



# Engineering the structural and photoluminescence properties of $\beta$ - $\text{In}_2\text{S}_3$ nanopowders for luminescence application

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## ABSTRACT

Indium sulfide ( $\beta$ - $\text{In}_2\text{S}_3$ ) nanopowders with tetragonal structure were synthesized by a cost effective chemical route at a low temperature using acetic acid as a complexing agent. Effect of acetic acid concentration on the structural, optical and photoluminescence properties of the synthesized  $\text{In}_2\text{S}_3$  nanopowders were analyzed by powder X-ray diffraction, UV-Vis-NIR and photoluminescence spectroscopy at room temperature. Tunable luminescence intensity without affecting the wavelength was observed by tuning the acetic acid concentration. The optimized results on the structural, optical absorption and photoluminescence properties are presented and elaborated in the present work.

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## Introduction

Luminescent materials or phosphor materials can be found in a vast range of everyday applications such as cathode ray tubes (CRT), projection television displays, X-ray detectors, fluorescent tubes, and biomedical probes. Efforts over the last three decades have led to high luminous materials that operate close to their physical limits [1]. Effect of quantum confinement on the nano scale luminous materials may offer significant improvements in device application compared with conventional bulk phosphors [2]. Indium sulphide ( $\text{In}_2\text{S}_3$ ) nanomaterial has attracted research interest due to their potential use in the optoelectronic device manufacturing. Depending on the preparation method and preparation condition the  $\text{In}_2\text{S}_3$  nanomaterial have wide band gap tunable from 2.0 eV to 3.7 eV and having a high transmittance in the visible part of the spectrum. Therefore  $\text{In}_2\text{S}_3$  have been used as buffer layer in solar cell structures.  $\text{In}_2\text{S}_3$  also been used as an absorber layer in nano structured solar cells.  $\text{In}_2\text{S}_3$  thin films are relatively non-toxic and can be prepared by many physical as well as chemical methods. Wei Han et al. have reported recently on the synthesis and Shape-Tailoring of Copper Sulfide/Indium Sulfide-Based Nanocrystals [3].  $\text{In}_2\text{S}_3$  presents both direct and indirect conduction- to-valance transitions which leads to exist both direct and indirect band gap nature. The Indium defects inherent in  $\text{In}_2\text{S}_3$  nanomaterial allows it to serve as a host for metal ions in forming semiconducting materials with magnetic properties [4-8]. In the present work the  $\text{In}_2\text{S}_3$  nanopowders were synthesized at identical experimental conditions except the complexing agent concentration. Effects of the complexing agent concentration on the structural, optical absorption and photoluminescence emission properties were realized and the optimized results are presented and discussed.

## Experimental

The following figure (1) shows the complete outline of the experimental and synthesis procedure of  $\beta$ - $\text{In}_2\text{S}_3$  nanopowders with various complexing agent concentrations.

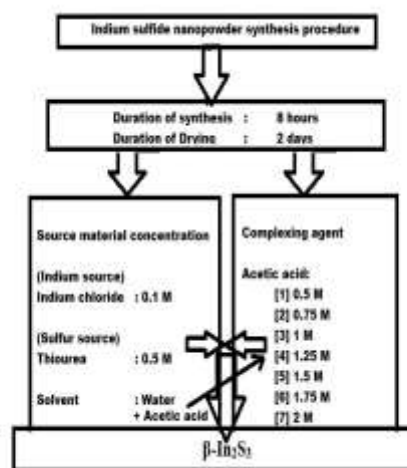


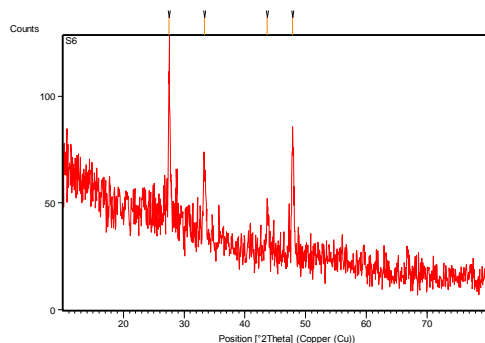
Figure 1 The experimental and synthesis procedure of  $\beta$ - $\text{In}_2\text{S}_3$  nanopowders

## Results and discussion

### Structural Properties

$\beta$ - $\text{In}_2\text{S}_3$  nanopowders were synthesized by a cost effective chemical route and effect of acetic acid concentration (complexing agent) on the structural properties of the synthesized powders were investigated by powder X-ray diffraction (XRD) analysis with minimum scan steps of  $0.001^\circ$  per minute. The wavelength of the X-ray source utilized for XRD measurement was Cu-K $\alpha$ : 1.5406 Å. Compared to all other complexing agent concentration on the synthesized  $\text{In}_2\text{S}_3$

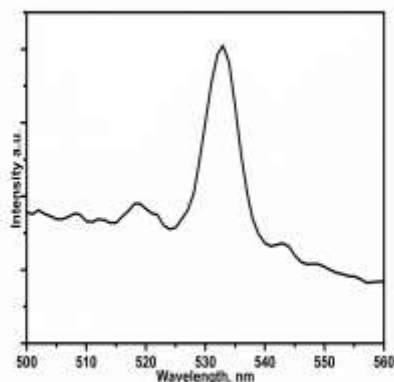
nanopowder the good crystallinity was observed at the acetic acid concentration of 1.75 M. The following figure (3) shows the X-ray diffraction pattern of the synthesized  $\text{In}_2\text{S}_3$  nanopowder at the above said complexing agent concentration of 1.75 M. The maximum intensity peak at  $2\theta = 27.53^\circ$  was due to the diffraction from the (109) plane and was in good matched with the reported JCPDS card 25-390. The other peaks such as  $2\theta = 33.3, 43.7$  and  $47.85^\circ$  were due to the X-ray diffraction from the (220), (323) and (400) planes respectively. All the observed peaks of the synthesized  $\beta\text{-In}_2\text{S}_3$  nanopowder reflect the tetragonal crystal structure arrangement. The particle size was calculated from the scherrers formula and the calculated particle size from the maximum intensity XRD peak centered at  $2\theta = 27.53^\circ$  was found to be  $\sim 30$  nm.



**Figure 2 The X-ray diffraction pattern of the synthesized  $\text{In}_2\text{S}_3$  nanopowder at the complexing agent concentration of 1.75 M.**

#### Photoluminescence properties

The photoluminescence (PL) analysis was carried out for the all the synthesized  $\text{In}_2\text{S}_3$  nanopowder at the excitation wavelength of 330 nm, 360 nm, 385 nm and 390 nm respectively to investigate the defect state emission, near band edge emission, band to band transition and higher energy band transition. The  $\text{In}_2\text{S}_3$  nanopowder optimized from X-ray diffraction analysis i.e., the sample prepared at the complexing agent concentration of 1.75 M shows intense PL emission properties at an excitation wavelength of 390 nm.



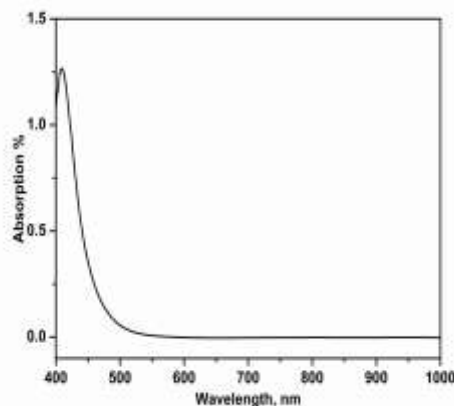
**Figure 3 Photoluminescence of synthesized  $\text{In}_2\text{S}_3$  nanopowder at the complexing agent concentration of 1.75 M.**

Figure 3 shows the PL properties of the  $\text{In}_2\text{S}_3$  nanopowder synthesized at the acetic acid concentration of 1.75 M. The PL properties are also mainly depends on the structural quality of the sample. The width of the PL emission peak is around 9 nm which shows the sharp emission property which also resembles the very less defect state emission and the emission probably

due to the band to band transition. Our observed PL result of the above said concentration retrieving the crystalline quality of the prepared  $\text{In}_2\text{S}_3$  nanopowder and is in good agreement with the observed XRD pattern.

#### UV-Vis-NIR spectroscopy

The optical absorption spectrum of the  $\text{In}_2\text{S}_3$  nanopowder at optimized acetic acid concentration was investigated in the wavelength range of 300 to 1000 nm.



**Figure 4 UV-Vis-NIR Spectrum of  $\text{In}_2\text{S}_3$  nanopowder with the complexing agent concentration 1.75 M**

The optical absorption edge of the grown  $\text{In}_2\text{S}_3$  nanopowder was 483 nm and the calculated band gap was around 2.57 eV and the PL emission band centered at 532 nm and the calculated energy was around 2.33 eV. The observed two energy gap values are in line and the emission energy was 0.24 eV lower than that of the calculated band gap from UV-Vis-NIR spectrum.

#### Conclusions

Indium sulfide nanopowders were synthesized by a cost effective chemical route and the grown sample having  $\beta$  phase ( $\beta\text{-In}_2\text{S}_3$ ) with tetragonal crystal structure which was found from the XRD peak matching with JCPDS card and reported literatures. The crystalline quality of the synthesized  $\beta\text{-In}_2\text{S}_3$  was investigated by XRD and the better crystallinity was observed at the acetic acid concentration of 1.75 M. The calculated particle size is about 30 nm which evidences the  $\beta\text{-In}_2\text{S}_3$  compound formation in nanoscale level. The sharp PL emissions with band width 9 nm shows the band to band emission and very less defect energy state emission occur from our synthesized  $\beta\text{-In}_2\text{S}_3$  nanopowder. The calculated band gap from the UV-Vis-NIR spectroscopy was around 2.57 eV. The observed PL emission property of the synthesized  $\beta\text{-In}_2\text{S}_3$  compound leads to the applicability of luminescence devices.

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