2024 ,Volume 1 , Issues 4 PSIJK 17 - 21

Pure Sciences International Journal of Kerbala
Journal Homepage:https://journals.uokerbala.edu.iq/index.php/psijk

Silver Sulfide Nanostructures: Synthesis and Characterization

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P A P E R I N F O

Received 29 May 2024
Accepted 8 August 2024
Published 31 December 2024

Keywords:
Ag_2S nanoparticles,
Optical properties,
Chemical precipitation

A B S T R A C T

Ag_2S semiconductor nanoparticles were prepared successfully using the chemical precipitation method. The XRD pattern shows that the Ag_2S particles are crystalline with a monoclinic phase. "Debye-Scherrer" formula was used to calculate the crystal size and it was found to be 64.22 nm. According to FE-SEM images, all particles have a spherical shape. The band gap for Ag_2S was estimated from the optical absorption curve and it was 3.89 eV.

1. INTRODUCTION

Characteristics of semiconductor nanostructured materials are well understood and they depend on their size, shape, and surface charge [1,2] . Chalcogenides of transition metals are used [3], with their remarkable photoelectron transformation capabilities and prospective applications, in chemistry ,physics [4,5] ,biology, medicine, and materials science[6]. They are also used as important components in solar cells, photovoltaic devices, sensitive sensors, and slow-release medication[7,8]. Due to its excellent optoelectronic qualities, Ag_2S is one of the most significant chalcogenides[9]. At the nanoscale level, Ag_2S exhibits electronic and optoelectronic properties which lead to use them in many applications such as in electrical and optical devices [10]. Owing to the narrow band gap (0.9-1.05 eV) [11,12], silver sulfide nanoparticles reveal photoelectric and thermoelectric properties. Ag_2S is a significant chalcogenide that finds widespread use in a variety of scientific and technological fields[13,14], including IR detectors, photovoltaic cells, electrochemical storage cells, and photoconducting cells [15]. It is also widely known for its ability to function as mixed conductor of ions and electrons at temperatures higher than 200°C[16,17]. Some chemical and physical methods are used to synthesize Ag_2S nanoparticles, including chemical bath deposition (CBD), spray pyrolysis deposition (SPD), sequential ionic layer adsorption reaction (SILAR), molecular beam epitaxy (MBE), gamma irradiation, thermal evaporation, and sol-gel, and ion implantation techniques [11, 18]. The purpose of this work was to use the chemical precipitation approach to explain the growth process of silver sulfide nanostructures. By adjusting variables including pH, precursors' concentration, reaction time, and reaction temperature, the structural and optical features of the synthesized Ag_2S nanoparticles can be controlled. Previously, chemical precipition approache is used to prepare Ag_2S nanorods because it is an environmentally friendly and inexpensive method. The authors used silver nitrate and thiourea as starting materials with different molar concentration.[19] Emadi group used sonochemical method to fabricate Ag_2S nanoparticles. The authors used thioacetic acid as a source for sulphide and they found that the ultrasound radiation with 60 W for 20 minutes radiation was capable to produce nanoparticles with an average size of 11.8 nm.[20]

2. MATERIALS AND METHODS

2.1 Chemical Substances

Silver acetate (99.9%, CH_3CO_2Ag) and sodium sulfide (99%, Na_2S) were purchased from THOMAS BAKER, deionized water was used as a solvent.

2.2 Preparation of Silver Sulfide

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To create silver sulfide nanoparticles, first. 0.16691 g of silver acetate was dissolved in 100 mLof deionized water and stirred. No particles were visible. This produced 0.01 M of silver acetate. Silver acetate solution was mixed with 100 mL of 0.01 M sodium sulfide solution .The solution was stirred for an hour at 50˚C on the magnetic stirrer Maintaining the temperature while stirring after the addition was finished. After centrifugation at 4000 rpm, the precipitate was finally recovered and dried at 50˚C for three hours**.** preparation equation**.**

$Na_2S + 2AgC_2H_3O_2 \rightarrow Ag_2S + 2NaC_2H_3O_2$

3. CHARACTERIZATION AND INSTRUMENTATIONS

To characterize the crystal properties of the prepared silver sulphide, X-ray diffraction, was used. Structural properties of Ag_2S nanoparticles were determined using field emission scanning electron microscopy (FE-SEM). Elemental analysis was performed using EDX. Fourier Transform Infrared Spectroscopy, also known as FTIR was used to study the functional groups of prepared sample. The band gap was investigated from the UV-Vis chart using tauc equation.

4. RESULT AND DISCUSSIONS

The XRD chart, which is shown in Figure 1, showed the appearance of many narrow diffraction peaks indicating the crystalline nature. According to JCPDS Card No .14-0072, peaks appeared at 26.32°, 28.97°, 31.51°, 33.62°, 34.39°, 36.82°, 37.73°, 40.75°, 43.40°, 47.77°, 48.76°, 53.27°, 58.36°, and 63.75° are corresponding to -101, 111, -112, 120, -121, 121, -103, 031, 200, 023, 113, 311, 212, 222, 024, and 034 diffraction planes.

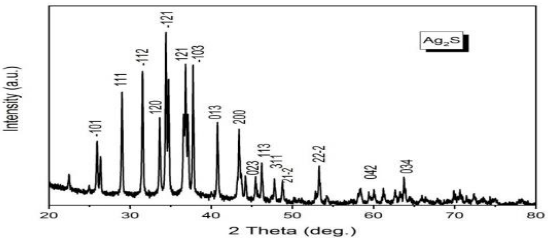

Figure 1. XRD pattern of Ag_2S nanoparticles**.**

The diffraction angle of 34.39° was used to obtain the crystallite size of Ag_2S particles Scherrer equation 22D equals $D = K\lambda / \beta \cos\theta$. Here, θ is the diffraction angle , K is a constant equal to 0.9 and β is the full width at half maximum., and the wavelength of the Cukα is1.54056 E [21].

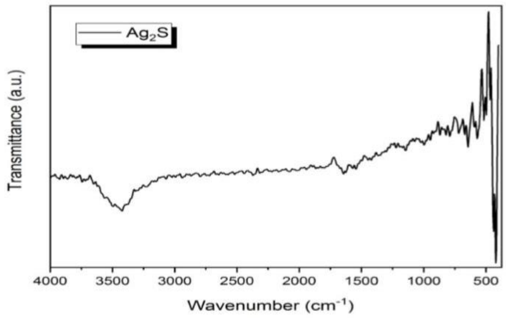

Figure 2. FTIR Spectrum of Ag_2S Nanoparticles.

Figure2 shows the FTIR spectrum of Ag_2S nanoparticles. The peaks that appeared in the range of 400–600 cm^{-1} are related to Ag–S bonds, supporting the formation of silver sulfide nanoparticles. The structural properties of the prepared particles were determined from the FE-SEM images. It is clear from the image in Figure 3 that the particles are spherical and their average size is calculated using imageJ program and it is found to be 64.3 nm.

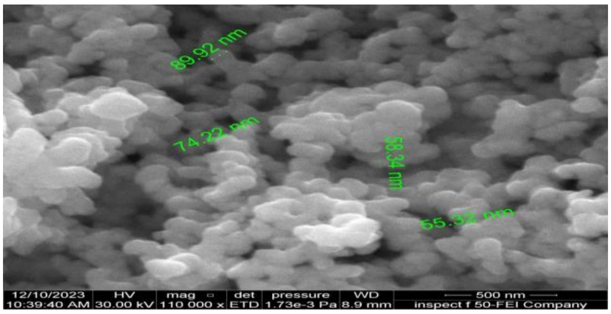

Figure 3. FE-SEM images of Ag_2S nanoparticles.

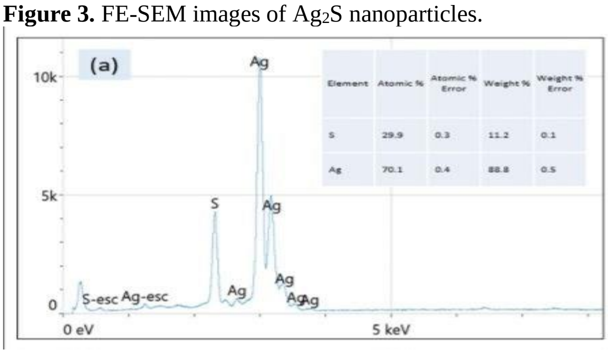

Figure 4. EDS chart of Ag_2S particles.

The presence of silver and sulphide elements within Ag_2S nanoparticles was confirmed using EDS chart. It is clear from Figure 4 that our sample has no impurities due to the absence of any peak except for silver and sulphide.[22] The atomic percentage for Ag is 70.1%, and for S is 29.9%.

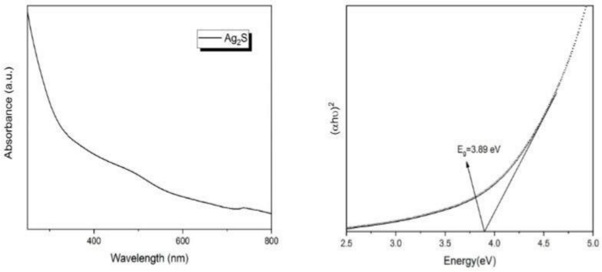

Figure 5. UV_V is absorbance spectrum for silver sulfide nanoparticles and band gap energies of Ag2S nanoparticles.

is absorbance spectrum of silver sulphide nanoparticles (leaft image) and the band gap energy of Ag_2S nanoparticles (right image).

The optical properties of Ag_2S were studied using UV-Vis spectroscopy. It is clear from Figure 5 that the absorption band edge [23] of the as- prepared nanoparticles is around 550 nm. The band gap energy, calculated using Tauc's equation, is 3.89 eV. This value is larger than that of bulk Ag_2S(0.9-1.05 eV) [24], suggesting the effect of quantum confinement as the size of the particles decreases.

5. CONCLUSTION

In this study Ag2S nanoparticles were fabricated using chemical precipitation technique. The crystal properties of particles were confirmed by XRD patterns. It seems that the particles are monoclinic with a crystallite size of 64.22356 nm. Most of Ag2S particles are spherical in shape with an average diameter of 64.3 nm. Their optical properties show that the as-prepared particles are in nanoscale level due to the value of band gap (3.89 eV) which is greater than that of bulk Ag2S that is possibly related to the quantum size effect.

6. REFERENCES

1. T. M. Hammad, J. K. Salem, and R. G. Harrison, "Synthesis, characterization, and optical properties of Y-doped ZnO nanoparticles," Nano, vol. 4, pp. 225-232, 2009.
2. J. K. Salem, T. M. Hammad, S. Kuhn, I. Nahal, M. A. Draaz, N. K. Hejazy, et al., "Luminescence properties of Mn and Ni doped ZnS nanoparticles synthesized by capping agent," Journal of Materials Science: Materials in Electronics, vol. 25, pp. 5188-5194, 2014.
3. T. M. Hammad and J. K. Salem, "Synthesis and characterization of Mg-doped ZnO hollow spheres," Journal of Nanoparticle Research, vol. 13, pp. 2205-2212, 2011.
4. T. M. Hammad, J. K. Salem, and R. G. Harrison, "The influence of annealing temperature on the structure, morphologies and optical properties of ZnO nanoparticles," Superlattices and Microstructures, vol. 47, pp. 335-340, 2010.
5. A. Kryukov, A. Stroyuk, N. Zin'chuk, A. Korzhak, and S. Y. Kuchmii, "Optical and catalytic properties of Ag2S nanoparticles," Journal of Molecular Catalysis A: Chemical, vol. 221, pp. 209-221, 2004.
6. M. Wu, X. Pan, X. Qian, J. Yin, and Z. Zhu, "Solution-phase synthesis of Ag2S hollow and concave nanocubes," Inorganic Chemistry Communications, vol. 7, pp. 359-362, 2004.
7. D. Brühwiler, C. Leiggener, S. Glaus, and G. Calzaferri, "Luminescent silver sulfide clusters," The Journal of Physical Chemistry B, vol. 106, pp. 3770-3777, 2002.
8. M. Hraja, A. Al Hindawi, and N. Shiltagh, "Investigation of Electronic and Molecular Features of Zn3S3/PEG4000 Nano-Composite Using the DFT Method," Journal of the Turkish Chemical Society Section A: Chemistry, vol. 11, pp. 565-574.
9. S. Liu, X. Qian, J. Yin, L. Hong, X. Wang, and Z. Zhu, "Synthesis and characterization of Ag2S nanocrystals in hyperbranched polyurethane at room temperature," Journal of Solid State Chemistry, vol. 168, pp. 259-262, 2002.
10. T. M. Hammad, J. K. Salem, S. Kuhn, N. M. A. Shanab, and R. Hempelmann, "Surface morphology and optical properties of PVA/PbS nanoparticles," Journal of Luminescence, vol. 157, pp. 88-92, 2015.
11. I. Ezenwa, N. Okereke, and N. Egwunyenga, "Optical properties of chemical bath deposited Ag2S thin films," International Journal of Science and Technology, vol. 2, pp. 101-106, 2012.
12. J. Liu, P. Raveendran, Z. Shervani, and Y. Ikushima, "Synthesis of Ag 2 S quantum dots in water-in-CO 2 microemulsions," Chemical communications, pp. 2582-2583, 2004.
13. L. Armelao, R. Bertoncello, E. Cattaruzza, S. Gialanella, S. Gross, G. Mattei, et al., "Chemical and physical routes for composite materials synthesis: Ag and Ag 2 S nanoparticles in silica glass by sol–gel and ion implantation techniques," Journal of Materials Chemistry, vol. 12, pp. 2401-2407, 2002.
14. A. H. Wdaah, H. I. Salman, and A. A. Balakit, "Synthesis and characterization of selenium-polyvinyl alcohol nanoparticles as eco-friendly corrosion inhibitor for carbon steel in 1.0 M H2SO4," Inorganic Chemistry Communications, vol. 165, p. 112505, 2024.
15. J. Xiao, Y. Xie, R. Tang, and W. Luo, "Template-based synthesis of nanoscale Ag 2 E (E= S, Se) dendrites," Journal of Materials Chemistry, vol. 12, pp. 1148-1151, 2002.
16. M. Chen, Y. Xie, H. Chen, Z. Qiao, and Y. Qian, "Preparation and characterization of metal sulfides in ethylenediamine under ambient conditions through a γ-irradiation route," Journal of colloid and interface science, vol. 237, pp. 47-53, 2001.
17. W. P. Lim, Z. Zhang, H. Y. Low, and W. S. Chin, "Preparation of Ag2S nanocrystals of predictable shape and size," Angewandte Chemie International Edition, vol. 43, pp. 5685-5689, 2004.
18. T. Hammad, A. Shallah, and J. Salem, "Investigation of New Optical Properties of Cd and Co-doped Ag2S Colloidal Solution," Material Science: An Indian Journal, vol. 16, 2018.
19. S. Kasim, F. Khaleel, F. Kasim, and M. Mahdi, "Preparation Ag2S nanorods and nanoparticles via a simple chemical method," Advanced Materials Research, vol. 364, pp. 500-503, 2012.
20. H. Emadi, M. Salavati-Niasari, and F. Davar, "Synthesis and characterisation of silver sulphide nanoparticles by ultrasonic method," Micro & Nano Letters, vol. 6, pp. 909-913, 2011.
21. F. Ezema, P. Asogwa, A. Ekwealor, P. Ugwuoke, and R. Osuji, "GROWTH AND OPTICAL PROPERTIES OF Ag," Journal of the University of chemical Technology and Metallurgy, vol. 42, pp. 217-222, 2007.
22. A. Q. Abed, A. M. A. Hindawi, and H. F. Alesary, "Synthesis and characterization of zinc sulfide nanomaterials for removal methylene blue dye from aqueous solution," in AIP Conference Proceedings, 2023.
23. Z. T. Turki, A. M. A. Hindawi, and N. M. Shiltagh, "Fabrication and characterization of cadmium sulfide nanoparticles using chemical precipitation method," in AIP Conference Proceedings, 2023.
24. S. I. Sadovnikov, A. V. Ishchenko, I. A. J. J. o. A. Weinstein, and Compounds, "Synthesis and optical properties of nanostructured ZnS and heteronanostructures based on zinc and silver sulfides," vol. 831, p. 154846, 2020.

Arabic Abstract

في هذه الدراسة تم تصنيع الجسيمات النانوية Ag_2S باستخدام تقنية الترسيب الكيميائي. تم تأكيد الخصائص البلورية للجسيمات بواسطة مخطط XRD ويبدو أن الجسيمات أحادية الميل بحجم بلوري قدره 64.22 nm. معظم جسيمات Ag_2S كروية الشكل ويبلغ متوسط قطرها 64.3 nm. أظهرت خصائصها البصرية أن الجسيمات المحضرة موجودة على مستوى النانو بسبب قيمة فجوة النطاق (3.9 فولت) والتي هي أكبر من قيمة Ag_2S السائبة والتي ربما تكون مرتبطة بتأثير الحجم الكمي.