# Preparation of silver Indium sulfide nanorods by a facile Microwave approach

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## Abstract

In this work, $AgInS_2$ (AIS) semiconductor nanorods were synthesized by an efficient and facile microwave heating technique using silver nitrate as silver source, Indium (III) chloride tetrahydrate as Indium source and thiourea as sulfur sources. The reaction was performed using ethylene glycol (EG) as solvent and SDS as surfactant under microwave irradiation with the power of 600 W for 7 min.The product was characterized by X-ray powder diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), Energy Dispersive X-ray analyze (EDX)and Transmission electron microscopy (TEM).

**Keywords:** Microwave; Nanorods; Thiourea; $AgInS_2$

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## Introduction

The ternary semiconductor nanomaterials with the general formula of $XY_mZ_n$(X = Cu, Ag, Zn, Cd; Y = Ga, In; Z = S, Se, Te; m, n = integer) have got much attention due to considerable physical and chemical properties[1,2]. Due to considerable physical and chemical properties[3],these compounds are employed in various fields such as solar cells [4, 5], photocatalysis [6], non-linear optical switch, lasers [7, 8] and photovoltaic and optoelectronic devices [9]. $AgInS_2$ can be crystallized in two different phases known as tetragonal (chalcopyrite) and orthorhombic structures. Chalcopyrite and orthorhombic phases have the direct band gap energy in the range of 1.86-2.04 eV [9, 10]. Mentioned band gap energy values for each of the phases are more than the optimal energy for absorber material (1.45eV) in solar cell. Therefore $AgInS_2$ can be nominated as an appropriate absorber in the shorter wavelength to apply in the solar cell films [11-12].

In recent years, several methods are used to prepare $AgInS_2$ nanorods[13-16,6,17-18]. As an outstanding method, microwave irradiation process is a facile way to produce nanomaterials at the short time with less secondary impurities. In recent years, the use of microwave approach to prepare nanomaterials has increased because the reaction conditions and particles growth can be easily managed by microwave route [1, 18-19]. There are very few reports about the using microwave to synthesis of AIS [7].

Here in, we report the synthesis of $AgInS_2$ nanorods by utilizing microwave heating technique.

## Results and discution

### *3.1. The structural characterization*

Fig. 1 indicates X-ray diffraction pattern of the synthesized AIS nanorods using microwave heating technique. This pattern confirms the formation of orthorhombic phase of $AgInS_2$ (JCPDS

No. 25-1328). The diffraction peaks at 2θ values of 24.993°, 25.428°, 26.578°, 28.383°, 28.757°, 36.806°, 37.121°, 43.694°, 44.53°, 48.050°, 48.267°, and 52.618° matching with the 120, 200, 002, 121, 201, 122, 202, 040, 320, 123, 203 and 322 planes of orthorhombic AIS phase belong to the prepared sample. This pattern reveals a good crystallinity of AIS and no other peaks related to the impurities were detected.

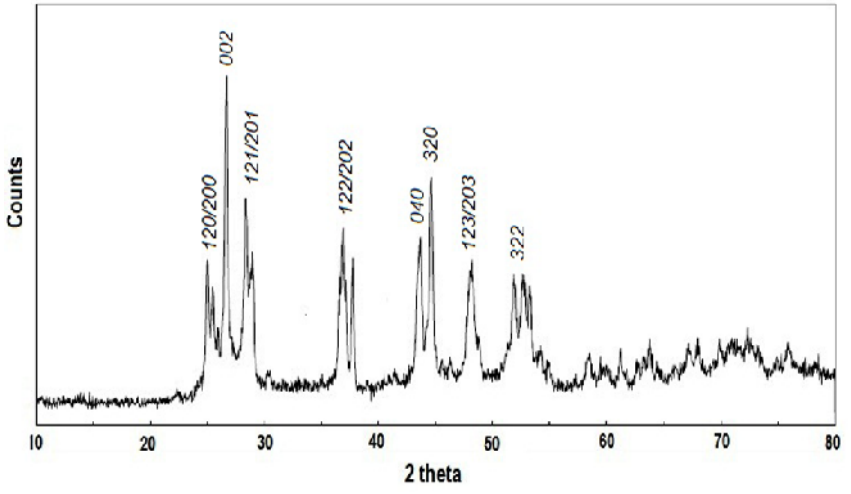


**Fig. 1.** XRD pattern of obtained $AgInS_2$ nanorods.

There are no peaks in the FT-IR spectrum of the product, which proves the formation of pure AIS phase (Fig. 2).

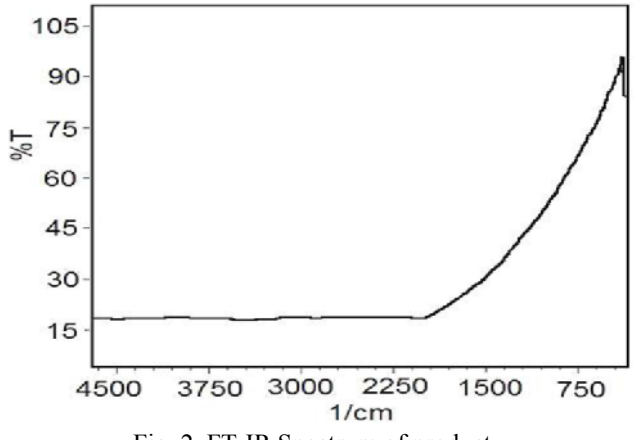


Fig. 2. FT-IR Spectrum of product

Fig. 3 shows the typical EDX pattern of the $AgInS_2$ nanorods. The result showed that the sample was composed of only silver, indium, and sulfur elements. The ratio of Ag:In:S is close to 1.04:1:1.92, which is obviously inconsistent with the stoichiometric of AIS.

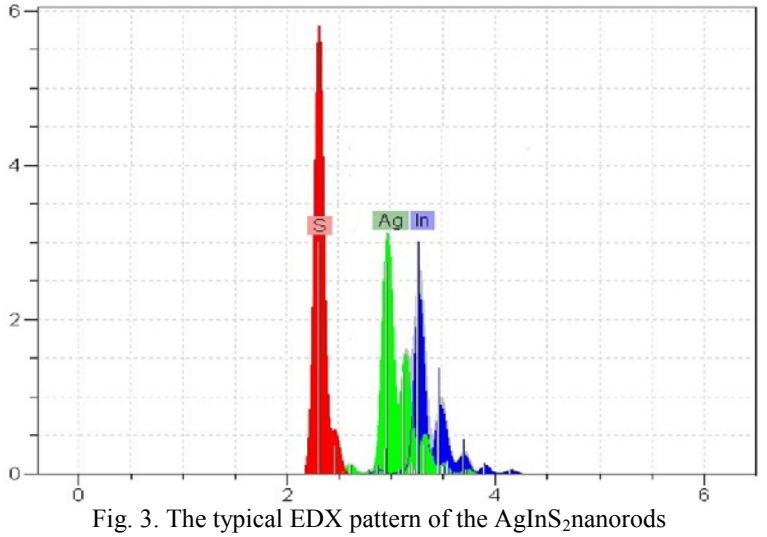


Fig. 3. The typical EDX pattern of the $AgInS_2$nanorods

Fig. 4 indicates the TEM images of the AIS nanorods, which have been synthesized using microwave approch. These images clearly show the uniform morphology of rod with the size of 25-50 nm.

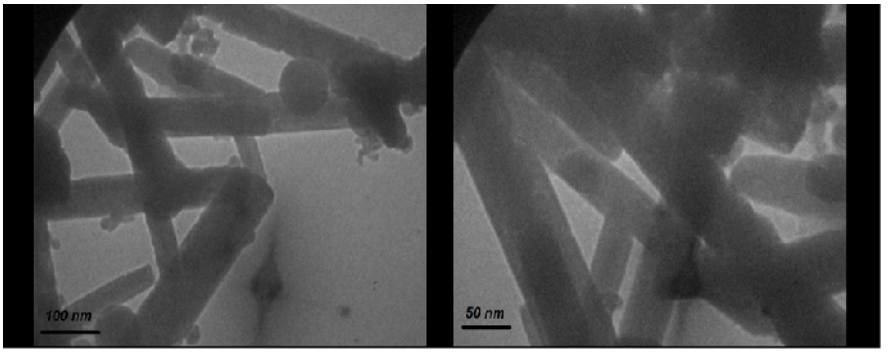


Fig. 4. TEM images of the $AgInS_2$nanorods

## 4. Conclusions

In a summary, $AgInS_2$ nanorods successfully were prepared using a novel, fast and facile microwave heating technique and by employing $AgNO_3$, $InCl_3.4H_2O$ and thiourea as the starting materials. Ethylene glycol and SDS were used as solvent and surfactant, respectively. The reaction was performed under microwave irradiation with the power of 600 W for 7 min. The product was characterized by means of XRD, FT-IR, EDX and TEM. The XRD analysis revealed that a pure orthorhombic phase of $AgInS_2$ was synthesized. TEM images confirmed the rod morphology with the size of 25-50 nm for the product.


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## References


[1] J.S. Gardner, E. Shurdha, C. Wang, L.D. Lau, R.G. Rodriguez, J.J. Pak, Rapid synthesis and size control of $CuInS_2$ semi-conductor nanoparticles using microwave irradiation, J. Nanopart. Res., 10 (2008) 633-641.

[2] M. Ortega-López, O. Vigil-Galán, F.C. Gandarilla, O. Solorza-Feria, Preparation of $AgInS_2$ chalcopyrite thin films by chemical spray pyrolysis, Mater. Res. Bull., 38 (2003) 55-61.

[3] Y. Akaki, S. Kurihara, M. Shirahama, K. Tsurugida, S. Seto, T. Kakeno, K. Yoshino, Structural, electrical and optical properties of $AgInS_2$ thin films grown by thermal evaporation method, J. Phys. Chem. Solid, 66 (2005) 1858-1861.

[4] C.C. Landry, J. Lockwood, A.R. Barron, Synthesis of chalcopyrite semiconductors and their solid solutions by microwave irradiation, Chem. Mater., 7 (1995) 699-706.

[5] R. Klenk, J. Klaer, R. Scheer, M.C. Lux-Steiner, I. Luck, N. Meyer, U. Rühle, Solar cells based on $CuInS_2$-an overview, Thin Solid Film, 480-481 (2005) 509-514.

[6] W. Vallejo, C.A. Arredondo, G. Gordillo, Synthesis and characterization of Zn(O,OH)Sand $AgInS_2$ layers to be used in thin film solar cells, Appl. Surf. Sci., 257 (2010) 503-507.

[7] W. Zhang, D. Li, Z. Chen, M. Sun, W. Li, Q. Lin, X. Fu, Microwave hydrothermal synthesis of $AgInS_2$ with visible light photocatalytic activity, Mater. Res. Bull., 46 (2011) 975-982.

[8] J. Hu, Q. Lu, K. Tang, Y. Qian, G. Zhou, X. Liu, Solvothermal reaction route to nanocrystalline semiconductors $AgMS_2$ (M = Ga, In), Chem. Commun., (1999) 1093-1094.

[9] Z. Aissa, A. Bouzidi, M. Amlouk, Study of the I-V characteristics of $SnO_2$:F/$AgInS_2$ (p)/Al Schottky diodes, J. Alloys Compd, 506 (2010) 492-495.

[10] L. Tian, J.J. Vittal, Synthesis and characterization of ternary $AgInS_2$ nanocrystals by dual- and multiple-source methods, New J. Chem., 31 (2007) 2083-2087.

[11] M.L.A. Aguilera, J.R.A. Hernández, M.A.G. Trujillo, M.O. López, G.C. Puente, Photoluminescence studies of chalcopyrite and orthorhombic $AgInS_2$ thin films deposited by spray pyrolysis technique, Thin Solid Film, 515 (2007) 6272-6275.

[12] M.L.A. Aguilera, M. Ortega-López, V.M.S. Resendiz, J.A. Hernández, M.A.G. Trujillo, Some physical properties of chalcopyrite and orthorhombic $AgInS_2$ thin films prepared by spray pyrolysis, Mater. Sci. Eng.: B, 102 (2003) 380-384.

[13] Y. Cui, J. Ren, G. Chen, Y. Qian, Y. Xie, A simple route to synthesize $MInS_2$ (M = Cu, Ag)nanorods from single-molecule precursors, Chem. Lett., (2001) 236-237.

[14] J.Q. Hu, B. Deng, K.B. Tang, C.R. Wang, Y.T. Qian, Preparation and phase control of nanocrystalline silver indium sulfides via a hydrothermal route, J. Mater. Res., 16 (2001) 3411-3415.

[15] K. Yoshino, H. Komaki, T. Kakeno, Y. Akaki, T. Ikari, Growth and characterization of p-type $AgInS_2$ crystals, J. Phys. Chem. Solid, 64 (2003) 1839-1842.

[16] K. Yoshino, A. Kinoshita, K. Nomoto, T. Kakeno, S. Seto, Y. Akaki, T. Ikari, Pressure dependence of AgInS2 crystals grown by hot-press method, Phys. Status Solidi C., 3 (2006) 2648-2651.

[17] M. Calixto-Rodriguez, H. Martínez, M.E. Calixto, Y. Peña, D. Martínez-Escobar, A.Tiburcio-Silver, A. Sanchez-Juarez, Optical and electrical characterization of $AgInS_2$ thin films deposited by spray pyrolysis, Materials Science and Engineering B: Solid-State Mater. Adv. Technol., 174 (2010) 253-256.

[18] S. Ge, Z. Shui, Z. Zheng, L. Zhang, A general microwave-assisted nonaqueous approach to nanocrystalline ternary metal chalcogenide and the photoluminescence study of $CoIn_2S_4$, Opt. Mater., 33 (2011) 1174-1178.

[19] J.W. Lekse, A.M. Pischera, J.A. Aitken, Understanding solid-state microwave synthesis using the diamond-like semiconductor, $AgInSe_2$, as a case study, Mater. Res. Bull., 42 (2007) 395-403.