Zinc sulfide thin films produced by spray pyrolysis: optical and structural characteristics

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Zinc sulfide thin films were prepared using the economical spray pyrolysis process. A thin film of exceptional quality with a temperature difference of 300 °C to 400 °C is produced by optimizing variables such as concentration, flow rate, and nozzle to substrate distance. These films' optical characteristics and structure were examined. The deposited thin films displayed a direct and allowed transition, as indicated by the optical transmittance spectra. XRD analysis confirmed that the deposited thin films were polycrystalline with a cubic phase. This film can be used in solar cell applications since the band gap energy fluctuation is high enough, ranging from 3.42 to 3.81 eV.

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1. Introduction

Zinc sulfide has an n-type conductivity and a wide straight band gap, it can be used in optoelectronic device applications such electroluminescent devices and solar cells. Zinc sulfide has unique optical, electrical, and structural properties. As like SnS, ZnO, and MnO [1,2,3,4,5] thin films, these thin films also have many applications that includes gas sensing [6], LED [7], solar cells [8], field emitters [9], Piezo electric generators [10]. Zinc sulfide can be prepared by chemical bath [11], metalorganic vapour-phase epitaxy [12] spray pyrolysis technique [13], magnetron sputtering [14], RF sputtering [15] and SILAR [16]

2. Experimental

Zinc sulfide is deposited on a glass substrate at temperatures ranging from 300°C to 400°C while holding constant other deposition parameters including concentration, solution flow rate, gas flow rate, and nozzle to substrate distance. Spraying the solution onto the glass substrate involved mixing 0.1 M $ZnCl_2$ and 0.1 M thiourea in methanol. Through the spray head, compressed air, the carrier gas was allowed to flow. Allowing the spray head to move manually resulted in an equal coating of films on the substrate. With a precision of ± 5˚C, the substrate temperature was tracked and adjusted using a chrome-alumel thermocouple. Following a distilled water rinse, the substrate was ultrasonically cleaned three times using trichloroethylene, acetone, and methyl alcohol. UV and XRD were used to characterize the produced films.

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3. Results and discussion

3.1. Optical properties

A UV-VIS-NIR spectrophotometer was used to analyze zinc sulfide thin films, which had a white surface, were generated at temperatures between 300˚ and 400˚C. The spectral range of 300–1000 nm is represented by the optical transmittance curve of sprayed ZnS films in Figure 1.

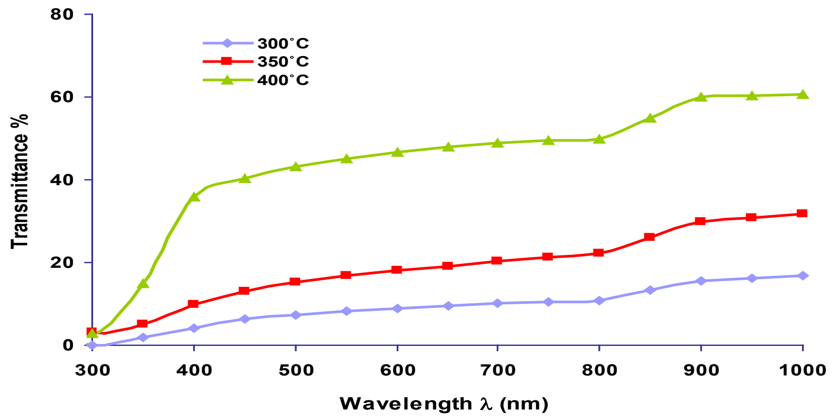

Fig. 1. ZnS thin fims, Optical transmittance spectra at different temperature.

The temperature-sensitive film (with a transmittance of 15% at 300˚C) exhibits a lower transmittance than the temperature-sensitive film (61% at 400˚C). These films have maximum transparency and less absorption in the near IR region (Fig. 2). The films obtained at 300˚C and 400˚C were interfered with in the 600 nm range, which shows the homogeneity of the films with uniform thickness.

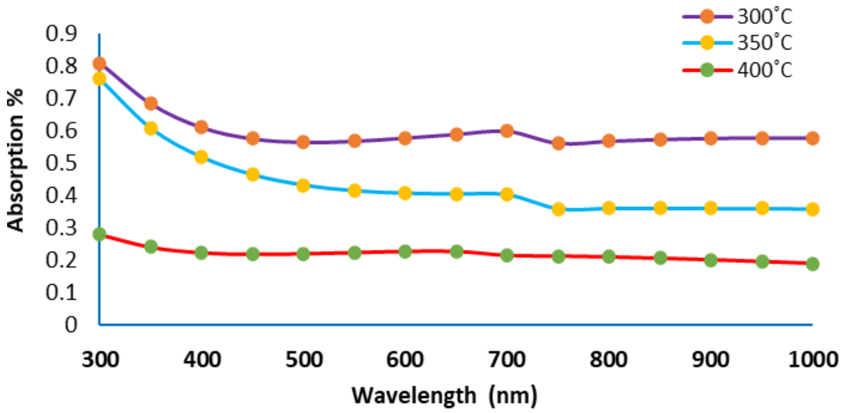

Fig. 2. ZnS thin films, absorption spectra at different temperature.

The ZnS thin film's optical energy gap was calculated using the optical measurements. After extrapolating to the abscissa, the optical energy gaps for substrate temperatures of 300 ˚C is 3.42, 350 ˚C is 3.54, and 400˚C is 3.81. The calculated values are greater than those obtained for amorphous ZnS, Eg = 3.4 eV, while the average value of the band gap, Eg = 3.58 eV, is higher than that of the cubic phase, Eg = 3.4 eV.

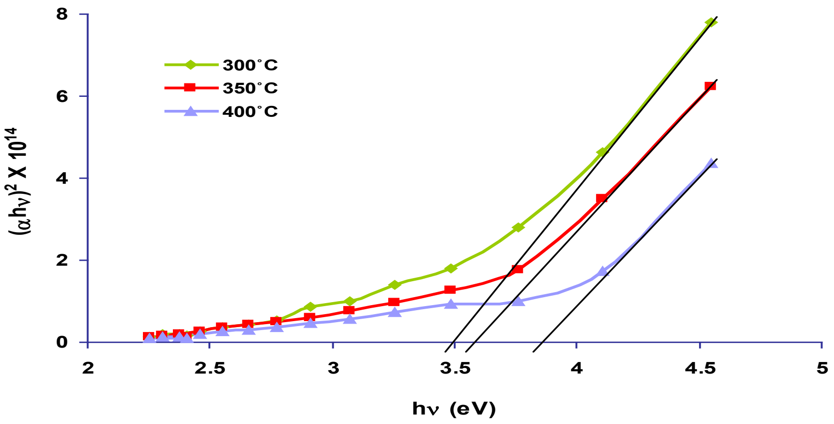

Fig. 3. Band gap of ZnS films prepared at different temperature.

3.2. Structural properties

The ZnS films formed by spray pyrolysis were smooth, uniform, adhered to the substrate, and had a grey-white tint, according to ocular inspection. The tightly spaced X-ray diffraction spectra of evaporated ZnS films were obtained at three different temperatures 300˚C, 350˚C, and 400˚C see Fig. 4. The spectra revealed that the single (111) plane that appeared at 2θ = 29.90˚ and had cubic structure was present in all the layers developed at various substrate temperatures. The single peak seen at 2θ = 29.90˚ suggested that the layers grew significantly preferentially in the (111) direction. However, the diffraction peak was enhanced in intensity and widened when the films were formed at a higher substrate temperature of 400˚C. From the scanning electron microscope, it is clear that at 400˚C the structure formed is a cubic structure with a particle size varying from 2.205 µm to 3.125 µm.

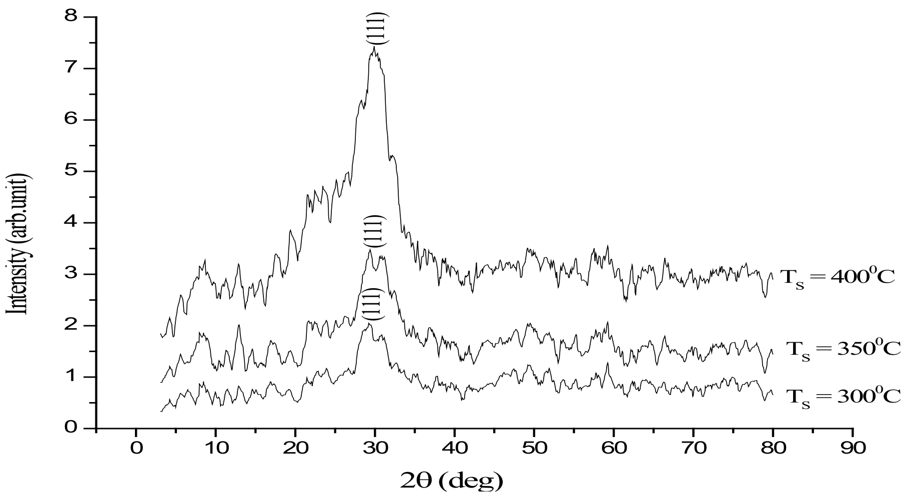

Fig. 4. X –Ray diffraction of ZnS thin films.

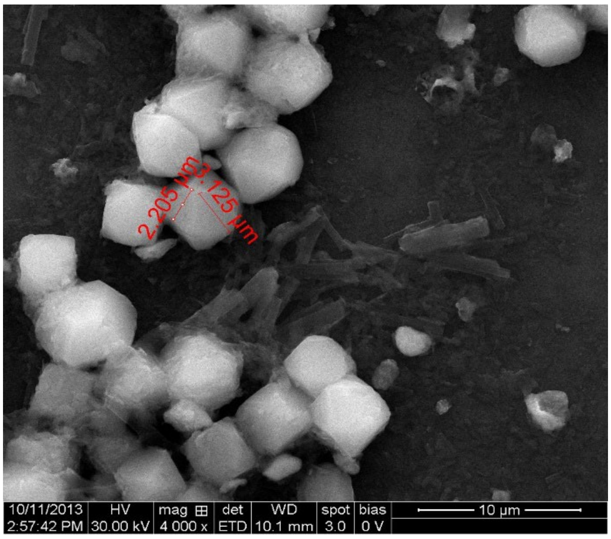

Fig. 5. SEM of ZnS film at 400°C.

4. Conclusion

The ZnS thin films were deposited through the application of spray pyrolysis. The deposited thin films displayed a direct and allowed transition, as indicated by the optical transmittance spectra. As substrate temperature increased, it was seen that both the transmittance and optical band gap values also increased. The band gap energy fluctuates from 3.42 to 3.81 eV, which is sufficiently large to allow these films to be used in solar cell applications. The thin films that were deposited were found to be polycrystalline with a cubic phase, according to XRD examination. The film preferred orientation in the (111) direction. It is clear from SEM analysis that as substrate temperature increases, grain size also increases.

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