Optical and structural properties of CdS thick film

D Patidar, S Kumar*, R Sharma, N S Saxena, Kananbala Sharma & T P Sharma
Semiconductor and Polymer Science Laboratory, 5-6, Vigyan Bhawan, Department of Physics,
University of Rajasthan, Jaipur 302 004, Rajasthan
*Department of Physics, CCS University, Meerut 250 004
Received 4 October 2005; revised 19 April 2006; accepted 3 August 2006

Cadmium sulphide film has been prepared in open-air atmosphere by sintering technique using ZnCl₂ as an adhesive source and glycol as a binder. The reflection spectra of covered sintered film of CdS are recorded by a spectrophotometer at room temperature in the wavelength range 300-700 nm. From reflection spectra, energy band gap has been determined. It is found that energy band gap of this film is 2.57 eV, which is the energy band gap of Cd₀.₈Zn₀.₂S. This is suggestive of the fact that Cd₀.₈Zn₀.₂S is a wide band gap semiconducting material. X-ray diffraction patterns also confirm the formation of Cd₀.₈Zn₀.₂S.

Keywords: Sintering technique, Reflection spectra, Energy band gap
IPC Code: B82B

1 Introduction
CdS is an important II-VI group compound semiconductor material. CdS films are regarded as one of the most promising materials for heterojunction thin film solar cells. Wide band gap CdS has been used as the window material together with several semiconductors such as Cu₂S/CdS (Ref. 1) and CdS/CuInSe₂ (Ref. 2). However, due to the high cost of such a material, studies were developed towards polycrystalline semiconductor and particularly thin polycrystalline films. There are many different techniques for depositing the films. Chemical bath deposition³, vacuum evaporation⁴, spray pyrolysis⁵ and screen-printing with sintering⁶ are well known and widely used techniques for the preparation of the films. Generally, in each of these methods, polycrystalline, stable, uniform, adherent and hard films are obtained. Screen-printing technique is an inexpensive and convenient technique for large area preparation of the films. This technique is suitable for coating surfaces of any morphology and geometry. In particular, screen-printing is low cost and relatively simple technique for achieving good quality thick films.

Extensive research has been done on deposition and characterization of CdS semi-conducting thin films due to their potential application in the area of electronic device fabrication. CdS films attracted much interest because of their preferred properties of intermediate band gap⁷.

The optical and structural properties of thick film of chemically precipitated CdS prepared by ZnCl₂ as adhesive source using the screen-printing technique and sintered at 400°C for ten minutes have been investigated in the present paper.

2 Experimental Details
In the present work, the sample has been prepared by the chemical method using Cd, HCl and H₂S. Cadmium metal was completely dissolved in the HCl solution. Then H₂S gas was passed through this solution. The reaction for precipitation in this process is given below.

\[ \text{Cd} + 2 \text{HCl} \rightarrow \text{CdCl}_2 + \text{H}_2 \]

\[ \text{CdCl}_2 + \text{H}_2\text{S} \rightarrow \text{CdS} + 2 \text{HCl} \]

The yellow precipitate obtained in the process was filtered. This composite was then dried in an oven at 50°C for 30 min. When the precipitate was completely dried, it was then crushed to a fine powder by the grinding process. Cadmium sulphide (CdS) films have been prepared by the sintering technique. In an appropriate amount of cadmium sulphide, zinc chloride was added as an adhesive and ethylene

Indian Journal of Pure & Applied Physics
Vol. 44, October 2006, pp. 729-731
glycol as the binder. ZnCl₂ was added in different ratio of CdS. After thoroughly mixing CdS and ZnCl₂ a few drops of ethylene glycol were added to form the paste. The paste thus prepared was screen printed on glass substrates, which were cleaned by acetone and distilled water.

The films thus prepared were dried at 100°C for two hours in open air. The reason of drying the sample at a lower temperature was to avoid the cracks in the samples. After this, the film was covered by a glass substrate. The film was then sintered at 400°C for ten minutes in the open-air atmosphere. The melting point of CdCl₂ is 283°C. To obtain a stable sintered film, organic material and zinc chloride should not remain in the sample. As the removal of organic substance takes place at about 400°C, the sintering temperature cannot be less than 400°C.

The optical behaviour of covered sintered film of cadmium sulphide prepared by ZnCl₂ (as adhesive source) was studied using Hitachi spectrophotometer model U-3400. The crystallographic structure of the film was analyzed with a Philips PW-1729 X-ray diffractometer using the discrete Fe Kα line.

3 Results and Discussion

3.1 Optical characterization

The screen-printed and dried film of chemically precipitated CdS, prepared by ZnCl₂ as the adhesive source was sintered at the higher temperature for the chemical reaction to take place for the possible formation of CdZnS. The reflection spectra of this film was taken by Hitachi spectrophotometer model U-3400 at room temperature in the wavelength region 300-700 nm. Almost all the II-VI compounds are direct band gap semiconductors. According to the Tauc relation, the absorption coefficient for a direct band gap material is given by:

\[ \alpha h \nu = A (h \nu - E_g)^{1/2} \]  \hspace{1cm} \ldots(1)

where \( \alpha h \nu \) is the photon energy, \( E_g \) the band gap and \( A \) is constant which is different for different transitions. The absorption coefficient \( \alpha \) may be written in terms of reflectance as:

\[ 2\alpha t = \ln[(R_{max} - R_{min})/(R - R_{min})] \]  \hspace{1cm} \ldots(2)

where \( t \) is the thickness of the sample and \( R \) is the reflectance for any intermediate photon energy. The reflectance falls from \( R_{max} \) to \( R_{min} \) due to the absorption of light by the material.

When we plot a graph between \((\alpha h \nu)^2\) (as ordinate) versus \( h \nu \) (as abscissa), a straight line is obtained. The extrapolation of straight line to \((\alpha h \nu)^2 = 0\) axis gives the value of the energy band gap of the film material.

Figure 1 represents the reflection spectra of covered sintered films of chemically precipitated CdS. In Fig. 2, a graph is plotted between \((\alpha h \nu)^2\) and \( h \nu \), for determination of the energy band gap of this film, which comes out to be 2.57 eV. This value of energy band gap is in good agreement with the value of Cd₀.₅Zn₀.₅S composition reported by other researchers. It is also confirmed from the X-ray diffraction pattern.
3.2 Structural characterization

The X-ray diffraction pattern of CdS film prepared with ZnCl₂ is shown in Fig. 3. The d-values are calculated from the relation \( d = \frac{\lambda}{2 \sin \theta} \), where \( n = 1 \) and \( \lambda = 1.937355 \text{Å} \) by taking \( \theta \) values from the peaks of the X-ray diffraction pattern (XRD). These d-values are compared with the standard ASTM data (\( d^* \)) for the confirmation of the structure of the film. It is observed that most of the calculated d-values are the same as d-values (\( d^* \), ASTM) of Cd₀.₈Zn₀.₂S using Vegard's law (Table 1).

4 Conclusions

Structural and optical properties of thick film of chemically precipitated CdS prepared by ZnCl₂ have been investigated. It is concluded from both studies that CdZnS can be prepared by screen-printing technique using the different ratios of CdS and ZnCl₂. It is a desired band gap material having the intermediate band gap between CdS and ZnS, suitable as window material for solar cells.

Acknowledgement

One of us (Dinesh Patidar) is thankful to DRDO, New Delhi (India) for providing junior research scholarship. Authors are also thankful to Mr Neeraj Jain, Mr Vibhav Kumar Saraswat and Mr Vimal Kishore for their help in various ways.

References