STUDY OF PROPERTIES CDS NANOCRYSTALLINE THIN FILM AS A PHOTODETECTOR

Haider Abdulelah 1, Ghufran Mohammad Shabeeb 2
[1,2] Department of Material Science, Polymer Research Centre, University of Basrah, Iraq

Article Info

Article history:
Received Jun 10, 2024
Revised Jul 15, 2024
Accepted Aug 05, 2024

Keywords:
CdS, white light, photodetector

ABSTRACT

It has been discussing the use of cadmium sulfide (CdS) as a material for photodetectors. CdS is a direct bandgap II-VI semiconductor with desirable properties for photodetectors, including high sensitivity, fast response time, and wide spectral range from ultraviolet to near-infrared. X-ray diffraction analysis confirmed the cubic crystal structure of the porous CdS thin film. Scanning electron microscopy revealed a porous morphology with macropores ranging from 200-300 nm in size. The performance of the porous CdS photodetector was evaluated. Under visible light illumination, the device generated a photocurrent of 16 nA, with response times of around 5 seconds for both the rising and falling edges of the light-induced current.

Corresponding Author:
Haider Abdulelah, Ghufran Mohammad Shabeeb
University of Basrah
E-mail address: haider.abdulelah@uobasrah.edu.iq

INTRODUCTION

Cadmium sulfide (CdS) is a direct bandgap II-VI semiconductor with a wide range of applications in electronics, optics, and solar cells [1-4]. Its unique properties make it particularly well-suited for use in photodetectors, devices that convert light into electrical signals. CdS photodetectors have been extensively studied for their high sensitivity, fast response time, and low cost, making them ideal for a variety of applications ranging from security systems to medical imaging [5-7]. One of the key advantages of CdS as a photodetector material is its wide spectral response range, which extends from the ultraviolet to the near-infrared region [8, 9]. This makes CdS detectors highly versatile and capable of detecting a broad range of light wavelengths [10]. In addition, CdS has a high quantum efficiency, meaning that it can convert a large percentage of incident photons into electrical signals, making it highly sensitive to low light levels [11]. CdS photodetectors also exhibit a fast response time, with rise and fall times on the order of nanoseconds, making them suitable for high-speed applications where rapid signal detection is critical. Furthermore, CdS is a stable and durable material, with good resistance to environmental factors such as temperature and humidity, ensuring long-term reliability of the photodetector [6]. In recent years, CdS photodetectors have found widespread use in various fields, including spectroscopy, environmental monitoring, and industrial automation. They are also commonly used in sensors for detecting ultraviolet radiation, as well as in light-sensitive devices such as light meters and camera sensors [12]. Despite its numerous advantages, CdS does have some limitations, including its toxicity and potential environmental impact. CdS is classified as a hazardous material due to its cadmium content, which can pose health risks if not handled properly[13]. Efforts are underway to develop alternative materials with similar properties but reduced toxicity, such as cadmium-free quantum dots or perovskite materials. Overall, CdS remains a popular choice for photodetectors due to its high sensitivity, fast response time, and spectral range. Continued research and development in this field will likely lead to further improvements in CdS-based photodetectors and the emergence of new technologies for a wide range of applications.

METHODS

This method of research uses qualitative study of literature, which is a method of gathering data by understanding and studying theories from various literature related to research. According to Sarwono [4], library research is the study of reference books and similar previous research results carried out by others. The aim is to obtain a theoretical basis for the problem being studied. Data collection uses different methods of searching for sources and construction from various sources, including books, journals, and research that has been done. Library materials derived from various references should be critically analyzed and thoroughly analyzed to support suggestions and ideas.

RESULT AND DISSCUSION

Structural and morphology

X-ray diffraction (XRD) analysis is a crucial technique for nondestructively determining a material's crystal structure, physical properties, and chemical composition. In the case of the porous CdS nanocrystalline thin film, Figure (a) displays the XRD diffractograms obtained. The prominent peaks at (2 0 0), (2 2 0), and (1 1 1) confirm the cubic structure of the film. Additionally, a small peak corresponding to the (511) plane of sulfur was observed at approximately 2θ~330, indicating its presence in the crystalline structure. The remaining peaks can be attributed to the glass substrate. According to the provided information, macropores are characterized by their size, which exceeds 50 nm. On the other hand, micropores are defined as having a size smaller than 2.0 nm, while mesopores fall within the range of 2 to 50 nm. In Figure (b), a micrograph obtained through field-emission scanning electron microscopy (FE-SEM) showcases the porosity state of CdS. The image clearly illustrates that CdS has been formed within the macropores, which exhibit an average distribution of porous sizes ranging from 200 to 300 nm, as depicted in Figure (B).

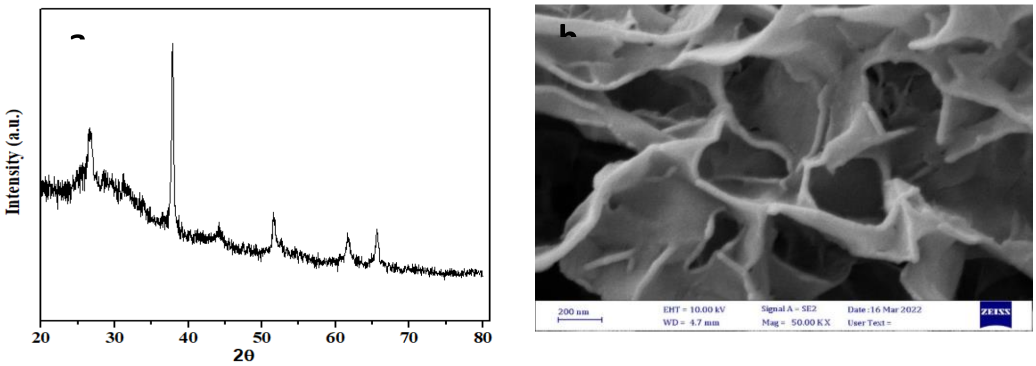

Fig.(1): XRD patterns (a), and FESEM

Porous CdS as a detector

Figure 2 illustrates the diagram of a porous CdS photodetector. The researchers first examined the light intensity dependency of the CdS porous device. The graph in Figure 2 displays the I-T plots of the CdS porous device under visible light, with increasing incoming light power starting from 3 mW cm−2. When exposed to white light power, the device generated a photocurrent of 16 nA. The response times for the raising and decaying currents were approximately 5.35 seconds and 4.99 seconds, respectively.

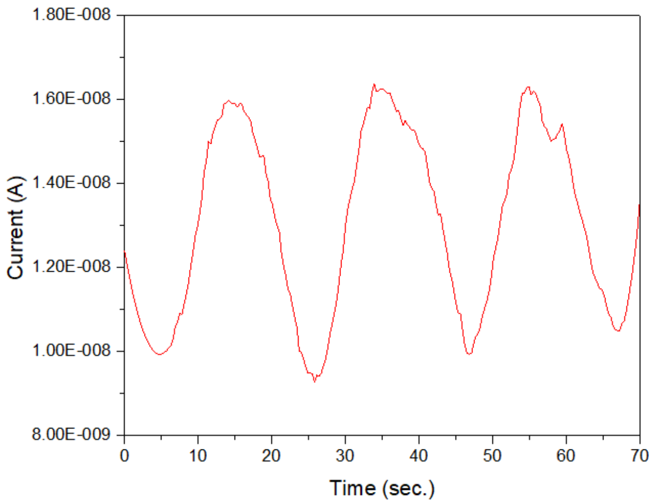

Fig.(2) : Photo response time of CdS

CONCLUSION

1. Cadmium sulfide (CdS) is a promising material for photodetector applications due to its favorable properties, including high sensitivity, fast response time, and broad spectral sensitivity from ultraviolet to near-infrared.

2. X-ray diffraction analysis confirmed the cubic crystal structure of the porous CdS thin film, with the presence of some sulfur in the crystalline structure as well.
3. Scanning electron microscopy revealed a porous morphology in the CdS thin film, with macropores ranging from 200 to 300 nm in size.
4. The fabricated porous CdS photodetector device exhibited good photoresponse characteristics, generating a photocurrent of 16 nA under visible light illumination.
5. The response times of the CdS photodetector were relatively fast, with rise and fall times of around 5 seconds, indicating its suitability for high-speed applications.
6. While CdS has many advantages as a photodetector material, its toxicity due to the presence of cadmium is a potential limitation that may require the development of alternative, less hazardous materials in the future.
7. Overall, the results demonstrate the potential of porous CdS as an effective and versatile material for photodetector applications, with further research and optimization needed to address any remaining challenges.

REFERENCES

[1] A. Majid, M. Bibi, Cadmium based II-VI semiconducting nanomaterials, Gewerbestrasse 11 (2018) 6330.

[2] M. Moghaddam, N. Naderi, M. Hosseinifard, A. Kazemzadeh, Improved optical and structural properties of cadmium sulfide nanostructures for optoelectronic applications, Ceramics International 46(6) (2020) 7388-7395.

[3] G. Korotcenkov, Cd-and Zn-Based Wide Band Gap II-VI Semiconductors, Handbook of II-VI Semiconductor-Based Sensors and Radiation Detectors: Volume 1, Materials and Technology, Springer2023, pp. 21-65.

[4] S. Ali, F.K. Butt, J. Ahmad, Z.U. Rehman, S. Ullah, M. Firdous, S.U. Rehman, Z. Tariq, Recent Developments in Group II-VI Based Chalcogenides and Their Potential Application in Solar Cells, 2D Nanomaterials (2022) 245-262.

[5] K. Deng, L. Li, CdS nanoscale photodetectors, Advanced Materials 26(17) (2014) 2619-2635.

[6] L. Li, Z. Lou, G. Shen, Hierarchical CdS nanowires based rigid and flexible photodetectors with ultrahigh sensitivity, ACS applied materials & interfaces 7(42) (2015) 23507-23514.

[7] F. Cao, L. Meng, M. Wang, W. Tian, L. Li, Gradient energy band driven high-performance self-powered perovskite/CdS photodetector, Advanced Materials 31(12) (2019) 1806725.

[8] W. Jin, L. Hu, Review on quasi one-dimensional cdse nanomaterials: synthesis and application in photodetectors, Nanomaterials 9(10) (2019) 1359.

[9] L. Zhu, C. Li, Y. Li, C. Feng, F. Li, D. Zhang, Z. Chen, S. Wen, S. Ruan, Visible-light photodetector with enhanced performance based on a ZnO@ CdS heterostructure, Journal of Materials Chemistry C 3(10) (2015) 2231-2236.

[10] I. Ibrahim, H.N. Lim, R.M. Zawawi, A.A. Tajudin, Y.H. Ng, H. Guo, N.M. Huang, A review on visible-light induced photoelectrochemical sensors based on CdS nanoparticles, Journal of Materials Chemistry B 6(28) (2018) 4551-4568.

[11] X. Huang, S. Han, W. Huang, X. Liu, Enhancing solar cell efficiency: the search for luminescent materials as spectral converters, Chemical Society Reviews 42(1) (2013) 173-201.

[12] M. Zubair, C. Zhu, X. Sun, H. Liu, B. Zheng, J. Yi, X. Zhu, D. Li, A. Pan, Record high photoresponse observed in CdS-black phosphorous van der Waals heterojunction photodiode, Sci. China Mater. 63 (2020) 1570-1578.

[13] G. Gou, G. Dai, C. Qian, Y. Liu, Y. Fu, Z. Tian, Y. He, L. Kong, J. Yang, J. Sun, High-performance ultraviolet photodetectors based on CdS/CdS: SnS 2 superlattice nanowires, Nanoscale 8(30) (2016) 14580-14586.