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Dual Solution Synthesis and Characterization of Sns:Zns Alloyed Thin Films and Possible Applications in Solar Systems and Others

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Abstract: *Energy is required for the creation of wealth and sustainability of development. The importance of energy in economic development has been recognized historically but the equitable distribution of energy amongst the masses has generated great concern in recent times. This study was conducted to investigate the influence of varying annealing temperatures on the synthesis and characterization of SnS:ZnS alloyed thin films for solar applications. SnS:ZnS alloyed thin films were successfully deposited on glass substrates using two solutions-based methods: electroless and SILAR. The deposited alloyed sulphides were annealed between (373-423) K using a master chef annealing machine. The crystallographic studies were done using X-ray diffractometer and scanning electron microscope which indicates that the samples are polycrystalline and have cubic crystal systems. Rutherford Back Scattering analysis confirmed the percentage of the elements of tin, zinc and sulphur in the alloyed sulphide thin films. The results of the findings revealed that alloyed materials were deposited. The deposited materials were uniform and adherent to the substrates. The structural properties show that SnS:ZnS are polycrystalline. The microstructure shows the optical micrograph of the deposited samples. The properties exhibited make the films good material for protective coating, window coating, galvanization of metal and non-metal surfaces to prevent corrosion, etc. These properties also enhanced the material suitability for photovoltaic (PV) in solar energy conversion, sensors for the detection of poisonous substances most especially in the Oil-producing areas, light emitting diode (LED) and flat panel displays for optoelectronic applications.*

Keywords: *Alloy, Thin films, Annealing, SnS:ZnS, Applications*

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1.0 Introduction

Nature has provided various sources of energy such as hydro, solar, wind and other sources. Effective utilization of these energy sources has not been fully realized by the global society. However, the search for newer technologies associated with these natural sources of energy is ongoing and is receiving great attention because of the green nature of some of the sources (especially solar energy). Sustainability of development is not achieved in the absence of renewable energy because of the environmental requirements, which include accessibility, cost-effectiveness, environmentally friendliness and others (Al-Shetwi, 2022). Solar energy has the dynamic potential to solve several challenges in the energy sector; such energy has been acknowledged to be greater than the world's present and future energy needs (Jurasz *et al*., 2019). The operation of the solar system is majorly concerned with the conversion of solar energy to chemical and electrical energy. The thin film technology sustained the conversion of light energy to electrical energy (Katarzyna, et al., 2018). Therefore the role of the thin film in the operation of solar cells cannot be overemphasized (Bjatia, 2014). Due to the exponential growth of the global population, the need for energy is increasingly multiplied. But this huge demand can be met by solar energy alone. Thin films are applied in the fabrication of semiconductor-integrated circuits. The fabrication process always involves the deposition of thin films on glass or ceramics material (Oriaku and Osuwa, 2009). Therefore, thin film now occupies prominent place in research and solid-state technology. In an expanding variety of applications in various electronic and optoelectronic devices, much interest has been attracted as a result of the use of thin film semiconductors due to their low cost of production. This study aims to investigate the influence of varying annealing temperatures on the synthesis and characterization of SnS:ZnS alloyed thin films for solar application.

2.0 Materials and Methods

2.1 Preparation of SnS:ZnS alloy thin films

2.1.1 Substrate preparation

The substrates (glass slides) were degreased in aqua regia (HCL and HNO_3) for twenty-four hours. The degreased samples was washed in cold water with detergent and rinsed with distilled water and allowed to dry in the air. The degreased and clean surface had the advantage of providing nucleation centers for the growth of the films, hence yielding adhesives and uniformly deposited film (Daniel-Umeri *et al.,* 2012).

2.1.2 Deposition of SnS:ZnS alloy thin films using dual solution synthesis (SGT and SILAR)

The binary compounds were deposited using solution growth and SILAR technique. Tin sulphide (SnS) alloy thin films were deposited using SILAR after which it was dipped in a bath of ZnS prepared by solution growth technique respectively. The end product was SnS:ZnS deposited thin films using the two techniques with variations in annealing temperature.

2.2 Characterization of deposited thin films

The XRD analysis was carried out using X-ray diffractometer modeled GBC Enhanced Mini Material Analyzer (EMMA), XRD pattern gives information relative to the nature and structure of the alloyed thin films of CuS:ZnS. The crystallite sizes given in Table 5 are obtained using Debye-Scherer's equation expressed as equation 1 (Onwuemeka and Ekpunobi, 2018; Osuwa and Anusionwu, 2011; Offiah *et al.,* 2012; Nwaokorongwu *et al.,* 2018).

$$D = k\lambda\beta\cos\theta \quad (1)$$

where k is the shape factor (k=0.9) , D is the grain size or average crystallite size, λ is the wavelength of Cukα radiation used (λ =1.54A≡0.154nm), β is the experimentally observed diffraction peak with width at half maximum intensity (Full Width at Half Maximum FWHM) and θ is the Bragg's diffraction angle.

The microstructure of the thin films of SnS:ZnS were determined using a surface electron microscope. The elemental compositions and thicknesses of the samples were determined using Rutherford back scattering spectroscopy (RBS).

3.0 Results and Discussion

3.1 Elemental composition and thickness of SnS:ZnS Alloyed Thin Films

In this study, elemental compositions and the thicknesses of the samples were determined using RBS. Results obtained for the elements in sample T2 (SnS:ZnS annealed at 473K) are shown in Table 1 while Fig. 1 is a graphical representation of the elemental composition of sample T2 (SnS:ZnS annealed at 473K) with thickness 360 nm.

Results obtained for the elements in sample T3 (SnS:ZnS annealed at 523K) are shown in Table 2 while Fig. 2 isa graphical representation of the elemental composition of sample T3(SnS:ZnS annealed at 523K) with thickness 440 nm.

Results obtained for the elements in sample T4 (SnS:ZnS annealed at 373K) are shown in Table 3 while Fig. 3 is a graphical representation of the elemental composition of sample T4 (SnS:ZnS annealed at 373K) with thickness 440 nm.

Table 1: The elements in sample T2 of SnS:ZnS

Elements	Layer 1 % Composition	Layer 2 % Composition
Sn	29.28	
Si		23.74
Al		0.02
Zn	32.20	
O		63.42
K		0.69
S	70.66	
Na		8.91
Fe		0.59
Ca		2.63

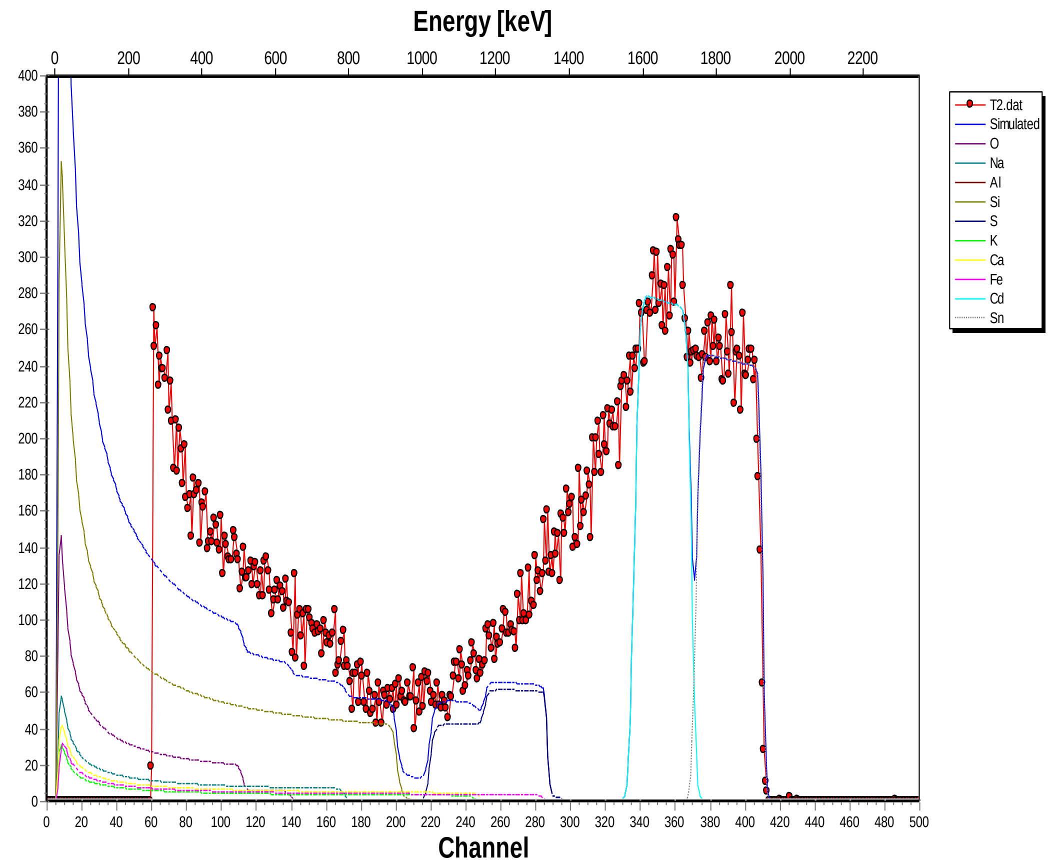

Fig. 1: The composition of sample T2 with a thickness 360nm, of SnS:ZnS measured by RBS

Table 2: The elements in sample T3 of SnS:ZnS

Elements	Layer 1 % Composition	Layer 2 % Composition
Sn	12.10	
Si		23.74
Al		0.02
Zn	13.20	
O		63.42
K		0.69
S	24.63	
Na		8.91
Fe		0.59
Ca		2.63

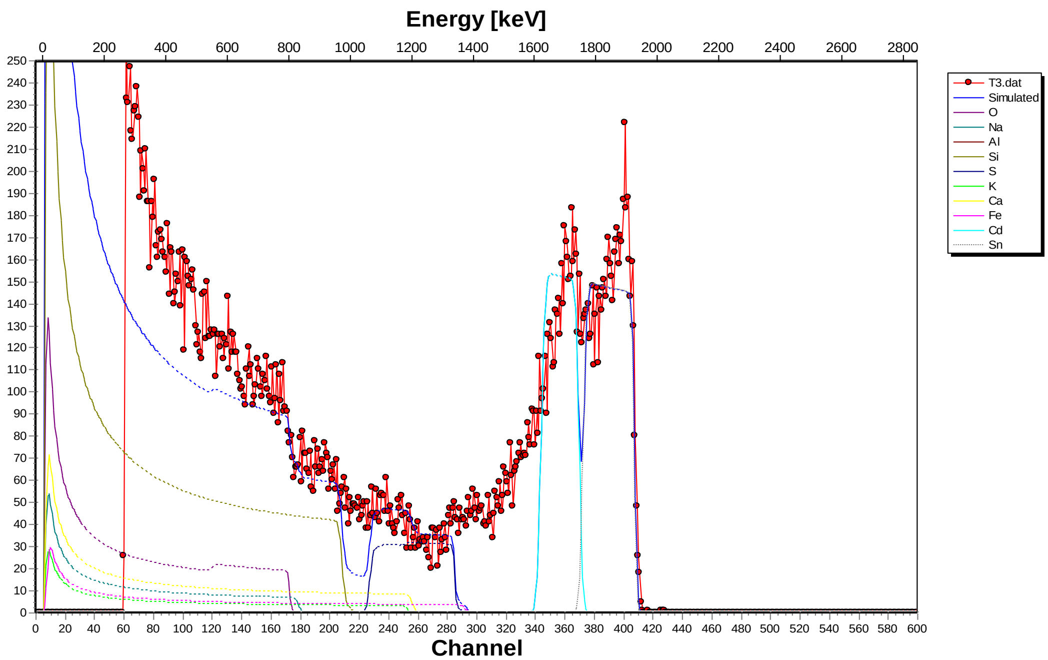

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Fig.2: The composition of sample T3 with thickness 440nm, of SnS:ZnS measured by RBS

3.2 The XRD Pattern of SnS:ZnS alloyed thin films of sample R6

The XRD pattern of SnS:ZnS alloy thin film shows sharp and well-defined peaks that indicate the polycrystalline nature of the alloyed thin film.

In table 4, the crystallite sizes given are obtained using Debye- Scherer's equation (Reka *et al*., 2014)

$$D = \frac{k\lambda}{\beta cos\theta} \quad (2)$$

re k is the shape factor (k=0.9) , D is the grain size or average crystallite size, λ is the wavelength of Cukα radiation used (λ =1.54A≡0.154nm), β is the experimentally observed diffraction peak with width at half maximum intensity (Full Width at Half Maximum FWHM) and θ is the Bragg's diffraction angle. The table presents information for the XRD result of sample T2 (SnS:ZnS annealed at 473K) while the XRD pattern of SnS:ZnS annealed at 473K is shown in Fig. 4.

Table 3: The elements in sample T4 of SnS:ZnS

Elements	Layer 1 % Composition	Layer 2 % Composition
Sn	7.60	
Si		23.74
Al		0.02
Zn	11.20	
O		63.42
K		0.69
S	50.63	
Na		8.91
Fe		0.59
Ca		2.63

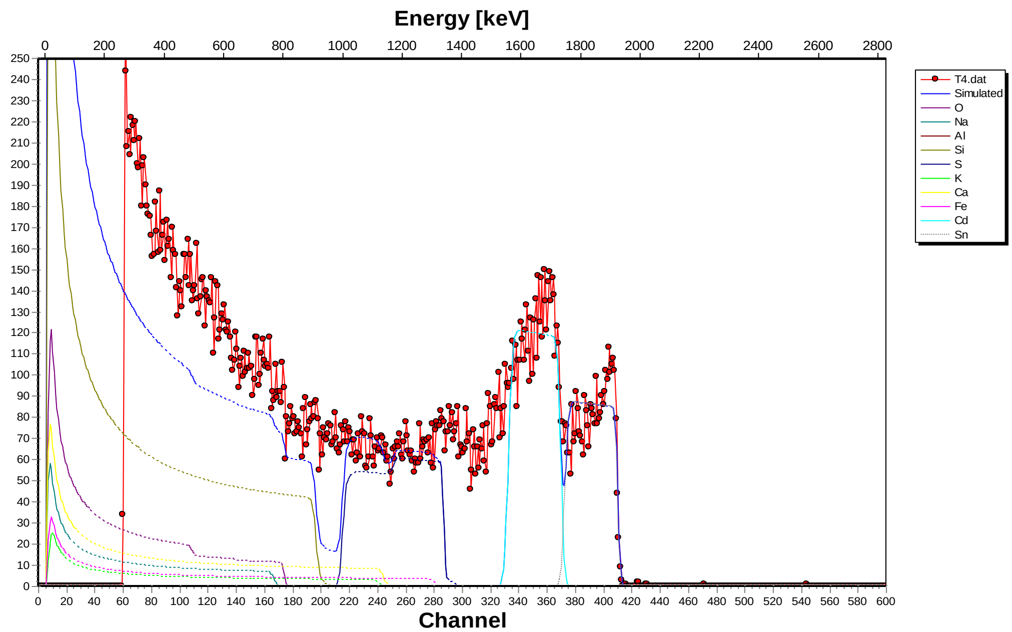

Fig. 3: The composition of sample T4 with a thickness 440nm, of SnS:ZnS measured by RBS

Table 4: XRD results of SnS:ZnS alloyed thin film

Sample	hkl	d-spacing (Å)	FWHM (radian)	Grain size (nm)	Position (◦2theta)	Count (height)
T6 (SnS:ZnS annealed at 200◦C)	002	2.92893	0.1535	0.9371	30	1222.16
	200	2.76673	0.2303	0.6263	32	1678.01
	020	2.61005	0.2047	0.7082	34	1714.48
	111	1.61750	0.2047	0.5114	56	641.61
	202	1.46498	0.3070	0.5296	62.5	596-54

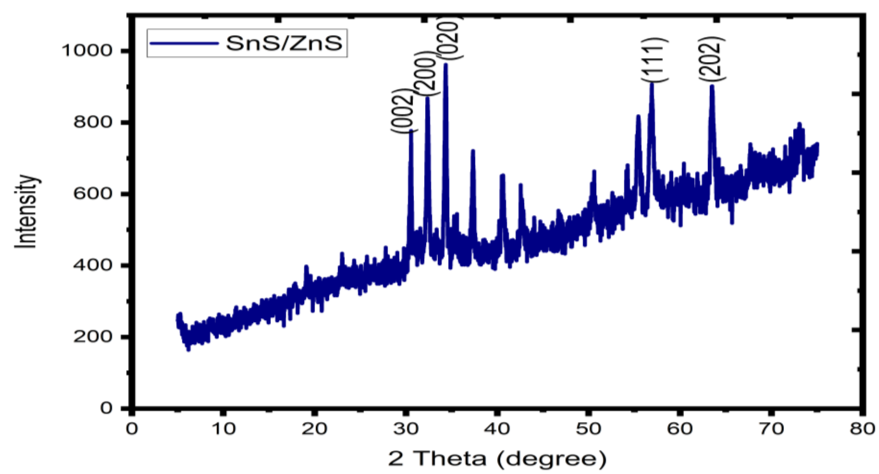

Fig. 4: XRD pattern of SnS:ZnS alloyed thin film of samples T6 annealed at 200◦C

3.3 Microstructure of the deposited samples

The microstructure of the SnS:ZnS thin films was determined using the surface electron microscope. The process of analysis is through imaging. Samples T1 and T6 have coarse but well-defined granular surfaces. The observed spectrum shows a rough texture in Fig. 5.

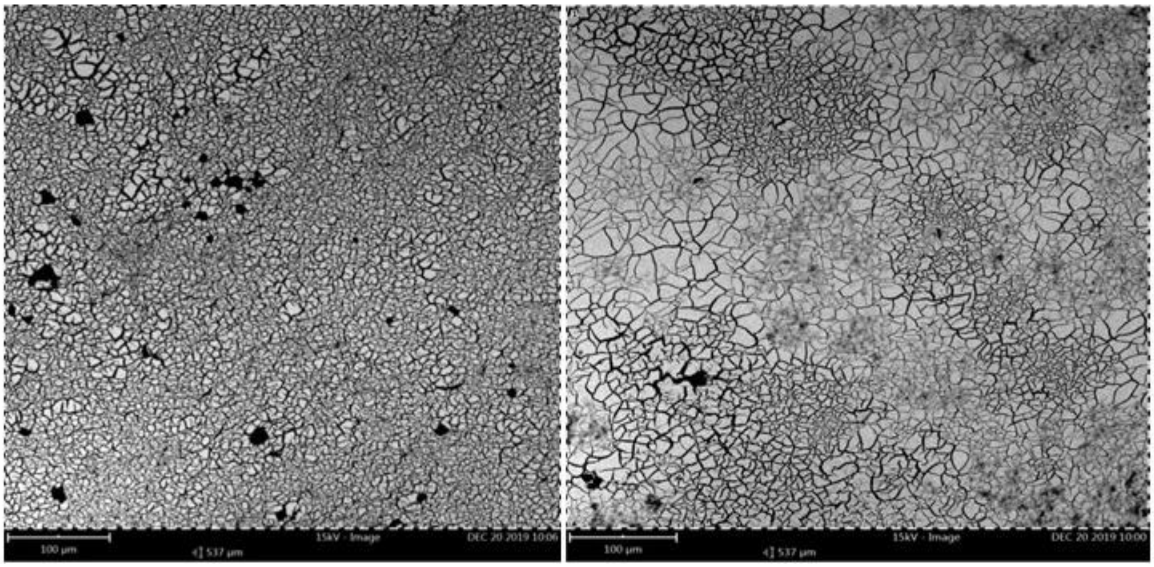

Fig. 5: Optical micrograph of SnS:ZnS alloyed thin films of samples T1 and T6

4. 0 Conclusion

In this study, it was revealed that the alloyed materials were deposited. The deposited materials were uniform and adherent to the substrates. The elemental compositions show different percentages of the desired elements in the deposited samples. The structural properties show that SnS:ZnS are polycrystalline. The microstructure shows the optical micrograph of the deposited samples. These properties indicate that the films may be good material for protective coating, window coating, galvanization of metal and non-metal surfaces to prevent corrosion, etc. This makes the material suitable for photovoltaic (PV) in solar energy conversion, sensors for detection of poisonous substances most especially in the oil-producing areas, light emitting diode (LED) and flat panel displays for optoelectronic applications.

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Not Applicable

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