SPECTROSCOPIC STUDIES ON LEAD SELENIDE (PbSe) AND TIN SELENIDE (SnSe) THIN FILMS

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Semiconducting thin films of lead selenide (PbSe) and tin selenide (SnSe) were deposited on glass substrate at 300K using the chemical bath deposition (CBD) method. Chemical deposition of thin films of PbSe and SnSe from solution containing Pb²⁺, Sn²⁺ and selenium sulphite is presented. The optical properties of the films were studied using a spectrophotometer in the wavelength range of 0.36µm-1.10µm. Optical properties of the films comparatively studied include: the absorbance, reflectance, transmittance, refractive index and extinction coefficient.

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1. Introduction

Lead selenide and tin selenide are amongst group IV–VI semiconductor compounds which have attracted growing interest due to their important unique properties in optoelectronic devices such as infrared production and detection (1). They are considered as very important technological semiconductor having potential solar cell material (2-3). PbSe is used as a target material in infrared sensor, grazing, lenses and various opto-electronic devices (4). PbSe is an important material for application in photographic plates and photo resistors (5-7). SnSe is a narrow band gap binary IV-VI semiconductor displaying variety of applications in photo electrochemical solar cells to enhance the fill factor in electrical switches and in junction devices (8).

Chemical bath deposition (CBD) is found to be very good and low cost method to fabricate the high quality compound semiconductor metallic and non-metallic substrates (9-10). The method is well studied and produces films that have comparable structural and opto-electronic properties to those produced using other sophisticated thin film deposition techniques (11). The technique has been applied in producing emerging materials for solar cells, protective coating, and solar thermal controls in buildings and is being adopted by some industries (12). Chemical bath technique is based on slow controlled precipitation of the desired compound from its ions in a reaction bath solution. A complexing agent is employed in other to avoid spontaneous reaction and sedimentation of materials. This paper deals with the optical and morphological studies of PbSe and SnSe films prepared from chemical bath deposition technique.

2. Materials and method

PbSe and SnSe films are synthesized using chemical bath deposition onto glass substrate at room temperature. The deposition of PbSe film was based on the reaction between lead nitrate (Pb(NO₃)₂) and K₂SeO₄ using TEA as complexing agent and ammonia was used to vary the pH of the reaction bath as well as to provide an alkaline medium needed for the maximum growth. On
the other hand, the baths for the deposition of SnSe were constituted with 0.2M solution of tin chloride (SnCl₂), 0.5M solution of potassium selenite (K₂SeO₄), 0.1M solution of EDTA used as complexing agent and 25% ammonia (aqueous as supplied) as pH adjuster.

In each case, both films were deposited on commercial glass slides (76mm x 26mm x 1mm) which was previously degreased, washed in detergent and rinsed in distilled water and dried in air. Measurements for the analysis of the optical and our morphological properties of the film were made using a Janway 6105 model of spectrophotometer.

From the spectrophotometer, the absorbance in arbitrary unit was measured. Optical properties such as absorbance, reflectance, transmittance, refractive index and extinction coefficient were then calculated. Film thickness was calculated using optical method by (13).

3. Results and discussion

It is observed in figure 1 that the transmittance of the films is as high as 85-95% in visible & infrared regions. Both of them have peak transmittance in infrared region but the transmittance of PbSe film is not as high as that of SnSe. The wide transmission range (0.4µm – 1.10µm) revealed in the figure makes the materials useful in manufacturing optical components, windows, mirrors, lenses etc for high power IR laser (14).

![Fig. 1 Spectral transmittance of PbSe & SnSe](image)

The transmittance of PbSe increases sharply from UV to the peak value (65%) in infrared region and can be as high as 40% in UV region.

Absorbance of both films is high UV region and in visible and IR regions as shown in figure 2. Generally, the absorbance of SnSe is very low as low as 0.11 in all the regions of the spectrum. Absorbance of PbSe decrease sharply from ultraviolet region to infrared region.

![Fig. 2 Spectral Absorbance of PbSe & SnSe](image)
1. The peak absorbance for PbSe films in ultraviolet region is about 0.32 and can be as low as 0.12 in infrared regions. These optical characteristics match the ideal solar control characteristics.

Fig. 3 shows the reflectance of PbSe and SnSe. The reflectance of the films is generally low, but that of the PbSe can be as high as 20% in ultraviolet region. This property makes the film suitable as anti-reflection coatings.

The refractive index (n) of the films is related to their reflectance (R) by

\[ R = \frac{(n - 1)^2}{(n + 1)^2} \] or

\[ n = \frac{(1 + R^{1/2})}{(1 - R^{1/2})} \]

The refractive indexes fall to a minimum from UV to infrared regions. The refractive indexes of the films were found to vary from 2.3 to 2.7. The graphs of refractive indices (n) as a function of wavelength (λ) are shown in figure 3. The refractive index of both films is high in ultraviolet region and low in infrared region of the electromagnetic region.

The range of values obtained for extinction coefficient (k) of PbSe and SnSe films were found to vary from 12 – 25. The graph of K as a function of wavelength is shown in figure 5.
The extinction coefficient of the films falls to a minimum from UV to visible and rises a little to NIR and falls again to infrared region. This shows that the films have the least absorption in visible and infrared regions and very high absorption in UV region.

The high absorbance in UV region makes the material useful in formation of p-n junction solar cells with other suitable thin film materials for photo voltaic application. These optical properties make PbSe and SnSe thin films nice glazing material for maintaining cool interior in buildings in warm climate regions while still keeping the rooms well illuminated. To ensure that the thermal radiation from the warm glazing to the interior is inhibited and the thermal energy dissipated in the glazing due to absorption is predominantly transferred to the exterior by enhanced convective heat transfer of the glazing to the exterior. It was suggested in (15) that reflectance in the spectral region should be strengthened while encouraging low thermal emittance.

Fig. 6  X-ray diffraction pattern of SnSe

Fig. 6 – 7 shows the x-ray diffraction patterns of SnSe and PbSe thin films. The XRD pattern of SnSe reveals the existence of (201), (011), (111) and (221) planes of reflections of orthorhombic phase. These are in good agreement with the reported values by (16) using chemical precipitation and vacuum evaporation technique and (17) using CBD technique.

That of PbSe film shows the existence of (111), (200) and (220) planes of reflections of cubic structure which compares very well with the reported values by (18) using vacuum evaporation technique and (19) using CBD technique.
4. Conclusion

PbSe and SnSe thin films have been prepared by chemical bath deposition technique. The films have peak transmittance in infrared region of the electromagnetic spectrum and high rate of absorption in the UV and NIR regions. The reflectance is low in all the regions of the electromagnetic spectrum. These make the films excellent glazing material for solar control in warm climatic regions.

References