Tin disulphide properties optimisation for solar cells applications

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***Abstract*—Tin disulphide semiconductors are used in various applications and specifically in solar cells. They are relatively inexpensive compared to other thin films used in the photovoltaic technology. Tin disulphide thin film has been promisingly proposed for this field application as buffer or window layer. In this work, we study the effect of deposition time on the structural, morphological and optical properties of tin disulphide thin films deposited on glass substrates using spray pyrolysis technique. The phase of SnS_2 are identified using X-Ray diffraction. A single phase without impurities is observed for the elaborated samples. The optical analyses show that the film prepared at 65 min present the highest transmittance in the visible region. The obtained results confirm that SnS_2 thin films can be good candidates for solar cells devices. These results are of great importance in the prediction of the good application of SnS_2 thin films in solar cells.**

Keywords*— *Tin disulphide, Spray pyrolisis, Characterization techniques, Sollar cells.

I. INTRODUCTION

Considerable attention has been paid for the last few decades to the binary compounds based on the Sn–S system, due to their excellent properties and the high potential use in optoelectronic devices [1–4]. In particular tin disulfide (SnS_2) was considered as one of very interesting tin sulfides semiconductors. SnS_2 has been known for its potential applications in solar cells as well as electrical switchings [5]. Also SnS_2 belongs to IV–VI group of semiconductor compound with hexagonal crystal structure (a= 0.3648 nm, c= 0.5899 nm) [6]. It has a wide band gap energy (2.88 eV) [7], and n-type electrical conductivity with magnitude depending on the preparation methods.

Thin films of SnS_2 compound has been prepared by different technologies deposition techniques. Such as, chemical bath deposition [8], vacuum thermal evaporation [9], close-spaced sublimation [10], successive ionic layer adsorption and reaction (SILAR) [11], spray pyrolysis [12].

In this paper we report a chemical method called ultrasonic spray, for the deposition of SnS_2 thin films at 350 °C onto ordinary glass substrates. Spray deposition is well established and widely used technique for thin film processing. It is a chemical vapour deposition that has been succefully used for the deposition of various materials.

The effect of deposition time parameter on the films properties and their characterization by X-ray diffraction, chemical analysis, and optical techniques are also reported.

II. EXPERIMENTAL DETAILS

Tin disulfide thin films were prepared by spraying an alcoholic solution containing tin chloride IV ($SnCl_4(2H_2O)$) and thiourea $CS(NH_2)_2$ on glass substrates using spray pyrolysis process. Substrates were degreased in successive rinses with acetone, ethanol, and distilled water. Then, the total solution was sprayed on heated substrates at 350 °C with a molarity equal to 0.08 mol/l. A set of samples was obtained by changing the deposition time 25, 45 and 65 in atmospheric pressure.

The films were characterized by means of structural, morphological, and optical methods. The X ray diffraction studies were carried out using a D8 ADVANCED BRUKER diffractometer using a Cu Kα radiation (λ=1.5405 Å) in range of 10-85°, the crystallite size were estimated to study the effect of the molar concentration. The surface morphology of the films was observed using a JEOL, model JSM 6301F Scanning Microscopy by field effect. The surface morphological studies were done with the SEM photographs taken with JEOL model JSM6400 scanning microscope. To have an idea about the surface elemental composition of the film, energy dispersive analysis by X-rays (EDAX) was carried out using EDX spectrometer related to the SEM used before.

III. RESULTS AND DISCUSSION

A. Structural characteristics

The XRD profile of the ultrasonic sprayed SnS_2 thin films on glass substrates is shown in Fig. 1. The prominent Bragg reflection occurring at about $2\theta \approx 32.98°$ along with many other weak peaks confirms the polycrystalline nature of the films. In all cases we found that (101) is the preferred orientation, so we can say that all SnS_2 thin films are in hexagonal crystallographic phase (JCPDS 31-1399), with the c-axis perpendicular to the substrate.

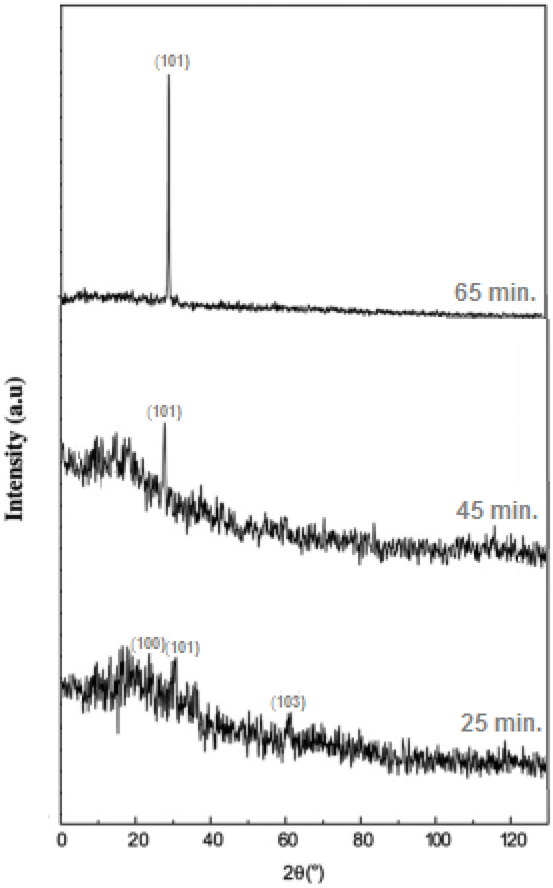

Fig. 1. X-ray diffraction pattern of SnS_2 thin films at different deposition time.

The average crystallite sizes of the films deposited with different molarities have been calculated using the Scherrer's formula:

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

Where λ, θ and β are X-ray wavelength, the Bragg's diffraction angle and the full width at half maxima of the peak corresponding to the θ value, respectively.

Crystallite size for samples obtained at different deposition times is shown in fig.2. It can be observed that the grain size increase with deposition time increasing of sprayed precursor solution from 9.46 nm to 13.5 nm. This later proves the crystallinity amelioration.

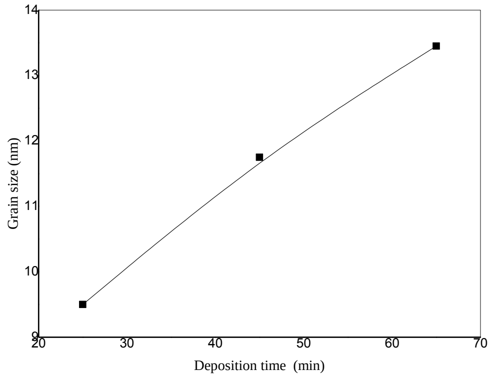

Fig. 2. Variation of crystallite size with different deposition time.

B. *Morphological characteristics*

The Fig. 3 shows typical SEM images and EDAX spectra of films deposited at the three studied deposition time and at substrate temperature 350 °C. Microscopic examination reveals that the obtained deposits are uniform and compact with good coverage to the substrate basis. As can be seen, the films morphology depends strongly on the deposition time. Film deposited at 65 min has a continuous and dense structure with a very smooth surface morphology as reveals Fig. 3.

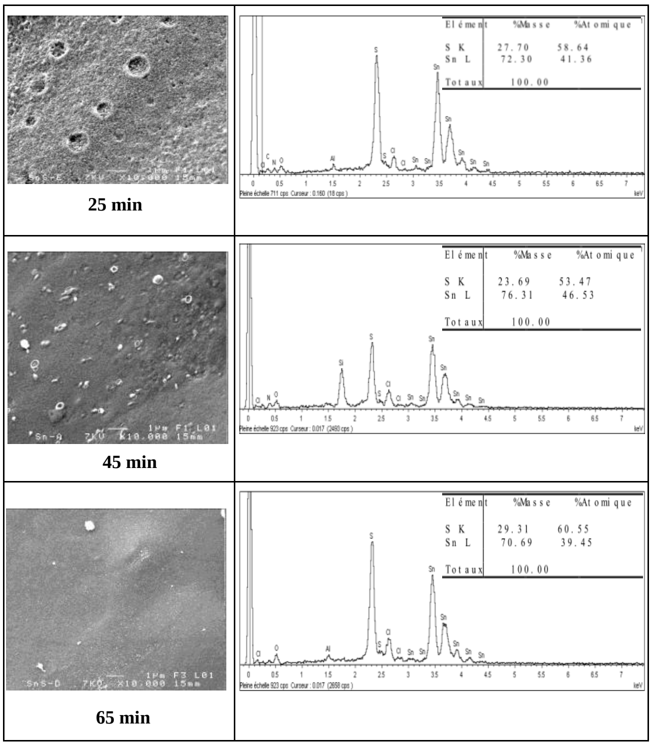

Fig. 3. SEM images and EDX spectra of SnS_2 thin films.

The EDX spectra of the SnS_2 films recorded in Fig. 3 shows the atomic and weight percentages of the elements present in the films and assure the chemical composition of SnS_2. As can be seen, atomic ratio for the samples increases with deposition time increasing. Also it can be noted, that the formed film at 65 min contain S and Sn with almost 39% and 61% ratio, respectively, which is the most near stoichiometric ratio for SnS_2 composition. In addition the presence of Cl is due to the used precursor, and those of O, N is due to the air.

C. Optical characteristics

Fig. 4 shows the optical transmittance curves as a function of the wavelength for the SnS_2 films deposited at 330°C with different molar concentrations.

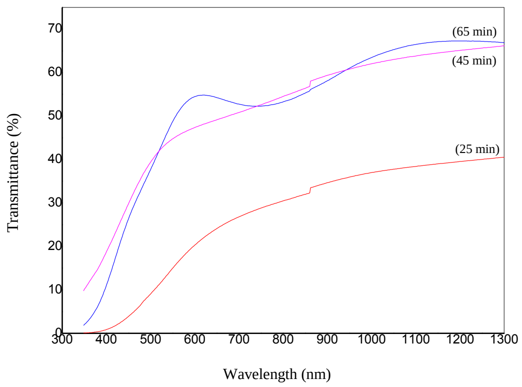

Fig. 4. UV-visible transmittance spectrum of SnS_2 thin films deposited at 350 °C at different deposition time.

As can be seen the optical transmittance increase with the molarity increasing. The fall of transmittance between 300 nm and 400 nm shows that the films absorb the light ultra violet. Furthermore, film deposited at 65 min exhibits interference fringe in the transmittance spectrum and a high transparency than the other films. This is due to the smooth surface of the former. It is well known that rough surface causes the light scattering resulting in transmittance reduction. This explains the low transmittance measured in films deposited at lowest deposition time.

IV. Conclusions

In the present work we have studied the influence of solution properties on SnS_2 thin films deposition by spray pyrolysis. Four molar concentrations were investigated. X-ray diffraction analysis reveals a polycrystalline nature (hexagonal phase) for all the films deposited at Ts = 330 °C. It was observed that the grain size is varied between ~ 14 and 9.5 nm. The morphological studies using SEM showed that the films are uniform and compact with good coverage to the substrate basis. EDS results confirm the presence of Sn and S. The optical characterization showed that the films transparent increase with molar concentration increasing. From these values we have suggested that the film deposited at 0.08 mol/l can be a potential candidate as an optical window in solar cells.

References

[1] G. Valiukonics, D.A. Guseinova, G. Krivaite, A. Sileica, Phys. Status Solidi, B Basic Res. 135 (1990) 299.

[2] M.T.S. Nair, P.K. Fair, J. Phys. D: Appl. Phys. 24 (1991) 83.

[3] A. Ortiz, J.C. Alonso, M. Garcı´a, J. Toriz, Semicond. Sci. Technol. 11 (1996) 243.

[4] S. Lo ´pez, A. Ortiz, Semicond. Sci. Technol. 9 (1994) 1.

[5] R. Bissessur, D. Schipper, Materials Letters 62 (2008) 1638–1641.

[6] A. Chakrabarti, J. Lu, A. M. McNamara, L. M. Kuta, S. M. Stanley, Z. Xiao, J. A. Maguire, N. S. Hosmane, Inorganica Chimica Acta 374 (2011) 627–631.

[7] F. Tan, S. Qu, X. Zeng, C. Zhang, M. Shi, Z. Wang, L. Jin, Y. Bi, J. Cao, Z. Wang, Y. Hou, F. Teng, Z. Feng, Solid State Communications 150 (2010) 58–61.

[8] K.T. Ramakrishna Reddy, G. Sreedevi, K. Ramya and R.W. Miles. Energy Procedia 15 (2012) 340 – 346

[9] Chengwu Shi, Zhu Chen, Gaoyang Shi, Renjie Sun, Xiaoping Zhan, Xinjie Shen, Thin Solid Films 520 (2012) 4898–4901

[10] Chengwu Shi, Pengfei Yang, Min Yao, Xiaoyan Dai, Zhu ChenThin, Solid Films 534 (2013) 28–31

[11] N.G. Deshpande, A.A. Sagade, Y.G. Gudage, C.D. Lokhande, Ramphal Sharma, Journal of Alloys and Compounds 436 (2007) 421–426

[12] O.A. Yassin, A.A. Abdelaziz, A.Y. Jaber. Materials Science in Semiconductor Processing 38 (2015) 81–86