Crystalline Indium Sulphide thin film by photo accelerated deposition technique

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Abstract. Indium sulfide thin films deserve special attention because of its potential application as buffer layers in CIGS based solar cells. Highly transparent indium sulfide (InS) thin films were prepared using a novel method called photo accelerated chemical deposition (PCD). Ultraviolet source of 150 W was used to irradiate the solution. Compared to all other chemical methods, PCD scores its advantage for its low cost, flexible substrate and capable of large area of deposition. Reports on deposition of high quality InS thin films at room temperature are very rare in literature. The precursor solution was initially heated to 90°C for ten minutes and then deposition was carried out at room temperature for two hours. The appearance of the film changed from lemon yellow to bright yellow as the deposition time increased. The sample was characterized for its structural and optical properties. XRD profile showed the polycrystalline behavior of the film with mixed phases having crystallite size of 17 nm. The surface morphology of the films exhibited uniformly distributed honey comb like structures. The film appeared to be smooth and the value of extinction coefficient was negligible. Optical measurements showed that the film has more than 80% transmission in the visible region. The direct band gap energy was 2.47eV. This method is highly suitable for the synthesis of crystalline and transparent indium sulfide thin films and can be used for various photovoltaic applications.

1. Introduction
Indium sulphide is a gifted contender for many technological applications in optoelectronic and photovoltaic field [1,2] due to its stability, wider band gap and photo conducting behaviour [3] and a good non toxic substitute for CdS in Copper Indium Gallium Sulphide (CIGS) based solar cells. Teny Therasa John et al deposited indium sulphide thin films using spray pyrolisis technique with different In/S ratios and the characterization showed that in terms of crystalline behaviour, band gap and photo response the samples with In/S ratio of 1.2/8 is very suitable for any photovoltaic application [4]. Amorphous indium sulphide films were synthesized on FTO coated glass substrate and explored the formation of In2O3/In2S3 multilayer film electrode and its use in photo-electro chemical cell [5]. Photo chemical deposition (PCD) became great successful in depositing semiconductor thin films from aqueous solutions [6-9]. For economic reasons, it should be very interesting if thin films can be deposited using a cheap deposition technique. Nearly stoichiometric CuInS films were deposited in acidic medium for the first time by photo chemical deposition technique [10] and it was observed that, the longer irradiation of CuSO4 solution enhances the Cu content of the films.

2. Experimental details
2.1. **Photo accelerated chemical deposition.** UV light source of 150W was used to irradiate the solution. The energy from the light source has been utilized to increase the kinetic energy and hence the inter diffusion of the adsorbing atoms. Since the substrate was kept vertically very near to the UV source, only a small part of energy gets diffused into the solution. The direct entry of UV rays on to the substrate causes an amplified vibration among the molecules of the glass substrate. These augmented vibrations support the adherence of the incoming atoms, and develops the crystalline behaviour.

The precursor solution was initially heated to 90°C for ten minutes and then deposition was carried out at room temperature for two hours. Films were deposited through double dips, each with one hour duration. All the chemicals used were of analytical grade and the chemical bath contained 0.025M indium chloride, 0.3M thioacetamide and 1drop glacial acetic acid. Glacial acetic acid acts as complex agent which allows slow release of cations. Well cleaned soda lime glass substrates were used to deposit the film. It was kept in detergent solution for many hours and boiled in chromic acid solution for days. A subsection

3. **Results and discussion**

The film was highly adhered to the substrate and appeared as lemon yellow to bright yellow as the deposition time improves. The thickness of the film using gravimetric technique was 215nm.

3.1. **Structural properties.** The structural aspects of the samples were studied using an X-ray diffractometer (Bruker AXS D8) with Cu- Kα radiation of wavelength 1.5405Å as the source. Figure.1 displays the XRD pattern of the film with mixed phases. The d value of monoclinic structure coincides with the orientations of (130) and (110). (332) and (220) corresponds to cubic structure of indium sulphide in accordance with the standard JCPDS data card [80-0126, 73-0844]. The average grain size from Debye Scherrer’s formula was 17nm.

Figure.2 shows the scanning electron microscopic images of the film, a large number of aggregates and discrete nano particles just like a honeycomb structure. The morphology shows that it can be sensitized with dyes for many other applications.

![Figure.1.XRD pattern of the Indium sulphide film](image-url)
3.2. **Optical properties.** The optical properties like absorption and transmission spectra were taken using a Varian Carry 5000 UV-Vis-NIR spectrophotometer in the range 200-2000nm. Fig. 3 displays absorbance and a transmission spectrum of the indium sulphide films deposited by double dips, each of one hour in freshly prepared chemical baths. The samples exhibit more than 80% optical transmission in the visible region and attain 88% at the wavelength about 300nm, which is noticeably better than previous reports. High transparency in the visible region indicates the absence of adsorbed powdery colloids formed by homogeneous reaction during the growth of the film. A sharp absorption edge is observed in the visible region, signifying good crystallinity and low defect density close to the band edge [11]. Band gap energy calculated from the band edge was 2.47eV.

![Figure 3: Absorbance and transmittance spectra of the Indium sulphide film](image)

Extinction coefficient ($k$) measures the rate of diminution of transmitted light through scattering and absorption for a medium and it was calculated from the absorption coefficient by using, $k=\alpha/4\pi$. The film appeared to be smooth and the value of extinction coefficient was negligible.
Figure. 4 extinction coefficient of the films as a function of wavelength

4. Conclusion

Crystalline indium sulphide thin films were prepared using photo accelerated deposition technique. Surface morphology of the films appeared to be of honey comb like and is useful in the fabrication of dye sensitized solar cell. Uniform transmission in the visible region signifies its application as window layer in solar cells. Hence this method is highly suitable for the synthesis of crystalline and transparent indium sulfide thin films which can be used for various photo voltaic applications.

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