate method	25	Tetragonal structure with stannite phase	1.32	Irregular sphere like morphology	0.1 M NaOH	1188.97	1.32
$Cu_2Fe_xSn_{(1-x)}S4$ CFTS (x=0.8)- Hydrothermal method	18	Tetragonal structure with stannite phase	1.37	Sphere like morphology	0.1 M NaOH	1513.78	1.49

10.2 SCOPE FOR THE FUTURE WORK

The present investigations concentrate on the synthesis, characterization and fabrication of absorber layer for thin film solar cells to assess their viability for commercial applications.

The following are the prospects for future study.

- Attention to be devoted to key areas such as Defect characterization, Phase stability and processing control and Interface optimization.
- The work will be extended towards the development of high efficiency $Cu_2M_xSn_{(1-x)}S_4$ (M= Ni and Fe) based superstrate and substrate thin film solar cells.
- The deposition conditions for the growth of $Cu_2M_xSn_{(1-x)}S_4$ (M= Ni and Fe) thin films are to be optimized.
- A more detailed study on the electrical properties of the synthesized compound is very much essential to make these materials potential for thin film solar cell applications.
- CdS and ZnO are promising candidates in this direction and the optimization of the deposition condition of window and buffer layers and their use in $Cu_2M_xSn_{(1-x)}S_4$ (M= Ni and Fe) based thin film solar cell will be a remarkable effort.
- The $Cu_2M_xSn_{(1-x)}S_4$ (M= Ni and Fe) films could be developed with the electrodes suitably fabricated for possible applications in photocatalysis, energy storage and gas sensors.