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Hydrothermal synthesis of undoped and inner transition metals (neodymium (Nd), gadolinium (Gd)) doped tin monosulfide (SnS) nanostructures: Comparative study of the morphological, opto-magnetic properties and antibacterial performance

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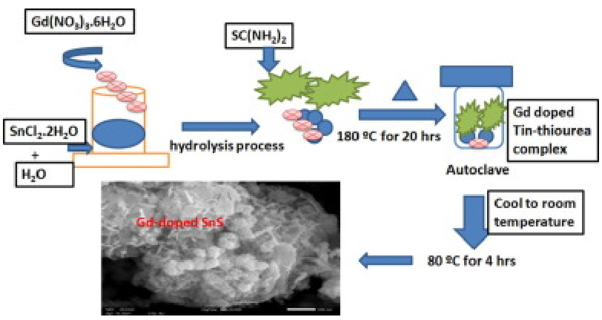
Abstract

Undoped SnS, and Nd and Gd-doped SnS nanostructures were fabricated by hydrothermal approach. The XRD study for the Gd-doped SnS powder proved the formation of an orthrhombic crystal structure. The SEM study reveals the particles' surface altered by introducing the Nd and Gd element into the SnS materials. Undoped and doped SnS materials have ferromagnetic characters detected, along with the distinct coercive force and intense magnetization revealed by VSM study. Significantly reduced band gap values have been observed for doped SnS in the optical absorption spectra. The antibacterial activity of prepared materials was tested, and the results have been discussed in detail.

Graphical abstract



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Introduction

Tin monosulfide (SnS) is one of the chalcogenide materials which has turned research topic and gained much attention for use in industrial applications, in photo detectors (photodiodes and photovoltaic) as optoelectronic devices, waste water treatment &biomedical, solar cells, gas sensors etc. [1], [2], [3], [4], [5]. From the available past and recent literature reports, some merits were noticed about SnS material, like narrow optical band gap energy, infrared (IR) and near-infrared (NIR) optical behaviour, non-toxicity, good light-absorption and transparency, and moderate electrical resistivity and conductivity.

A lot of web reports deal with the synthesis of metals (In, Fe, Ti, V, Se, Sb, Te, Cu, Na), non- metals (Carbon, Nitrogen, Phosphorus), reduced graphene oxide and g-C_3N_4 doped SnS material by different chemical routes for testing the optical, electronic, magnetic properties, electrical and thermoelectric behaviour when used in optoelectronic devices, solar cells, waste water treatment, electrochemical, gas sensing and spintronics device applications [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27]. For example, Pandey et al. [28] synthesized the undoped and various concentrations of Mn doped SnS nanoparticles through the chemical precipitation method. They found significant changes in the optical band gap and photoemission characteristic with respect to increasing the Mn dopant concentration on the SnS nanoparticles. Arepalli et al. [29] tested the concentration of 2%- Ag doped SnS thin film materials at various temperatures (200 to 350°C) via the sputtering method. They examined the surface modification of the morphologies, crystalline behaviour, interplanar distance, Full width half maximum, intrinsic strain, lattice constant, cell volume, composition of elements, optical and electrical parameters under the influence of temperatures ranging from 200 to 350°C. Jethwa et al. [30] made Se dopant admixtures in a SnS crystal by the direct vapour transport route. They found improved electrical responses like the hall coefficient, conductivity, mobility and carrier concentration and photodetector parameters in the Se doped SnS crystal. Purusottam Reddy Bommireddy and his groups [31] investigated the tuning of diffraction shifts, the Raman shift from the XRD and Raman spectra, surface modification, elemental composition ratio, optical band gap and electrical parameters (carriers' concentration, mobility, resisitivity, material type (p-n-type)) by introducing various concentrations of a copper dopant incorporated in the SnS thin film material via the spin coating route. Qin et al. [32] prepared an Ag doped SnS thin film using the solvo-thermal method followed by a study of the gas sensing characteristic. In this paper, the obtained gas sensing parameters of the Ag doped SnS film are compared with the computation theory based gas sensing parameters' results and discussed in detail. Janakiraman et al. reported [33] that undoped and Fe doped SnS thin films were deposited on the glass substrate by applying certain parameter conditions via the spray coating analysis. In this paper, they found that the average crystallite size was decreased in the SnS film material with increasing Fe doped concentration. Variation in the surface modifications were noticed in the microscopy studies by varying the Fe doped concentration admixtures in the SnS film. In addition, better optical absorbance and transmittance were found in Fe doepd SnS film at higher concentration in the optical spectra studies. Using co-precipitation, Parveen et al. [34] studied the undoped and different concentrations of Ni dopant assisted SnS nanocrystalline materials. They noticed that tuning affected the average crystallite size and physical properties like the lattice constant, crystalline strain, dislocation density, volume of the unit cell and internal surface modification and electrical characteristics (dielectrics and conductivity) under the influence of Ni dopant concentration in the SnS material. Muthalif et al. [35] reported the better electrochemical and photovoltaic activity of Cu doped SnS compared to the pure SnS material through the chemical bath deposition method. In addition, they noticed that improved photovoltaic behaviour of Cu doped SnS is suitable for solar cells applications. Ag doped SnS thin film was prepared using the spray route and the effects of the Ag dopant concentration on the optical band gap, and structural and electrical parameters values were comparatively discussed in detail by Santhosh Kumar and his groups [36]. Structural, optical absorption, emission behaviour and electrical properties of the co-precipitation synthesized pure and Pb doped SnS material were comparatively examined by Mohammad Reza Arefi-Rad et al. [37]. They noticed improved physico-chemical properties in the Pb doped SnS material. Based on the above literatures, it was noticed that on introducing the above dopants into the SnS material, the structural parameter results like the crystallite size, strain, and topographical particles etc. could be tuned. In addition, for the doped SnS material, an increase or decrease in the optical band gap and emission band peaks, depends on selecting the dopant material [6,7, 13–16, 27, 31, 33]. This happened due to the ionic radius variation between the dopant and tin ions. The optical band gap value is one of the reasons affecting the catalytic activity [2]. If the optical band gap values and PL emission intensity are decreased their consequences will generate more recombinations of electron-hole pairs. Thus, the optical property would enhance the catalytic activity of the nanomaterial. Moreover, improved coercivity and magnetization values of the SnS material by increasing the dopant concentrations were detected from the magnetization–applied field (M−H) curve, compared with the pure SnS compound [10], [34]. This was because of the interaction between the dopant ions and tin ions, when a magnetic field is applied on the doped SnS material.

The SnS material with the above dopants incorporated into was synthesized by applying different chemical routes. The hydrothermal route was used to synthesize the undoped, and Gd and Nd-doped SnS material. From the above literature reports it was noticed that, the hydrothermal route has some merits it could be used without any surfactants/inert gas for a high temperature reaction compared to the other chemical techniques [38], [39], [40], [41], [42], [43], [44], [45].

The present investigation, attempts to study undoped SnS, and Nd and Gd-doped SnS bioceramic nanopowders by taking tin (II) chloride salt, thiourea, water, gadolinium nitrate and neodymium nitrate salt used as a doping agent through the hydrothermal method. The synthesized undoped and doped SnS nanostructures were tested by various sophisticated analytical instruments such as UV–visible spectroscopy, Vibrating Sample Magnetometer (VSM), and the antibacterial studies and their results are discussed detail for the first time. In addition, it was found that the Gd doped SnS nanostructures has good optical and magnetic properties and antibacterial activity compared to the undoped and Nd-doped SnS compound. Hence, the powder X-ray powder diffraction (XRD) pattern for the Gd doped SnS material was examined with respect to its crystalline structure and its discussion is presented in detail.

Section snippets

Synthesis of Undoped, Nd-and Gd- doped SnS material

Synthesis chemicals of the analytical grade have been used without further purification to obtain undoped, Nd-and Gd-doped SnS material using the hydrothermal route. 0.1 mmol of tin (II) chloride di hydrate ($SnCl_2{\cdot}2H_2O$, Sigma-Aldrich-purity 99.9%) was taken as a tin precursor and dispersed in 80 mL quantity of distilled water. Now, the tin precursor salt was slowly dissociated into the distilled water, forming tin and chlorine ions separately due to the hydrolysis process. In the next step,…

Results and discussion

Different magnification images of the (a-c) undoped SnS, (d-f) Nd-doped SnS and (f-h) Gd-doped SnS materials are shown in Fig. 1. In the SEM images, the nanostructured formation of particles the synthesized undoped and doped SnS material could be clearly seen nanosheets, nanoflowers and nanosheets/rods along with spherical particle morphology was seen for the undoped SnS, Nd-doped SnS and Gd-SnS materials. It was noticed from the SEM results, that the introduction of the dopant plays a…

Conclusion

In this investigation, three different materials like undoped SnS, Nd- doped SnS and Gd-doped SnS material have been synthesized using the .hydrothemal method. Their optical absorption, optical band gap, magnetic nature, coercivity, and magnetic saturation and zone of inhibition values are compared and discussed in the results and discussion section. Based on the UV, VSM and antibacterial characterization, it is seen that relatively better optical, magnetic and antibacterial properties are…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

References (52)

H. Tian *et al.*
Appl. Surf. Sci. (2019)

A.M. Mostafa *et al.*
Opt. Laser Technol. (2020)

Y.T. Ma *et al.*
Vacuum (2020)

Shujaat Ali *et al.*
Materials Letters (2017)

K. Santhosh Kumar *et al.*
Optik (2014)

F. Jamali-Sheini *et al.*
Solid State Sci. (2018)

S.H. Chaki *et al.*
Mater. Res. Bull. (2015)

B. Parveen *et al.*
J. Magn. Magn. Mater. (2018)

P. Cermak *et al.*
J. Alloy. Compd. (2019)

K. Santhosh Kumar *et al.*
Spectrochim. Acta Part A Mol. Biomol. Spectrosc. (2013)

View more references

Cited by (1)

Review of Metal Sulfide Nanostructures and their Applications
2023, ACS Applied Nano Materials

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