ARTICLE
JOURNAL OF UNIVERSITY OF BABYLON
For Pure and Applied Sciences (JUBPAS)
Vol.31; No.2.| 2023

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

Structural and Electrical Properties of "Cadmium Sulfide- Cobalt" Compound and Using it as a Gas Sensor

Muaamar Hasan Idan[1], Raheem G. Kadhim[2] and M. A. Mohammed[3*]
1College of Science, University of Babylon, moeny7216@gmail.com, Babil, Iraq.
2College of Science, University of Babylon, sci.raheem.gaayid@uobabylon.edu.iq, Babil, Iraq.
3College of College of Agriculture, University of Al-Qadisiyah, mohammed.ahmed@qu.edu.iq, Al-Qadisiyah, Iraq.
***Corresponding author email:** mohammed.ahmed@qu.edu.iq ; mobile: 07801212466

الخصائص التركيبية والكهربائية لمركب "كبريتيد الكادميوم- كوبالت" واستخدامه كمستشعر غاز

معمر حسن عيدان[1]، رحيم كعيد كاظم[2]، محمد احمد محمد[3*]
1 كلية العلوم، جامعة بابل ، moeny7216@gmail.com ، بابل، العراق
2 كلية العلوم، جامعة بابل ، sci.raheem.gaayid@uobabylon.edu.iq ، بابل، العراق
3 كلية الزراعة ، جامعة القادسية، mohammed.ahmed@qu.edu.iq ، القادسية، العراق

Received:	**13/2/2023**	**Accepted:**	**9/5/ 2023**	**Published:**	**30 /6/2023**

ABSTRACT

Background: Both the cubic (zinc blend) and hexagonal (wurtzite) phases of cadmium sulphide are semiconductors due to the presence of a row of four equally spaced Cd atoms surrounded by one S atom. Both the cubic and hexagonal crystal forms of Cd-S have very similar nearest neighbor bond lengths.
Material and Methods: The cadmium sulfide compound was prepared at a concentration of 1 M by dissolving the percentage by weight of each of cadmium(13.326g) and sulfur (3.806g) in 100 ml of distilled water. Cobalt was prepared at a concentration of 0.5M by dissolving a percentage by weight of Cobalt acetate (14.55g) in 100 ml of distilled water. Films CdS and CdS:Co were prepared using the chemical method, which is the thermal chemical spraying technique, which deposited a solution of cadmium sulfide mixture of cobalt solution with cadmium sulfide on a glass floor.
Results: The thickness of the prepared films was 100 mm. The surfaces of the prepared films were studied by measuring transmission electron microscopy. The results showed that the prepared films are homogeneous and have crystalline granules of spherical shape, and the addition of cobalt to the cadmium sulfide compound led to an increase in the particle size values. The electrical properties represented by measuring the voltaic- current were studied, and the results showed that the relationship between the voltaic- current is linear, and this indicates that the prepared films behave as ohmic.
Conclusion: The continuous electrical conductivity was also calculated, and the results showed that the addition of cobalt acetate to the cadmium sulfide compound led to an increase in the electrical conductivity values. The gas sensitivity of the prepared films towards hydrogen sulfide gas was studied, and the results showed that the prepared films had good sensitivity, and adding cobalt acetate to the cadmium sulfide compound led to a decrease in the sensitivity values.

Keywords: Cobalt acetate, Cadmium sulfide, Thermal Chemical spraying technique, sensitivity.

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

الخلاصة

مراجعة : توجد أربع ذرات من الكادميوم متتالية ، متباعدة بشكل متساوٍ، محاطة بذرة S واحدة في الطور المكعب (مزيج الزنك) والسداسي (الورتزيت) من كبريتيد الكادميوم، مما يجعلها مادة شبه موصلة. يحتوي Cd–S على أطوال روابط مجاورة متطابقة تقريبًا في كل من الهياكل البلورية المكعبة والسداسية .

المواد وطرائق العمل:

تم تحضير المركب كبريتيد الكادميوم بتركيز (1) مولاري من خلال اذابة نسبة وزنية كل من املاح الكادميوم(13.326غم) واملاح الكبريت(3.806غم) في 100 مل من الماء المقطر. وكذلك تم تحضير الكوبالت بتركيز (0.5) مولاري من خلال اذابة نسبة وزنية من املاح كوبالت (14.55غم) في (100مل) من الماء المقطر. تم تحضير الاغشية الرقيقة باستخدام الطريقة الكيميائية هي تقنية الرش الكيميائي الحراري والذي رسبت محلول كبريتيد الكادميوم والكوبالت على ارضية من الزجاج وكان سمك الاغشية المحضرة (100) نانومتر.

النتائج:

تم دراسة سطوح الاغشية المحضرة من خلال قياس المجهر الالكتروني النافذ وبينت النتائج ان الاغشية المحضرة متجانسة وذات حبيبات بلورية شكلها كروي وان اضافة املاح الكوبالت الى المركب كبريتيد الكادميوم ادى الى زيادة في قيم الحجم الحبيبي.

الاستنتاجات: تم دراسة الخواص الكهربائية المتمثلة بقياس التيار الفولتية وبينت النتائج ان العلاقة بين التيار الفولتية هي علاقة خطية وهذا يشير الى ان الاغشية المحضرة تسلك سلوك اومي. وكذلك تم حساب التوصيلية الكهربائية المستمرة وبينت النتائج ان اضافة الكوبالت الى المركب كبرييتيد الكادميوم ادى الى زيادة في قيم التوصيلية الكهربائية. تم دراسة تحسس الغازات للأغشية المحضرة تجاه غاز كبريتيد الهيدروجين وبينت النتائج ان الاغشية المحضرة لها تحسسية جيدة وان اضافة الكوبالت الى المركب كبريتيد الكادميوم ادى الى نقصان في قيم التحسسية .

الكلمات المفتاحية:

املاح الكوبالت ، كبريتيد الكادميوم ، تقنية الرش الكيميائي الحراري ، التحسسية .

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

INTRODUCTION

There are four Cd atoms in a row, equally spaced, surrounded by one S atom in the cubic (zinc blend) and hexagonal (wurtzite) phase of cadmium sulfide, making it a semiconductor material. Cd-S has nearly identical nearest neighbor bond lengths in both cubic and hexagonal crystal structures **[1],[2].**

It has a direct gap of approximately 2.4 eV, is present close to the photon energy of maximum solar radiation spectrum, causes absorption on the short wavelength side, and has a high absorption coefficient within solar radiation to generate carriers across the band gap with wavelengths less than 0.520 m. When creating thin CdS window layers to prevent optical transition losses, the material is also put to use in low-cost photovoltaic devices **[3]**. This is because of the promising future of this material in applications such as very sensitive photodetectors, heterojunction diodes, solar cells, and semiconductors. The fact that CdS is readily available as a chemical solution, has a straight band gap, a high absorption coefficient, and can be easily provided as a thin film of good quality at room temperature are the most compelling arguments in favor of employing this material **[4],[5]**.

Materials and Methods

- **Preparation of Thin Films**

The compound cadmium sulfide (CdS) was prepared by dissolving each of the elements cadmium (13.32 g) and sulfur (3.8 g) in 100 ml of distilled water in a glass container placed on a heater at a constant temperature of 60 c using a magnetic needle for a process of dissolution lasting two hours. Cobalt (CO) with a concentration of 0.5M was prepared by dissolving cobalt by weight (14.55 g) in 100 ml of distilled water in a glass container, using it placed on a heater at a constant temperature of 60 c, and using the magnetic needle for the dissolution process for a period of two hours.

The films were prepared (CdS, CdS:CO,) using the spray pyrolysis technique on glass bases with dimensions of 2 cm by 3 cm at a fixed deposition temperature of 350 °C and a fixed spray rate of 15 sprays at a time rate of 15 minutes. All films prepared are 150 nm thick.

Results and Discussion

- **Transmission Electron Microscopy (TEM)**

Figure (1 and 2) shows the TEM examination images with an analysis power of 300nm for the prepared films CdS and CdS:Co. Where the images showed that the prepared films are homogeneous and have crystalline granules, their shape is spherical, some are superimposed and some are not superimposed, separated and different in granular size, where it was found that the addition of cobalt to the cadmium sulfide compound led to an increase in the values of the granular size. When cobalt atoms fuse with cadmium sulfide atoms, crystals of large granular size are formed**[6]-[9].**

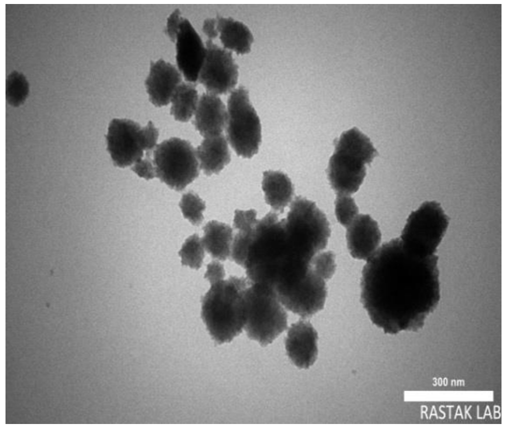

Figure (1) Shows the TEM images of the Preparation of thin film CdS.

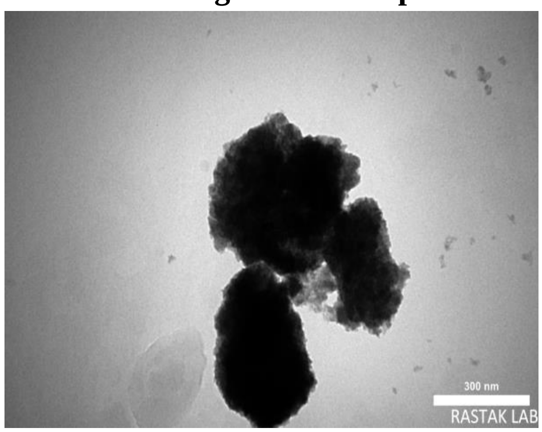

Figure (2) Shows the TEM images of the Preparation of thin film CdS:Co.

- **Current-Volte (I-V)**

The behavior of the prepared films CdS and CdS:Co was studied by measuring the current - voltage, which represents a graph of the current versus voltage values, as the ohmic conductors are represented by a linear behavior, while the semiconductors are represented by an exponential relationship.

Figure (3 and 4) show the results of the current-voltage measurement of the prepared films. Where the results showed that the relationship between the current and the voltage is a linear relationship, and this means that the relationship is direct between the voltage and the current, and this indicates that the prepared membranes behave in an ohmic behavior**[10],[11]**.

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

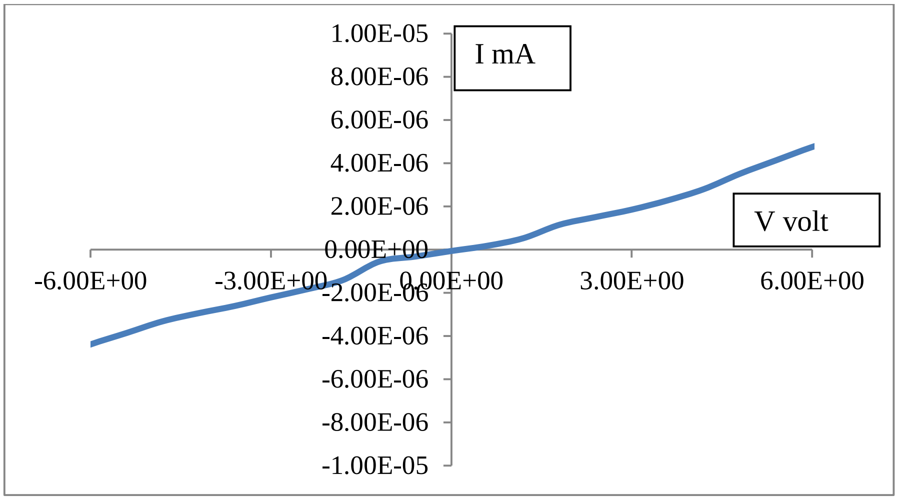

Figure (3) Shows the I-V measurement of the Preparation of thin film CdS.

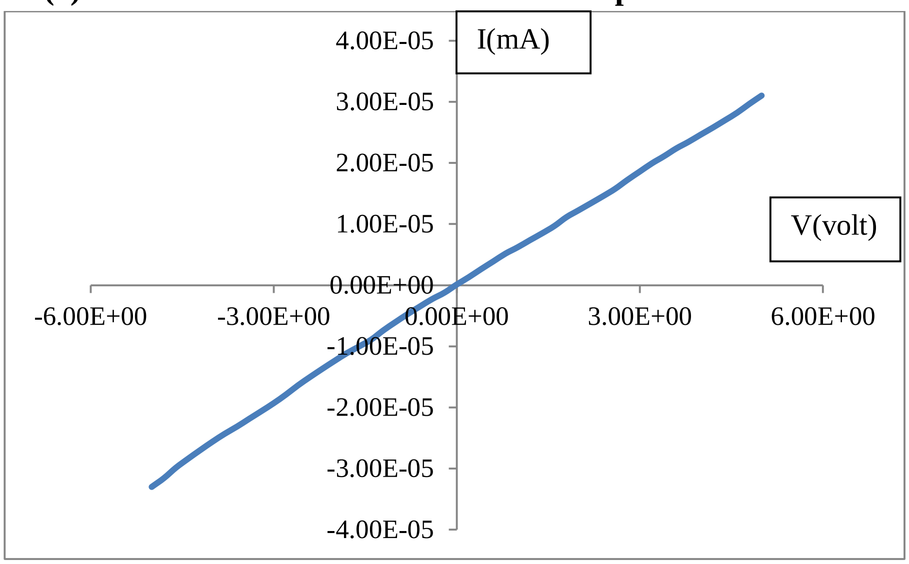

Figure (4) Shows the I-V measurement of the Preparation of thin film CdS:Co.

- **Electrical Conductivity (D.C)**

By studying and measuring the change of the electrical resistance of the prepared films as a function of temperature within the range of (250K-500K), the resistivity was calculated based on equation (1) and the continuous electrical conductivity based on equation (2)**[10],[11]:**

$$\rho = RWt/l \quad (1)$$

$$\sigma = 1/\rho \quad (2)$$

Where : w /width of the electrode, t thickness thin films and L /distance between the electrodes.

Figure (5 and 6) shows the results of measuring the electrical conductivity of the prepared films. Where the results showed that the conductivity increases with the increase of temperature

مجلة جامعة بابل للعلوم الصرفة والتطبيقية
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

and this is a characteristic of semiconductors, where when the temperature increases, the number of electron-hole pairs generated increases, and thus leads to an increase in electrical conductivity.

We notice from the results that the addition of cobalt to the cadmium sulfide compound led to an increase in the electrical conductivity values, and this is attributed to the fact that cobalt worked to form secondary levels within the energy gap that accommodated mobile electrons, and this leads to a decrease in the energy gap and the transition between levels becomes faster, and thus the electrical conductivity increases**[11],[12]**.

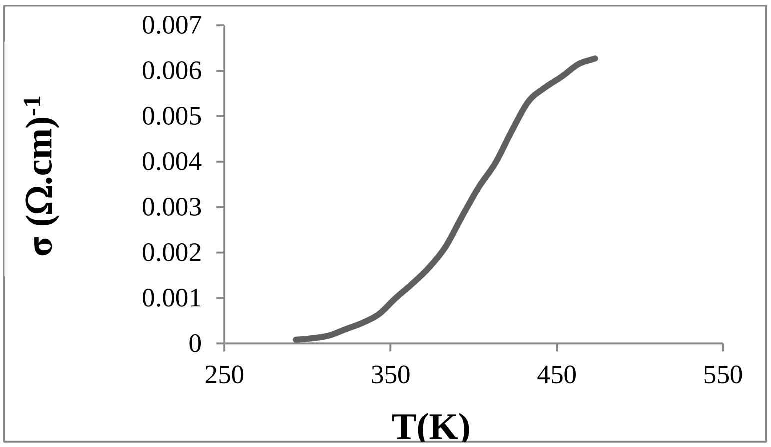

Figure (5) shows the measurement of conductivity as a function of temperature for the membrane of preparation CdS.

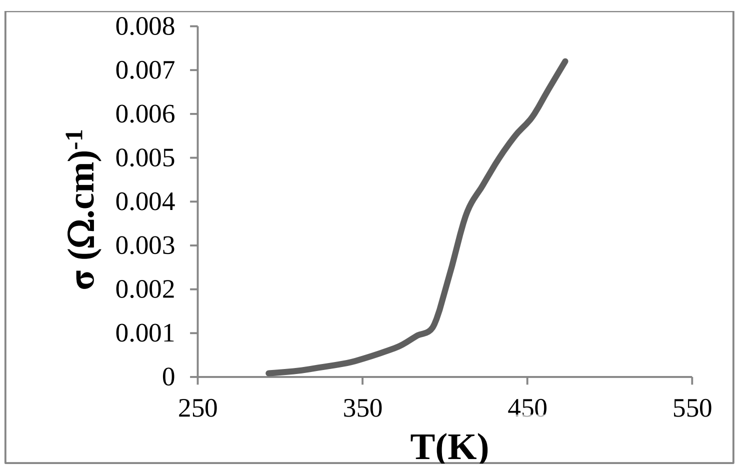

Figure (6) shows the measurement of conductivity as a function of temperature for the membrane of preparation CdS:Co.

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

- **Gas Sensor**

The sensitivity of the prepared films CdS and CdS:Co was studied by measuring the resistance in the absence of gas, and then measuring the resistance in the presence of hydrogen sulfide gas. Figure (7and 8) shows the measurement of the change in resistance of the prepared films with the gas reaction time at a constant operating temperature of 323.5K. We notice from the figures that the amount of resistance changes with the time required to reach a stable state in the case of opening and closing the gas, knowing that the process of opening the gas is a period of time of 5 seconds.

The sensitivity values of the prepared membranes were calculated based on equation (3)**[13]:**

$$S\% = Rg - Ra/Rg \quad (3)$$

Where Ra/ resistance in the absence of gas and Rg/ resistance in the presence of a gas.

The results showed that the highest value of sensitivity was 53% for the prepared cadmium sulfide film, with a response time of 1 second and a recovery time of 2 seconds. While when cobalt was added to the cadmium sulfide compound, it gave a lower sensitivity of 48.62%, with a longer response time of 3 seconds and a recovery time of 52 seconds. The reason for the decrease in the sensitivity values is because the addition of cobalt to the cadmium sulfide compound led to an increase in the granular size and a decrease in the granular boundaries as shown by measurements of 123. This leads to a decrease in the surface area and thus a decrease in the adsorption process for gases, which in turn decreases the sensitivity to hydrogen sulfide gases**[14]-[16]**.

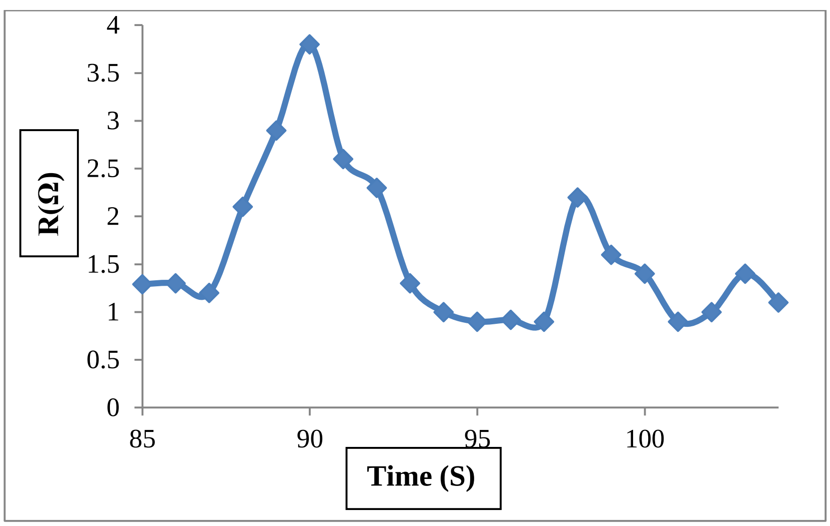

Figure (7) shows the measurement of the resistance as a function of time for the CdS.

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

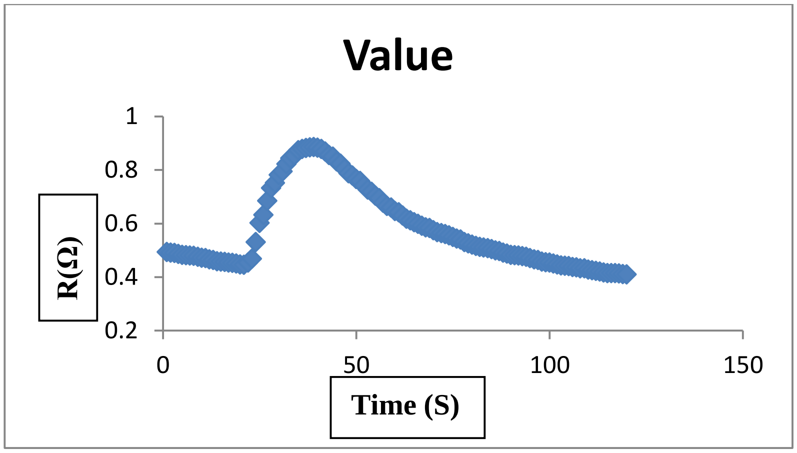

Figure (8) shows the measurement of the resistance as a function of time for the CdS:Co.

Conclusion

Through the results of the transmission electron microscope, it was shown that the shape of the crystalline grains is spherical. The addition of cobalt salts to the cadmium sulfide compound led to an increase in the electrical conductivity values. Current-voltage measurements showed that the prepared films behaved as ohmic. The prepared cadmium sulfide film CdS has a sensitivity to hydrogen sulfide gas that is higher than the sensitivity of the prepared film CdS:Co.

Conflict of interests.

There are non-conflicts of interest.

References

[1] C. Kittle, "Introduction to Solid State Physics ", 4th ed., John Wiley & Sons, New York , London , 1971.
[2] C. Kittle, "Introduction to Solid State Physics", John Wiely and Sons, 1976.
[3] J. P. Enriquez and X. Mathew," Solar Energy Materials and Solar Cells", 76 , p. 313-322 2003.
[4] S. J. Fonash "Solar Cell Device Phys." , Academic Press, New York, 1981.
[5] M. Rami, E. Benamar, M. Fahoume, F. Charabi and A. Ennaoui, "The Effect of CdCl2 and annealing treatments on structural properties of CdS/CdTe heterojunction" M. J. Condensed Matter, 3, 1, , p. 66-70 2000.
[6] S. Shirakata, T. Terasako, and T. Kariya, ''Properties of CuIn $(S_xSe_{1-x})_2$ polycrystalline thin films prepared by chemical spray pyrolysis'', J. Phys. Chem. Solids 66, p. 1970-1973, 2005.
[7] M.M. Mohamed and M.A.Ghanim, M.Khairy, E.Naguib and N.H.Alotaibi "Ultrasound-engineered synthesis of WS2@CeO2 heterostructure for sonocatalytic degradation of tylosin" , Applied surface science, vol.487, Pp.539-549, 2019.
[8] H. Chen, X. Wu and G. Shen, "Hydrothermally Grown ZnO Micro/Nanotube Arrays and Their Properties" Nanoscale Research Letters, Vol. 5, p.570 2010.
[9] V.K. Gupta, S. Rostami, H. Karimi-Male, F. Karimi, M. Keyvanfard, and T.A. Saleh, "Square Wave Voltammetric Analysis of Carbidopa Based on Carbon Paste Electrode Modified with ZnO/CNTs Nanocomposite and n-hexyl-3-methylimidazolium Hexafluoro Phosphate Ionic Liquid", Int. J. Electrochem. Sci., vol. 10, p. 1517 2015.

[10] S. W. Xue, X. T. Zu, W. L. Zhou, H. X. Deng, X. Xiang, L. Zhang and H. Deng, "Effects of post-thermal annealing on the optical constants of ZnO thin film", Journal of Alloys and Compounds, 2008.

[11] S. Saxena, "Polyvinyl Alcohol (PVA)", Chemical and Technical Assessment, First Edition, JECFA, 2004.

[12] D. K. Schroder, "Semiconductor Material and Device Characterization", John Wiley & Sons, New York, Pp.38-40, 1998.

[13] D. Newman, "Semiconductor physics and devices", Basis Principles, Richard, University of New Mexico, vol. 435, p.211 1992.

[14] Saryia D.M AL-Algawi, SelmaM.H Al-Jawad, Noor M. Saadoon, Physical Properties of Indium Tin Oxide (ITO) Nanopartical Thin Films Used as Gas Sensor. Eng. &Tech.Journal,. 33(1), 2015.

[15] H. Banimuslem, A. Hassan, T. Basova, A. Esenpınar, S. Tuncel, M. Durmuş, A. Gürek and V. Ahsen, Sensors and Actuators B: Chemical, vol.34, p.207, 2015.

[16] L. Zhu and W. Zeng, "A self-powered, visible-blind ultraviolet photodetector based on n-Ga:ZnO nanorods/p-GaN heterojunction" , Sensors and Actuators A: Physical, vol. 1, p.267, 2017.

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652