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Effects of Ligand on the Absorbance and Transmittance of Chemical Bath Deposited Zinc Sulphide Thin Film

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ABSTRACT

Zinc sulphide thin films have been grown by chemical bath deposition using zinc acetate (Zn(CH3COO)2) and thiourea (SC(NH2)2) as starting materials and ammonia solution (NH4OH) as ligand. The absorbance and transmittance spectra of the films were obtained using a Janway 6405 uv/visible spectrophotometer. Structural and surface characterization of the films were carried out using an x-ray diffractometer with Cukα radiation and Olumpus optical microscope respectively. XRD spectrum indicates that the films have cubic zinc blend structure.

INTRODUCTION

Zinc Sulphide belongs to II-VI group compound material with large direct band gap between 3.4 to 3.70 eV depending upon composition [1]. It is potentially important material to be used as an antireflection coating for heterojunction solar cells[2]. It is an important device material for the detection, emission and modulation of visible and near ultra violet light [3]. It has potential applications in flat-panel displays, electroluminescent devices, infrared windows, sensors, and lasers [4]. ZnS is also currently used as a shell or capping layer in core/shell nanoprobes such as CdSe/ZnS core/shell structures [5]. Various methods have been employed for deposition of ZnS thin films, which include magnetron sputtering [6].The chemical bath deposition technique [7] has been found to be an inexpensive and simple low cost method that could be used to produce good quality film for device applications. It is well studied and produces films that have comparable structural and opto-electronic properties to those produced using other sophisticated thin film deposition technique. This paper reports the chemical bath deposition of ZnS thin films from an aqueous solution bath containing zinc acetate and thiourea, using ammonia as ligand.

MATERIALS AND METHODS

Chemical bath deposition technique was used to deposit Zinc sulphide thin films on glass substrates which had been previously degreased in concentrated HNO_3 for 48 hours, cleaned in cold water with detergent, rinsed with distilled water and dried in air.

In this experiment, five reaction baths (50mls beaker) were used. 10mls of zinc acetate was measured into a 50ml beaker using burette; 10mls of thiourea was then added. On addition of thiourea, solution remained clear. Various volume of ammonia solution (ligand) was then added as show in Table. 1 below, the solution turned milky and after a very short time interval it became clear. The mixture was then topped to 50mls level by addition of distilled water and stirred gently to ensure uniformity of the mixture. A glass substrate was dipped vertically into all of the five reaction baths with the aid of a synthetic foam cover. Each bath was allowed to stand for twenty four hours, after which the slides were removed and dried in air. The experiment was conducted at room temperature. Janway 6405 uv/visible spectrophotometer was used to determine the spectra absorbance and transmittance. Structural and surface characterization of the films was carried out using an x-ray diffractometer with Cukα radiation and Olumpus optical microscope respectively. Other solid state and optical properties of the films had been investigated in our earlier publication [8]. The reaction mechanism is of the form:

Zinc acetate dissociates as:
$Zn(CH_3COO)_2 \longrightarrow Zn^{2+} + 2CH_3\,COO^-$

Ammonia hydrolyses in water to give OH^- according to

$NH_3+H_2O \longrightarrow NH_4^+ + OH^-$

$Zn^{2+} + 4NH_3 \longrightarrow Zn\,(NH_3)_4^{2+}$

Thiourea dissociates as:

$SC(NH_2)_2 + OH^- \longrightarrow SH^- + CH_2N_2 + H_2O$

$SH^- + OH \longrightarrow S^{2-} + H_2O$

Table 1: Bath constituents for the deposition of zinc sulphide Thin Film

Slide	Volume of zinc acetate (mls)	Volume of thiourea (mls)	Volume of Lgand (mls)	Time (hours)
Zn_1	10.00	10.00	5.00	24.00
Zn_2	10.00	10.00	7.50	24.00
Zn_3	10.00	10.00	10.00	24.00
Zn_4	10.00	10.00	12.50	24.00
Zn_5	10.00	10.00	15.00	24.00

RESULTS AND DISCUSSION

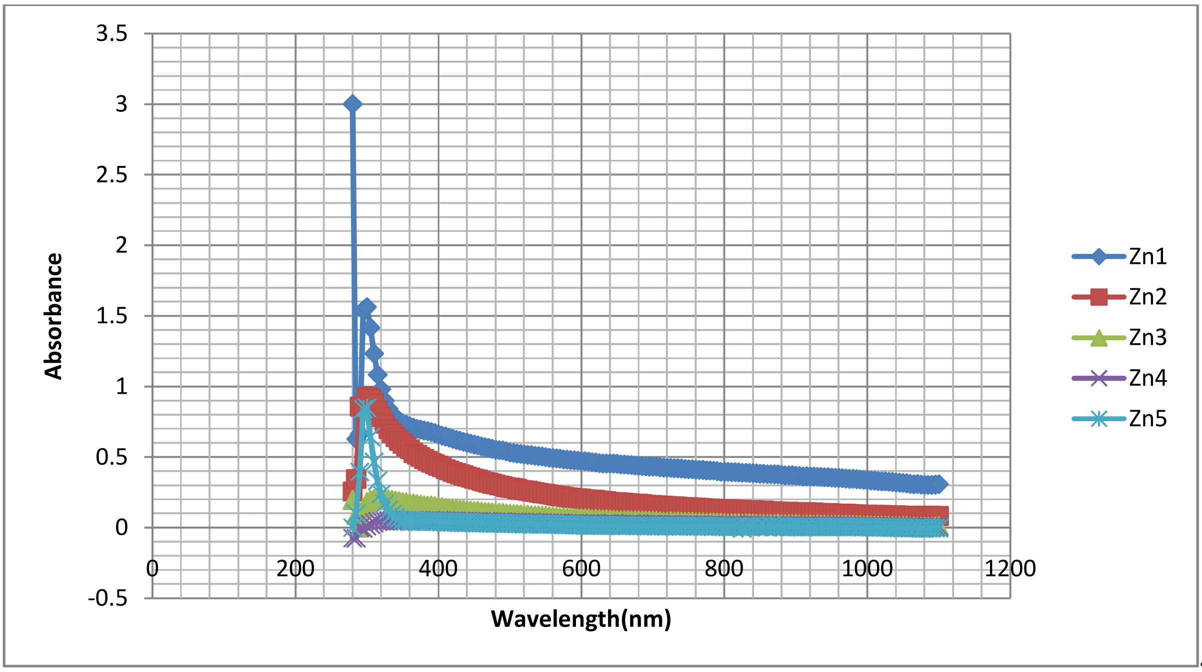

Fig.1: Spectral absorbance of ZnS films (Slide Zn1,Zn2, Zn3, Zn4, Zn5)

Fig.1 is a plot of absorbance of ZnS thin film as a function of wavelength. The optical absorption spectra of ZnS films deposited onto a glass substrate were studied at room temperature in the wavelength range of 300nm-1100nm.

The optical absorbance spectra were obtained for the film deposited at different ligand concentration. The curves show a decay of absorbance with longer wavelength. The absorbance tends to be very high in the uv region for all the samples. It also shows a moderate absorbance in the visible region for all the samples. In the near infra-red region, the curves reveal a very low absorption of energy. A critical look at the graph shows a progressive decrease in absorbance as the volume of the ligand increased from 5mls to 15mls. From this experiment one can infer that increase in the concentration of ligand in the chemical bath deposition of ZnS thin film has an inverse effect on the absorbance of the film.

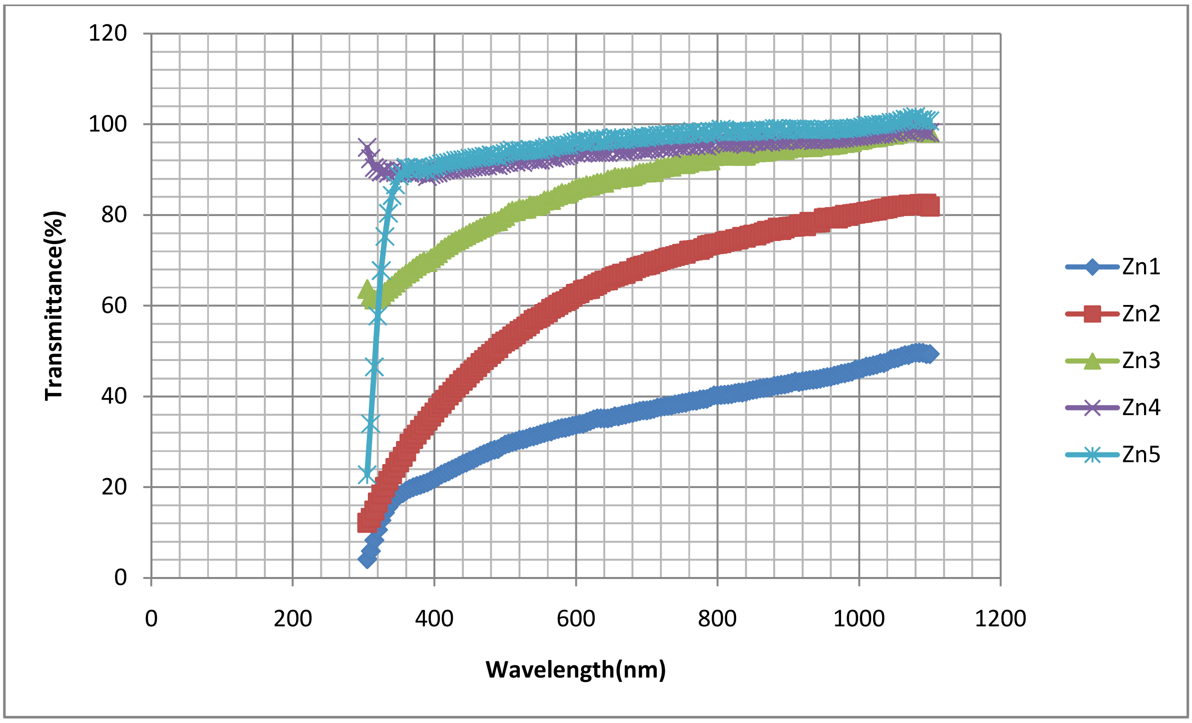

Fig.2: Spectral transmittance of ZnS films (Slide Zn1,Zn2, Zn3, Zn4, Zn5)

Fig.2 is a plot of transmittance of ZnS thin film as a function of wavelength. The optical transmittance spectra of ZnS films deposited onto a glass substrate were studied at room temperature in the wavelength range of 300nm-1100nm. The optical transmittance spectra were obtained for the film deposited at different ligand concentration. The curves show increase of transmittance with longer wavelength. The transmittance is low in the uv region for all the samples. In the visible cum near infra-red region of the spectrum, the curves reveal a very high transmittance of energy. A critical look at the graph shows a progressive increase in transmittance as the volume of the ligand increased from 5mls to 15mls. From this experiment one can infer that increase in the concentration of ligand in the chemical bath deposition of ZnS thin film increases the transmittance of the film. Sample Zn1 with the lowest concentration of ligand has a transmittance of 44% at 1100nm, while sample Zn5 with the highest concentration of ligand has a transmittance of approximately 90% and 100% at 600nm and1100nm respectively. The higher transmittance in the visible regions makes it a strong candidate for use in optoelectronic devices. The spectra also reveal wide transmission range covering 300nm – 1100nm. This makes the material useful in manufacturing optical components, windows, mirrors, and lenses for high power IR laser [9].

Fig.3 show the x-ray diffraction spectra of ZnS thin film. According to the XRD result, the chemically deposited film of ZnS is of cubic zinc blend structure. This is also consistent with the finding of [10].

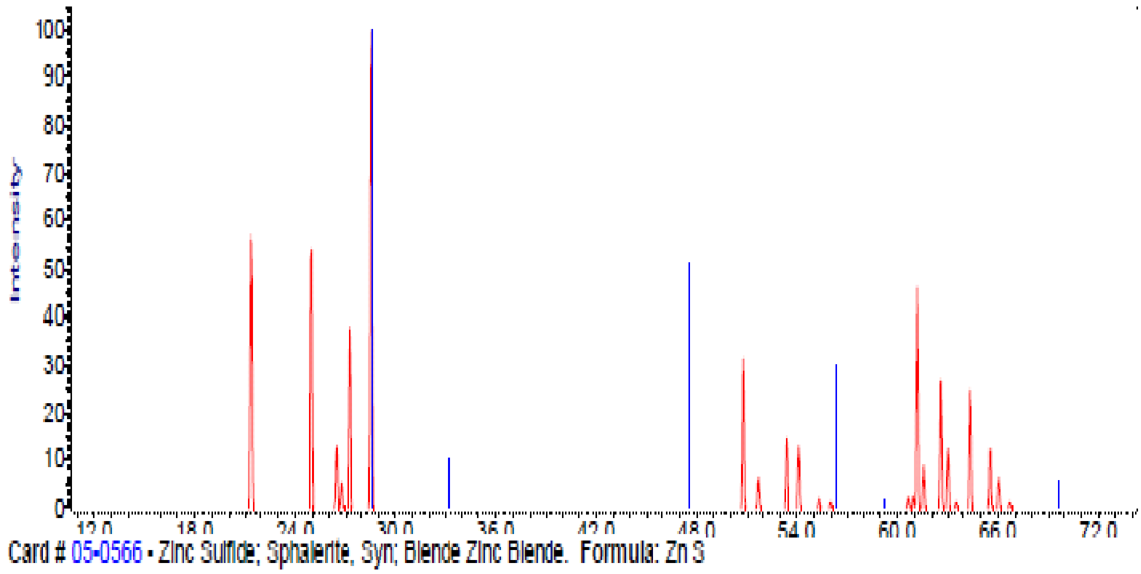

Fig .3: X – ray Diffraction spectra for ZnS

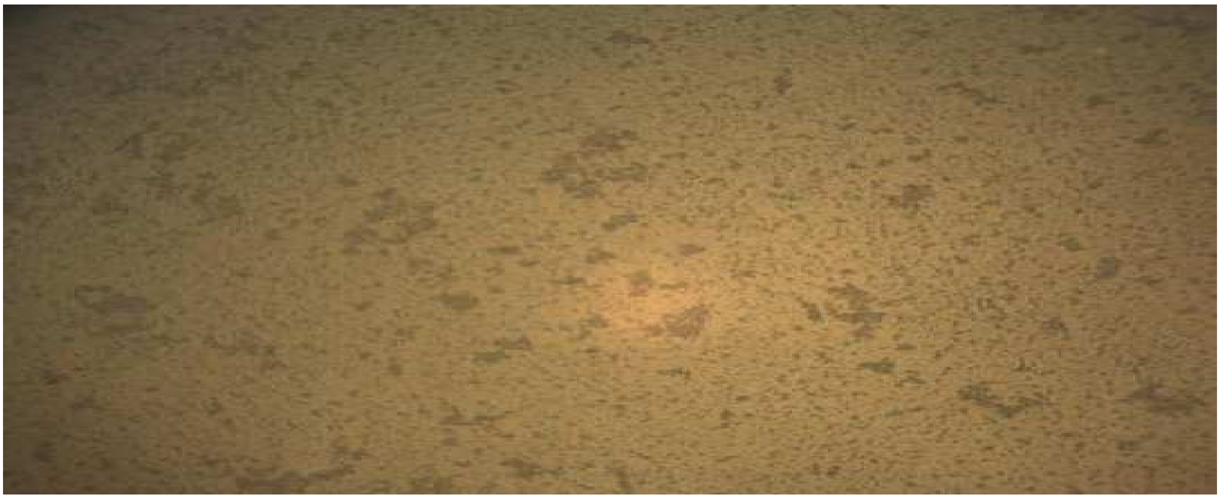

Fig.4: Optical Micrograph of ZnS Thin Film

Fig.4 shows the optical micrographs of ZnS thin film. From the optical micrograph, it can be seen that the surface of the film is smooth and covers the glass substrate well. The grains are very small with unequal size and shape.

CONCLUSION

ZnS films were successfully deposited using chemical bath deposition technique. Good quality films of Zinc sulphide with cubic zinc blend structure were deposited. The films have high absorbance in the uv region of the electromagnetic spectrum. The films also have high transmittance in the visible/ near infrared region of the electromagnetic spectrum. These make the films excellent glazing material for solar control in warm climate regions. The high transmittance makes the films potential for use in manufacturing optical components, windows, mirrors, and lenses for high power IR laser. We also established that increase in the concentration of ligand in the chemical bath deposition of ZnS thin film has an inverse relationship on the absorbance of the film and a direct relationship on the tranmittance.

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