Optical and structural properties of spin coated Cu_2NiSnS_4 (CNTS) thin film: effect of thiourea concentration

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Introduction

In order to meet the world's increasing demands great efforts are being focused on developing low cost, non-toxic and earth abundant thin film solar cells. Various earth abundant semiconducting nanoparticles like $Cu_2FeSnS_4(S_{1-x}Se_4)$ (CZTSSe), Cu_2ZnSnS_4(CZTS), Cu_2FeSnS_4 (CFTS), Cu_2CoSnS_4(CCTS) and Cu_2NiSnS_4(CNTS) have much attention as absorber layer for thin film solar cells due to their suitable direct band gap and high absorption coefficients (10^4 to 10^5 cm^{-1}) [1]. However, the CNTS films have recently been successfully used in photovoltaic applications using different deposition techniques such as electro deposition [2], solvothermal [3], spray technique [4], thermal chemical decomposition [5] and hot injection method [6]. Given the importance of CNTS in many applications and in many areas, we have considered the effect of sulfur (thiourea) concentration in the CNTS films by spin coating method.

Objectives

1. CNTS thin film samples such as CNTS-6M, CNTS-8M, CNTS-10M and CNTS-12M have been prepared
2. Optical properties such as absorbance, transmittance, absorption coefficient and band gap of the prepared CNTS thin films have been studied and compared with the prepared thin films.
3. Structural properties of the developed CNTS thin film have been analyzed.
4. Micro-structural properties have also been determined.

Thin Film Deposition Technology

CNTS thin films were deposited by spin coating technique starting with non-aqueous solution. This non-aqueous solutions were prepared by dissolving copper chloride dihydrate (2M), nickechloride hexahydrate (1M), tin chloride dihydrate (1M) and thiourea (6M, 8M, 10M, 12M) in 2-methoxyethanol and a few drops of monoethanolamine (MEA) and then stirred at 50 degree for an hour. The resulted solutions were deposited onto soda lime glass substrates by spin coating with a rotation speed of 1400 rpm for 30s. After first coating, the substrates were preheated at 150 degree for 10 min to evaporate the solvents and these coating processes were repeated for four times to get required thickness of the films. Finally dense CNTS films were annealed at 340 degree for 30 min.

Prepared Samples & Characterization Equipments

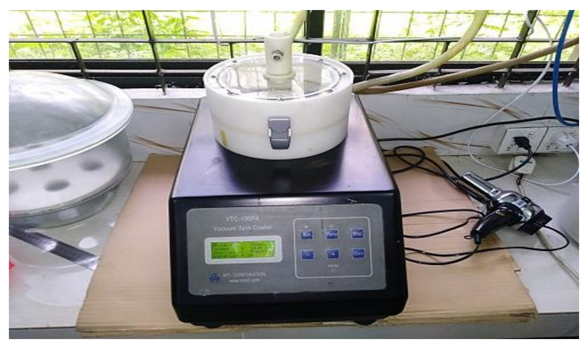

Fig. 1: Spin Coater

Fig. 2: Furnace

Fig. 3: Prepared CNTS thin films

Fig. 4: UV-visible Spectrometer

Fig. 5: X-ray diffractometer

Results

➢ Absorbance Measurements

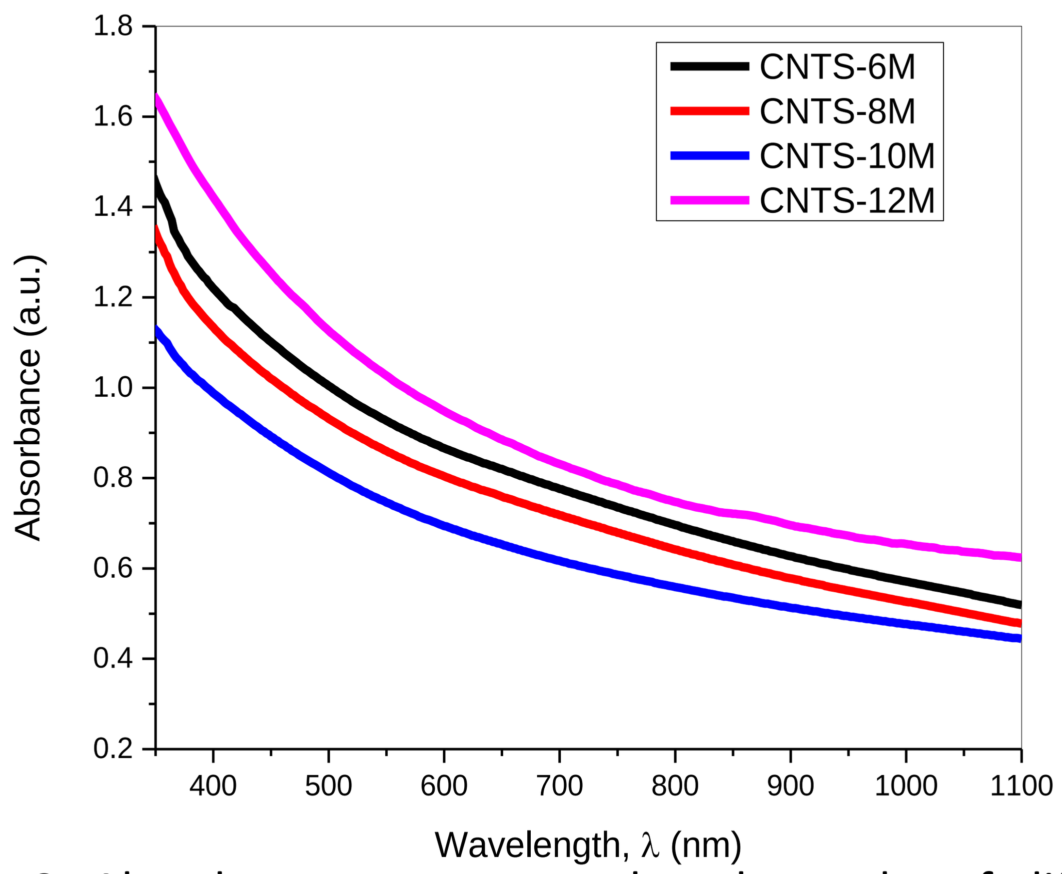

Fig. 6: Absorbance versus wavelength graphs of different types of CNTS thin films show maximum absorbance for CNTS-12M and also exhibit inverse relationship between the absorbance and the wavelength.

➢ Transmittance(%) Measurements

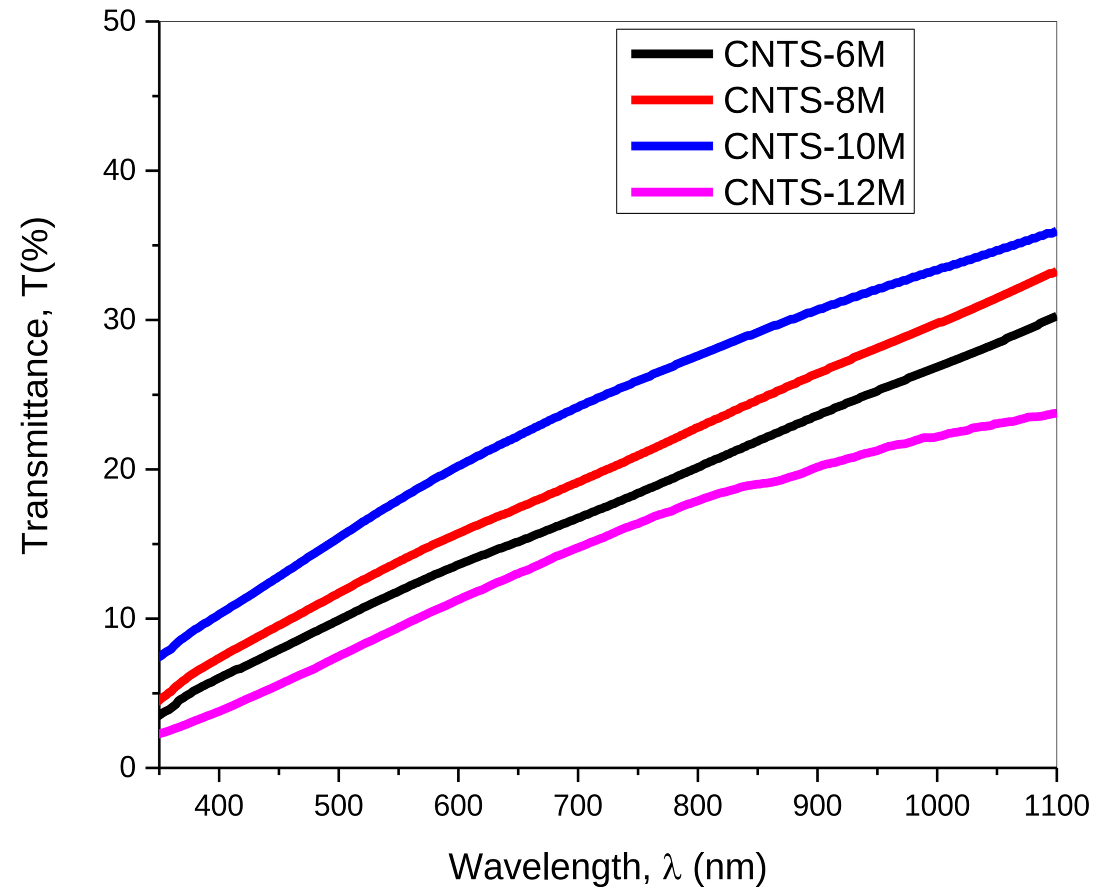

Fig. 7: Transmittance(%) versus wavelength graphs of different types of CNTS thin films show minimum transmittance(%) for CNTS-12M and also exhibit linear relationship between the absorbance and the wavelength.

➢ Absorption Coefficient Measurements

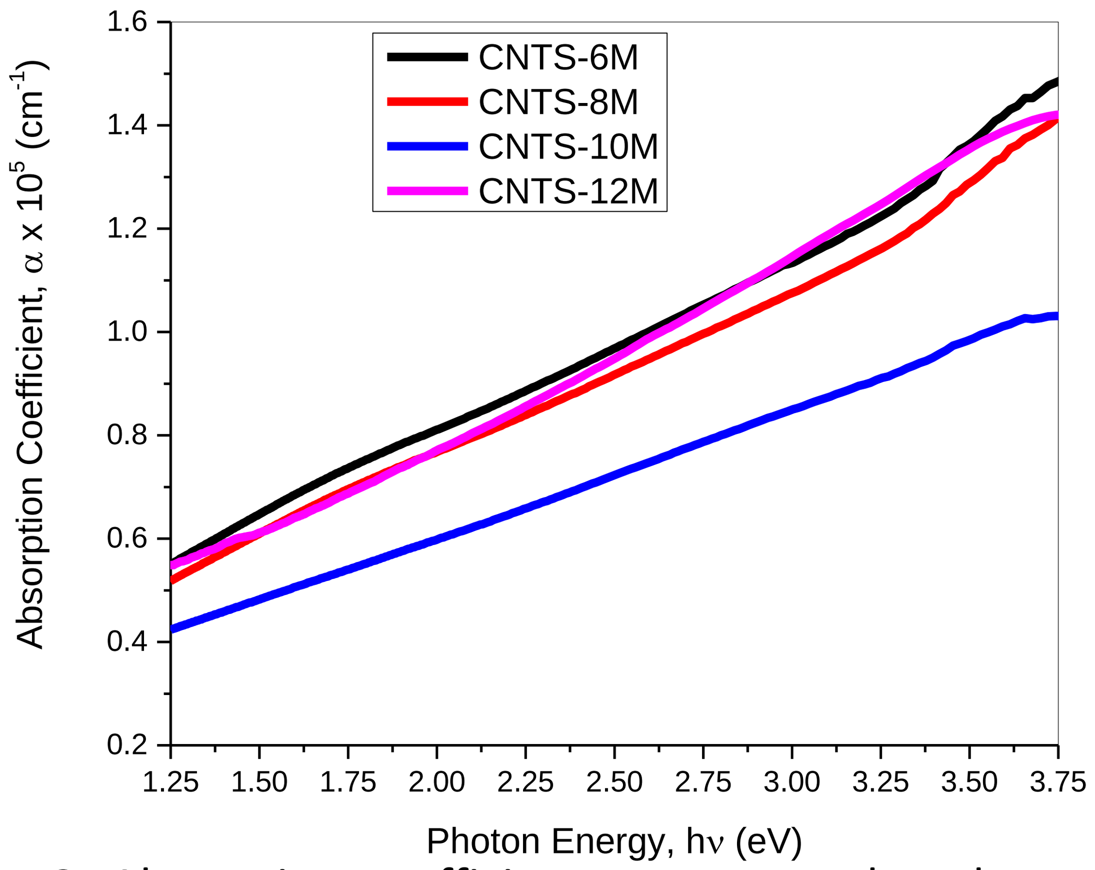

Fig. 8: Absorption coefficient versus wavelength graphs of different types of CNTS thin films show maximum absorption coefficient (1.27 X 10^5 cm^-1) for CNTS-12M in visible region and also exhibit linear relationship between the absorption coefficient and the photon energy.

➢ Optical Band Gap Measurements

Table 01:

Sample Name	CNTS-6M	CNTS-8M	CNTS-10M	CNTS-12M
Band Gap (eV)	2.83	2.86	2.62	2.56

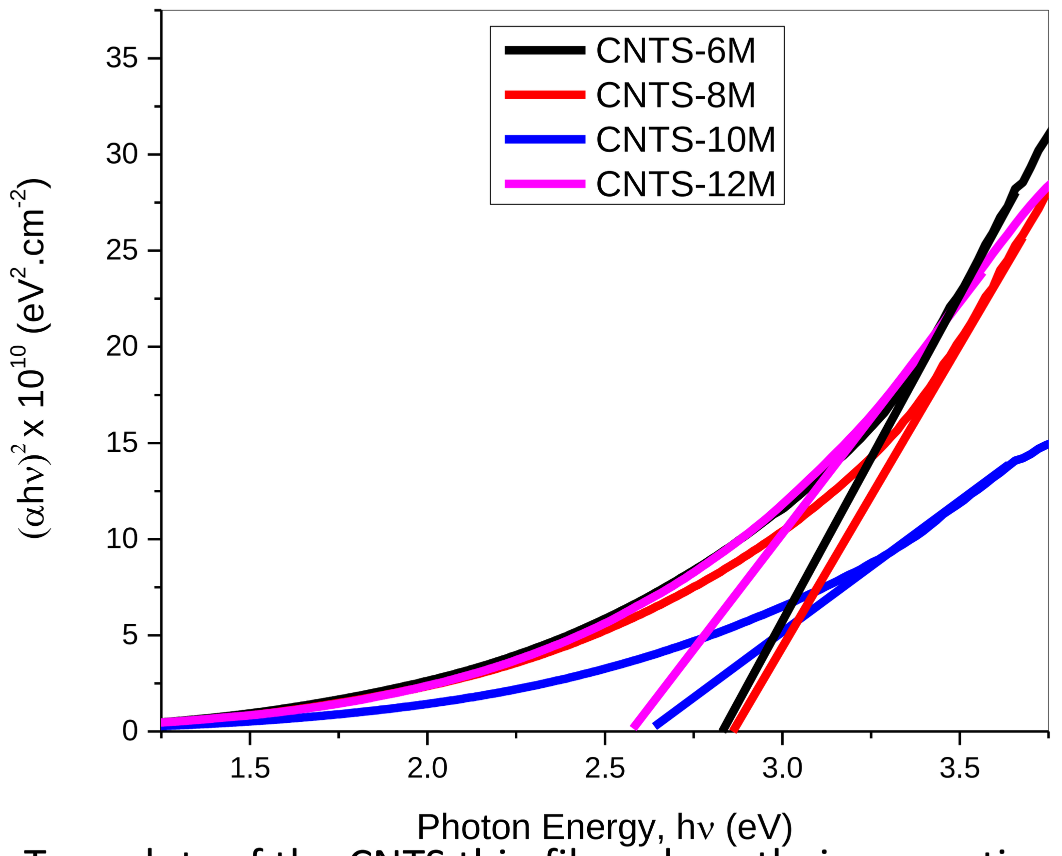

Fig. 9: Tauc plots of the CNTS thin films show their respective band gaps

➢ X-ray diffraction (XRD) Measurements

Table 02: Grain properties of the CNTS thin films for the prominent peak (111)

Sample Name	FWHM (deg.)	Crystall-ite size (nm)	Disloc-aion density (line/nm^2)	Micro-strain* 10^-3	Lattice param-eter (Å)
CNTS-6M	1.0331	7.93	0.0159	4.4	5.42
CNTS-8M	1.1313	7.24	0.0191	4.8	5.42
CNTS-10M	1.0010	8.19	0.0149	4.2	5.40
CNTS-12M	0.7581	10.81	0.0086	3.2	5.42

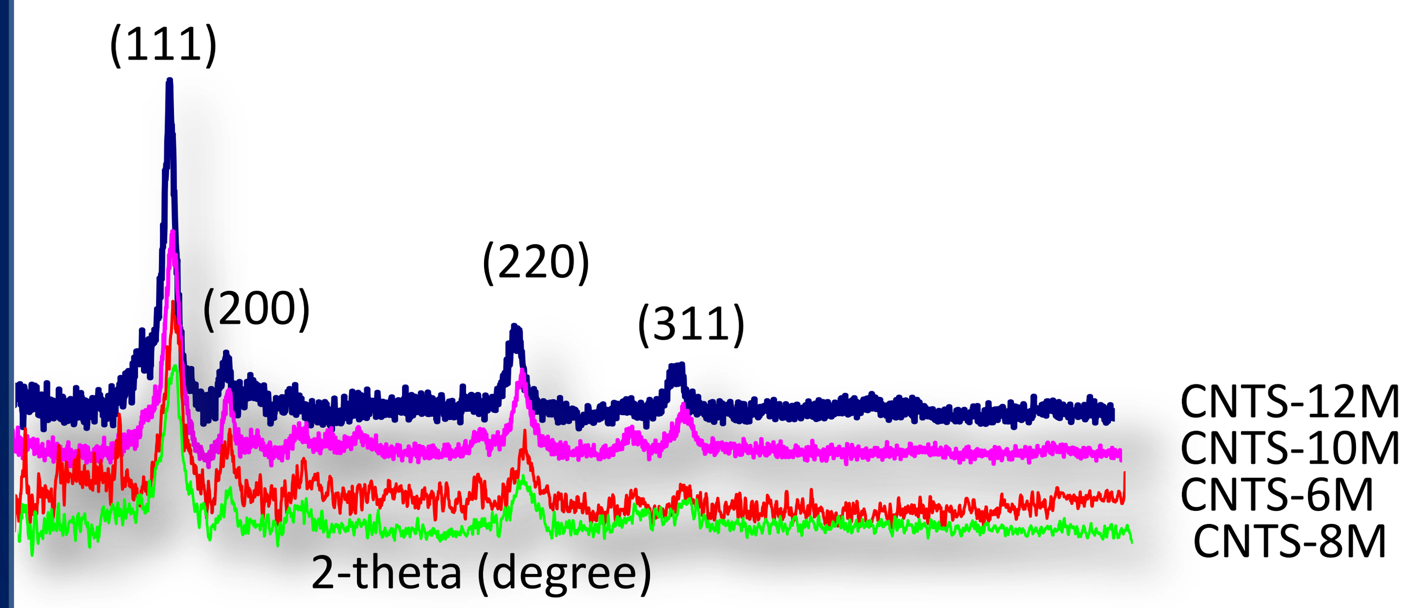

Fig. 10 : XRD pattern of CNTS thin films confirms cubic structure

Conclusion

From our investigation we may conclude that CNTS-12M thin film is more suitable for solar cell applications due to its higher absorbance, lower transmittance(%), higher absorption coefficient, lower band gap energy and better crystalline quality with low dislocation density than the other three thin films (CNTS-6M, CNTS-8M & CNTS-10M).

References

1. D.B. Mitzi, O. Gunawan, T.K. Todorov, K. Wang and S. Guha, "The path towards a high-performance solution-processed kesterite solar cell," Solar Energy Materials and Solar Cells, vol. 95, pp. 1421-1436, June 2011.
2. C. Hui-Ju, F. S. Wen and S. C. Feng, "Quaternary Cu2NiSnS4 thin films as a solar material prepared through electro deposition," Materials Letters, Vol. 166, P. 215–218, 2016.
3. T.-X. Wang, Y.-G. Li, H.-R. Liu, H. Li, S.-X. Chen, "Flower-like Cu2NiSnS4 nanoparticles synthesized by a facile solvothermal method", Mater. Lett. 124, 148–150, 2014
4. S. Dridi and M. Abaab, "Synthesis of quaternary Cu_2NiSnS_4 thin films as a solar energy material prepared through spray technique," Materials Letters, Vol. 204, June 2017.
5. N. Bitri, S. Dridi, F. Chaabouni, M. Abaab, "Studies on the electrical properties of Cu_2NiSnS_4 thin films prepared by a simple chemical method," Materials Letters 213, 31, 2018.
6. A. Kample, K. Mokurala, A. Gupta, S. mallick and P. Bhargava," Synthesis of Cu2NiSnS4 nanoparticles by hot injection method for photovoltaic applications," Materials Letters, vol. 137, pp. 440-443, September 2014.

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