INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue1)
Available online at: www.ijariit.com

Studies on Optical Properties of ZnS Thin Film by Thermal Evaporation Technique

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Abstract: The most significant process for optical coating is variant of vacuum deposition. Zinc sulphide having direct and large band gap which is use in opto electronics. By using ZnS material in thermal evaporation technique and characterizing the minimum reflectance and maximum transmittance in visible wavelength and energy gap increases with increasing thickness having direct and large band gap. When ZnS thin films doped with similar material then the transmission band can be widened in IR region. On this method we make many applications over IR windows and scintillation detectors and other electronic devices.

Keywords: Band Gap, Energy Band, IR Region, Optical Coating, opto Electronics, Reflectance, Scintillation Detector, Thin Films, Thermal Evaporation Technique, Transmission Band, Transmittance, ZnS.

I. INTRODUCTION

The production of thin film is a modern technology that was born from research. Thin film is a thin layer of any bulk material which is going to be deposited on any substrates. Thin film and devices play an important role in the development of modern science.

The investigations on thin films have led to the development of new kind of active devices and passive components, different types of sensors[4], storage of solar energy and conversion to other forms, magnetic memories [5], superconducting films, optical image storing devices, electromechanical device like strain gauge, gas detecting transducer, interference filter, reflecting and anti-reflecting coating and many others [2,3]

II. AN OVERVIEW OF MATERIAL

2.1 Zinc Sulphide and its Importance for Optoelectronic Devices

Zinc sulphide is an inorganic compound with the formula ZnS. It is the main form of zinc in nature, where it mainly occurs as the mineral sphalerite. Although the mineral is black owing to impurities, the pure material is white and is in fact used widely as a pigment.

ZnS exists in two main crystal forms, the more stable cubic form is known as zinc blende or sphalerite. The hexagonal form is known as the mineral wurtzite. Both sphalerite and wurtzite are intrinsic, wide-bandgap semiconductors. The cubic form has a band gap of 3.54 eV at 300 K whereas the hexagonal form has a band gap of 3.91 eV. It can be doped as both N and P type semiconductor.

2.2 Literature Survey

Many workers prepared single crystal as well as polycrystalline ZnS in bulk form and also in thin film form and characterized their structural, electrical, optical properties etc.

M.Y.Nadeem et al (1999) have studied on optical properties of ZnS thin films. Zinc sulfide (ZnS) thin films of different thickness were deposited on Corning 7059 glass substrate at room temperature and high vacuum using resistive heating technique. The film properties investigated include their absorbance / transmittance/ reflectance spectra, band gap, refractive index, extinction coefficient, optical conductivity, complex dielectric constant and thickness. The films were found to exhibit high transmittance

(60-99%), low absorbance and low reflectance in the visible/ near infrared region up to 1100 nm. However, the absorbance of the films was found to be high in the ultra violet region with peak around 360 nm. The thickness (using quartz crystal) of various films ranges from 100 nm to 400 nm. The band gap measured was found to be in the range 3.51 eV to 3.84 eV.

H. Rezagholipour Dizaji et al (2011) have studied on the effect of thickness on the structural and optical properties of ZnS thin films prepared by Flash evaporation technique equipped with modified feeder. From analyzed optical data, it was found that the optical parameters, namely, absorbance, transmittance, band gap energy and refractive index changed upon increasing the thickness of samples.

2.3 Aim and Objectives

The main objectives of the present investigations are,

- Deposition of ZnS thin films by thermal evaporation method with different thickness
- Study the Optical properties such as,
- *Transmittance*
- *Reflectance*
- *Refractive Index*
- *Band gap*

III.EXPERIMENTAL TECHNIQUES AND SAMPLE PREPARATION

3. Introduction

This chapter includes the details of sample preparation, vacuum evaporation techniques; characterization of samples, experimental techniques to study different optical properties has been discussed.

3.1 Physical Vapour Deposition

Physical deposition uses mechanical or thermodynamic means to produce a thin film of solid. The material to be deposited is placed in an energetic, entropic environment, so that particles of material escape its surface. The whole system is kept in a vacuum deposition chamber, to allow the particles to travel as freely as possible. Since particles tend to follow a straight path, films deposited by physical means are commonly directional, rather than conformal.

3.2 Materials used for Preparation

Purity of (97.5%) bulk ZnS in the form of powder procured from M/S Nice Chemical Co., India. Good quality molybdenum boats procured from HINDHIVAC Co (Pvt) Ltd., Bangalore, were used for ZnS evaporation.

3.3 Vacuum Coating Unit

The most important factor in thermal evaporation technique is the high vacuum, which can minimize the interaction between the residual gases and the sensitive surface of growing films.

For preparation of thin films and electrodes a conventional coating unit (Vacuum Coater, Hindhivac 12A4D, and Bangalore) was used (fig 3.3).

3.4 Selection of Substrate

For deposition of thin films of a material suitable supporting material known as Substrate is required.

Fig 3.3 Vacuum Coating Unit (Hindhivac 12A4D)

The surface of the substrate plays a major role in the nucleation and growth process of the film

An ideal substrate should have the following requirements,

(a) The surface should be flat and smooth.

(b) High mechanical strength to enable the substrate to withstand strain during processing and monitoring.

(c) High resistivity & High thermal conductivity.

3.5 Cleaning of Substrates

The substrates should be highly cleaned and uncontaminated for proper adhesion of the films and for producing reproducible film properties. The chemical reagents, such as acids, alcohol or alkalis with proper concentrations remove the contaminants by breaking the bonds between the contaminants molecules as well as between the contaminants and substrate.

3.6 Substrate Heating

The Electrode heater fitted above the substrate holder assembly was used to raise the temperature of the substrate during deposition to any desired value (called substrate temperature).

IV.OPTICAL CHARACTERIZATION

4.1 Introduction

The accurate determination of optical parameters, such as absorption coefficient, refractive index, extinction coefficient and optical band gap etc. help in explaining the structural and compositional characteristic of thin films. The transmittance and reflectance spectra for the films can be taken using UV- visible- near IR double beam spectrophotometer.

4.2 VIS-NIR Spectrophotometer

The optical properties like refractive index, absorbance, transmittance and optical band gap of the prepared thin films were measured using HR 4000CG (Fig.4.1) high resolution dual source VIS-NIR spectrophotometer Ocean Optics, USA having the resolution of 0.27nm.

4.3 Optical Analysis

Fig.4.1 Experimental Arrangement of HR 4000CG High Resolution Spectrophotometer

Reflection is a fundamental optical. Phenomenon, which occurs when light, propagates across a boundary between two media that have different refractive indices. There are two ways to achieve low reflection:

(a) Reduce the difference in refractive
(b) Index between the two media. Since the refractive index is a fundamental characteristic of each material, this approach usually involves the process of producing a graded index in one of the media.
(c) Utilize the interference principles of thin film optics to produce destructive interference of the reflected light at the upper and the lower interfaces of the thin film.

4.4 Reflection

Reflectance spectroscopy is the study of light as a function of wavelength that has been reflected or scattered from a solid, liquid, or gas. As photons enter a mineral, some are reflected from grain surfaces, some pass through the grain, and some are absorbed. Those photons that are reflected from grain surfaces or refracted through a particle are said to be scattered. Scattered photons may encounter another grain or be scattered away from the surface so they may be detected and measured.

4.5 Transmission

Transmission spectroscopy is highly interrelated to Absorption Spectroscopy. This technique can be used for solid, liquid, and gas sampling. Here, light is passed through the sample and compared to light that has not. The resulting spectrum depends on the path length or sample thickness, the absorption coefficient of the sample, the reflectivity of the sample, the angle of incidence, the polarization of the incident radiation. In the Beer Lambert Law the term I_T/I_o is called transmittance. This form of spectroscopy has a setup similar to the one used for absorption.

4.6 Band Gap

In solid state physics, a band gap, also called an energy gap or band gap, is an energy range in a solid where no electron states can exist. In graphs of the electronic band structure of solids, the band gap generally refers to the energy difference (in eV) between the top of the valence band and the bottom of the conduction band in insulators and semiconductors. This is equivalent to the energy required to free an outer shell electron from its orbit about the nucleus to become a mobile charge carrier, able to move freely within the solid material. So the band gap is a major factor determining the electrical conductivity of a solid. Reflection is a fundamental optical

V.RESULTS AND DISCUSSION

5.1 Introduction

The ZnS thin film samples of thickness 100nm, 200nm, and 300nm & 400nm has prepared by the resistive heat evaporation technique were characterized by using characterization technique as described in the previous chapter. The result of optical studies carried out under room temperature condition using VIS-NIR Spectroscopy is present in this chapter.

5.2 Transmittance

The ZnS film deposited on glass substrate was characterized for its transmittance properties.

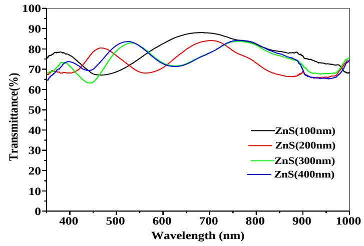
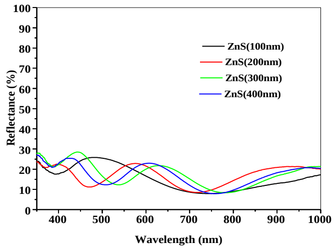


Fig 5.1 Transmittance Vs Wavelength

(a) The *fig.5.1* shows the transmittance spectra of the ZnS films with different thickness obtained at room temperature. It is noted that the interference pattern shift towards shorter wavelength. The transmittance decreases with increase in film thickness.

(b) 5.2 Reflectance

(c) The reflectance of ZnS thin film is small in the near infrared and visible region. The overall reflectance of the film increases with the film thickness.The films have minimum reflectance and maximum transmittance in visible wavelengths and can be used as good optical thin films.



5.2 Reflectance Vs wavelength

5.3 Refractive Index

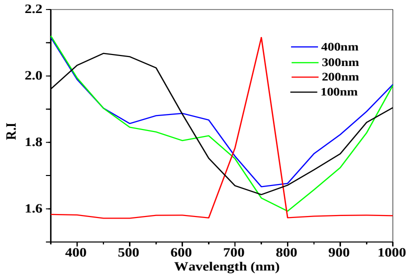


Fig 5.3 Refractive Index Vs Wavelength

The above figure shows the graph of Refractive Index (RI) versus Wavelength of ZnS film on glass substrate by envelope technique. From this graph it is evident that the refractive index of the thin films film has a slight decrease as the wavelength increases for all thickness.

5.4. Band Gap

It shows optical absorbance graphs for ZnS samples prepared at different thicknesses.

It can be observed that energy gap increases with increase in the thickness. The direct band gap approaches its bulk value with increase in thickness.

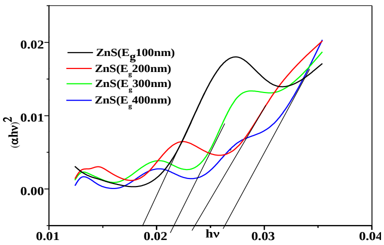


Fig 5.3 $(Ah\upsilon)^2$ Vs hυ

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VI. CONCLUSIONS

Based on the results presented, the following conclusions can be drawn. Uniform, optically smooth and homogeneous films of ZnS thin films have been obtained by thermal evaporation method. It is found that all the films deposited on glass substrates were highly transparent. There has been an decrease in transmittance with increase in thickness. This fact is probably due to the increase in crystallite size and increase of absorption. The optical spectral transmittance studies indicate that these films could be used for good optical coating applications. The refractive index of ZnS is in between 1.76 and 2.33 for the samples of thickness

100 to 400nm respectively. Finally the observed energy gap for different thickness indicates that band gap increases with increase in the thickness.

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