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EFFECT OF ZnS AND CdS ON SOME PHYSICAL PROPERTIES OF MgO FILMS[†]

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This article reports on the fabrication and characterization of MgO nanostructured films and the effect of ZnS and CdS on their structural, optical, and electrical properties. The MgO, MgO: ZnS, and MgO: CdS thin films were deposited using a Chemical spray pyrolysis technique onto glass substrates at 673 K. The XRD patterns revealed that the MgO thin films had a preferred (111) orientation with a pure cubic crystalline structure, while the ZnS and CdS layers had a hexagonal structure. The FE-SEM images showed that the MgO films had a nanostructured morphology with an average particle size of ~50 nm. The UV-Vis spectroscopy results showed that the addition of ZnS and CdS layers to the MgO films resulted in a shift in the absorption edge towards the visible region of the electromagnetic spectrum, indicating an improvement in their optical properties. These findings suggest that the MgOZnS and MgOCdS films could have potential applications in optoelectronic devices.
Keywords: *MgO films; Doping Effect; ZnS; CdS; Chemical spray pyrolysis; Physical properties*
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INTRODUCTION

Magnesium oxide (MgO) thin films have been studied for their potential use in a variety of applications, including as a dielectric material for microelectronic devices [1,2], To improve the performance of these devices, it is often necessary to introduce dopants into the MgO film. Doping involves introducing impurity atoms into the lattice structure of the MgO film to modify its electrical properties [3,4], Commonly used dopants for MgO include boron, phosphorus, and aluminum. These dopants can be introduced into the film during growth by adding them to the source material or by using ion implantation techniques, The effects of doping on the electrical properties of MgO thin films depend on both the type and concentration of dopant used. Generally, boron doping results in an increase in conductivity while phosphorus and aluminum doping results in a decrease in conductivity [5,6]. Magnesium oxide (MgO) thin films can be used to dope ZnS and CdS semiconductor materials. This doping process involves depositing a thin layer of MgO onto the surface of the ZnS or CdS material. The MgO acts as an acceptor dopant, meaning that it can donate electrons to the semiconductor material, thus increasing its conductivity [7,8], This process is often used in optoelectronic devices like solar cells. By doping ZnS and CdS with MgO, it is possible to improve their electrical properties, making them more suitable for use in these types of devices [9,10]. Chemical spray pyrolysis is a technique used to deposit thin films of semiconductor materials such as ZnS and CdS onto substrates. This technique involves spraying a solution of the desired material onto the substrate, followed by heating the substrate in an oven to evaporate the solvent and decompose the material into its constituent elements [11,12], The resulting thin film is then annealed at high temperatures to improve its crystallinity and electrical properties. Doping CdS and ZnS with magnesium oxide (MgO) can be achieved using chemical spray pyrolysis by adding MgO to the solution before spraying it onto the substrate, The MgO will then be incorporated into the thin film during pyrolysis, resulting in a doped semiconductor material [13], The doping concentration can be controlled by adjusting the concentration of MgO in the solution, as well as by varying other parameters such as temperature and time[14,15]. The goal of this research is to study the effect of ZnS and CdS on MgO films on the structural, optical, and electrical properties, The research will focus on understanding the influence of doping on the XRD, Energy gap, absorption coefficient, refractive index, and electrical conductivity of the thin films.

EXPERIMENTAL PART

Spray pyrolysis was used to deposit MgO,(MgO: ZnS), and (MgO: CdS) films. Magnesium chloride ($MgCl_2.6H_2O$), zinc nitrate ($Zn(NO_3).6H_2O$), cadmium chloride ($CdCl2.6H_2O$), and thiourea (CH_4N_2S) dissolved in distilled water with molarity (0.1M). (MgO) doped with 8% (ZnS) and (CdS). The chemical solution was sprayed onto glass substrates at 673K using a 1.5 bar compressor. The structural characteristics were determined using X-ray diffraction, field emission scanning electron microscopy, and An ultraviolet-visible (UV-Vis) spectrophotometer was used to measure the optical characteristics. and Hall effect measurement was used to determine the electrical properties.

RESULTS AND DISCUSSION

Figure (1) shows the X-ray diffraction patterns of (MgO) films doped with (CdS) and (ZnS). Table (1) shows the values of the diffraction angles, the width of the mid-peak, the crystal size, and the interlayer distances separating the

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$$n_o = \left[\frac{(1+R)^2}{(1-R)^2} - (k_o^2 - 1)\right]^{\frac{1}{2}} + \frac{(1+R)}{(1-R)} \quad (1)$$

The extinction coefficient of MgO films doped with CdS and ZnS can also be affected by the type and concentration of the dopants. The addition of ZnS and CdS to MgO films can increase the extinction coefficient due to the presence of larger particles with a higher degree of light scattering [3,4]. To determine the extinction coefficient (ko), equation (2) can be used [35] .

$$k_o = \frac{\alpha\lambda}{4\pi} \quad (2)$$

The refractive index and extinction coefficient of MgO films are shown in Figure (5).

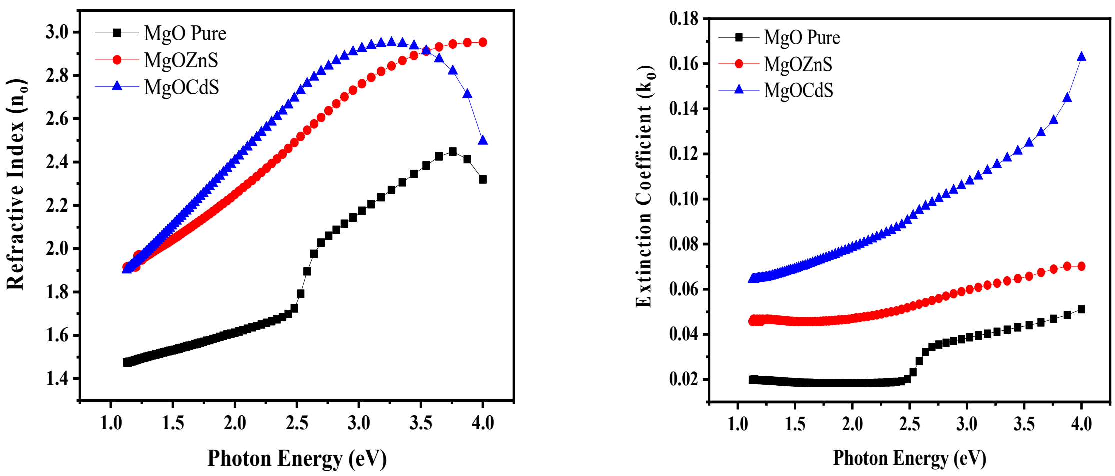

Figure 5. Refractive index and Extinction Coefficient of of MgO films doped with (CdS) and (ZnS)

The dielectric constant of a material is typically given by a complex quantity, with a real part (εr) and an imaginary part (εi) that relate to the material's ability to store and dissipate energy in an electric field, respectively. Equations (3) and (4) establish a relationship between the behavior of the real dielectric constant and the refractive index, as well as the imaginary dielectric constant and the extinction coefficient[36].

$$\varepsilon_r = n_\circ^2 - k_\circ^2 \quad (3)$$

$$\varepsilon_i = 2n_\circ k_\circ \quad (4)$$

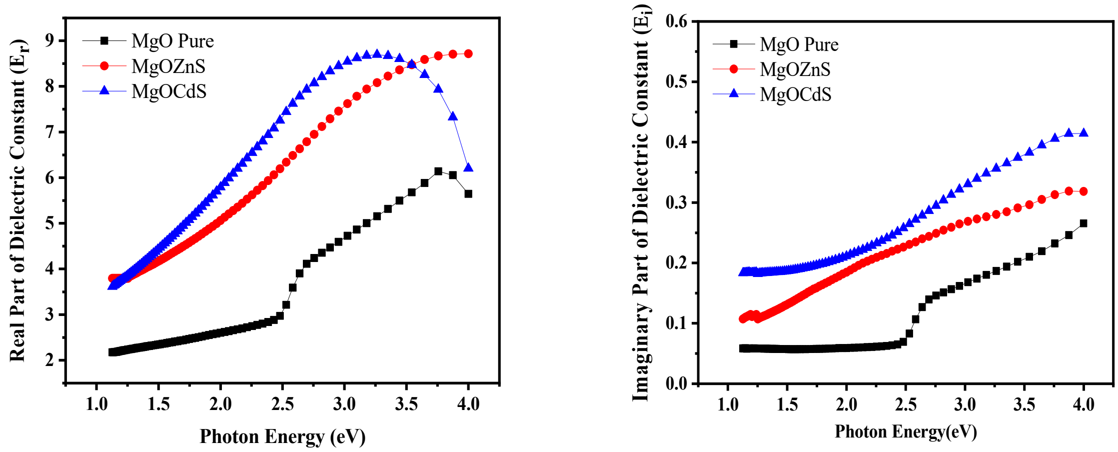

Figure 6. The real and imaginary part of the dielectric constant of MgO films doped with (CdS) and (ZnS).

MgO films doped with CdS and ZnS have been shown to have changes in their electrical properties . After studying Hall effect measurements of (MgO) thin films doped with ZnS and CdS at a 6% ratio, it was discovered that both types of films had negative charge carriers, as evidenced by the negative Hall coefficient (RH). This finding is consistent with previous research [36], The resistivity values of all films were observed to be high, with the films doped with ZnS and

CdS exhibiting the highest values. These high resistivity values are attributed to defects in the crystal structure of the film, which hinder the movement of charge carriers [37].

Table 2. Electrical Properties of MgO, MgO:ZnS , MgO:CdS Films.

Samples	Concentration $(cm)^{-3}$	Hall Coefficient Rh (m^2/C)	Conductivity $(\Omega.cm)^{-1}$	Resistivity $(\Omega.cm)$	Mobility $(cm^2/v.s)$
MgO	$2.584x10^6$	$2.416x10^7$	$1.035x10^{-5}$	$9.662x10^4$	$2.500x10^2$
MgO:ZnS	$4.325x10^7$	$-2.886x10^6$	$5.337x10^{-7}$	$1.874x10^7$	$1.540x10^1$
MgO:CdS	$4.953x10^6$	$-3.781x10^7$	$1.309x10^{-5}$	$7.638x10^4$	$4.950x10^2$

CONCLUSION

The structural and optical properties of magnesium oxide (MgO) films can be significantly influenced by the incorporation of zinc sulfide and cadmium sulfide, These compounds, when added to MgO films, can cause noteworthy changes, including an increase in the refractive index, a reduction in the band gap, and an elevation in the optical absorption coefficient, Various techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), UV-visible spectroscopy, and Electrical Properties have been employed in several studies to investigate these effects, The findings conclusively demonstrate the substantial impact of zinc sulfide and cadmium sulfide additions on both the structural and optical characteristics of MgO films, These findings hold promising potential for applications like antireflective coatings and other optoelectronic devices.

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REFERENCES

[1] R. Kant, A.K. Singh, and A. Arora, "Tuning of MgO nanoparticles on Ag dopant additions for charge storage applications," Vacuum, **189**, 110247 (2021). https://doi.org/10.1016/j.vacuum.2021.110247
[2] F.A. Miranda, G. Subramanyam, F.W. Van Keuls, R.R. Romanofsky, J.D. Warner, and C.H. Mueller, "Design and development of ferroelectric tunable microwave components for Kuand K-band satellite communication systems," IEEE Transactions on Microwave Theory and Techniques, **48**(7), 1181-1189 (2000). https://doi.org/10.1109/22.853458
[3] K. Gao, Q. Bi, X. Wang, W. Liu, C. Xing, K. Li, D. Xu, *et al.,*"Progress and Future Prospects of Wide-Bandgap Metal-Compound-Based Passivating Contacts for Silicon Solar Cells," Advanced Materials, **34**(26), 2200344 (2022). https://doi.org/10.1002/adma.202200344
[4] S.S. Chiad, N.F. Habubi, W.H. Abass, and M.H. Abdul-Allah, "Effect of thickness on the optical and dispersion parameters of Cd0. 4Se0. 6 thin films," Journal of Optoelectronics and Advanced Materials, **18**(9-10), 822-826 (2016).
[5] Y. Liu, Y. Li, Y. Wu, G. Yang, L. Mazzarella, P. Procel-Moya, A.C. Tamboli, *et al.*,"High-efficiency silicon heterojunction solar cells: materials, devices and applications," Materials Science and Engineering: R: Reports, **142**, 100579 (2020). https://doi.org/10.1016/j.mser.2020.100579
[6] Q. Liu, G. M. Dalpian, and A. Zunger, "Antidoping in insulators and semiconductors having intermediate bands with trapped carriers," Physical Review Letters, **122**(10), 106403 (2019). https://doi.org/10.1103/PhysRevLett.122.106403
[7] Z. Zhang, X.E. Verykios, and M. Baerns, "Effect of electronic properties of catalysts for the oxidative coupling of methane on their selectivity and activity," Catalysis Reviews, **36**(3), 507-556 (1994). https://doi.org/10.1080/01614949408009470
[8] A. Mahroug, B. Mari, M. Mollar, I. Boudjadar, L. Guerbous, A. Henni, and N. Selmi, "Studies on structural, surface morphological, optical, luminescence and Uv photodetection properties of sol–gel Mg-doped ZnO thin films," Surface Review and Letters, **26**(03), 1850167 (2019). https://doi.org/10.1142/S0218625X18501676
[9] A.T. Abood, O.A.A. Hussein, M.H. Al-Timimi, M.Z. Abdullah, H.M.S. Al Aani, and W.H. Albanda, "Structural and optical properties of nanocrystalline SnO_2 thin films growth by electron beam evaporation," AIP Conference Proceedings, **2213**(1), 020036 (2020). https://doi.org/10.1063/5.0000454
[10] A.V. Rane, K. Kanny, V.K. Abitha, and S. Thomas, "Methods for synthesis of nanoparticles and fabrication of nanocomposites," in: *Synthesis of inorganic nanomaterials*, (Woodhead publishing, 2018), pp. 121-139.
[11] M.H. Abdullal, R.A. Jaseen, and A.H. Resan, "Annealing effect on the optical energy gap of (CdTe) thin films," J. Pure Sciences, **7**(3), 205-213 (2011). https://www.iasj.net/iasj/pdf/ccf116d82c221e01
[12] A.B. Workie, H.S. Ningsih, and S.J. Shih, "An comprehensive review on the spray pyrolysis technique: historical context, operational factors, classifications, and product applications," Journal of Analytical and Applied Pyrolysis, **170**, 105915. (2023). https://doi.org/10.1016/j.jaap.2023.105915
[13] Z.X. Tang, and B.F. Lv, "MgO nanoparticles as antibacterial agent: preparation and activity," Brazilian Journal of Chemical Engineering, **31**, 591-601 (2014). http://dx.doi.org/10.1590/0104-6632.20140313s00002813
[14] A.J. Mawat, M.H. Al-Timimi, W.H. Albanda, and M.Z. Abdullah, "Morphological and optical properties of Mg1-xCdSx nanostructured thin films," AIP Conference Proceedings, **2475**(1), 090019) (2023). https://doi.org/10.1063/5.0103955
[15] H.S. Al-Rikabi, M.H. Al-Timimi, A.H. Abed, and W. Albanda, "Surface Topography and Optical Properties for $(MgO_{x-1}ZnS_x)$ Thin Films Prepared by Chemical Spray Pyrolysis," Diyala Journal for Pure Science, **18**(4), (2022). https://djfps.uodiyala.edu.iq/index.php/Home/article/view/36
[16] W. Cui, P. Li, Z. Wang, S. Zheng, and Y. Zhang, "Adsorption study of selenium ions from aqueous solutions using MgO nanosheets synthesized by ultrasonic method," Journal of Hazardous materials, **341**, 268-276 (2018). https://doi.org/10.1016/j.jhazmat.2017.07.073
[17] G.C. Ozcan, H.M. Gubur, S. Alpdogan, and B.K. Zeyrek, "The investigation of the annealing temperature for CdS cauliflower-like thin films grown by using CBD," Journal of Materials Science: Materials in Electronics, **27**, 12148-12154 (2016). https://doi.org/10.1007/s10854-016-5368-6

[18] A.J. Mawat, and M.H. AL-Timimi, “Structural Properties of ($MgO_{1-x}CdS_x$) Thin Films Prepared by Chemical Spray Pyrolysis technique,” Journal of the college of basic education, **27**(113) (2021). https://www.iasj.net/iasj/pdf/8e0e961ca70b4e80
[19] S. Barth, F. Hernandez-Ramirez, J.D. Holmes, and A. Romano-Rodriguez, “Synthesis and applications of one-dimensional semiconductors,” Progress in Materials Science, **55**(6), 563-627 (2010). https://doi.org/10.1016/j.pmatsci.2010.02.001
[20] N. Izyumskaya, Y.I. Alivov, S.J. Cho, H. Morkoç, H. Lee, and Y.S. Kang, “Processing, structure, properties, and applications of PZT thin films,” Critical reviews in solid state and materials sciences, **32**(3-4), 111-202 (2007). https://doi.org/10.1080/10408430701707347
[21] M. Afrooz, H. Dehghani, S.S. Khalili, and N. Firoozi, “Effects of cobalt ion doped in the ZnS passivation layer on the TiO_2 photoanode in dye sensitized solar cells based on different counter electrodes,” Synthetic Metals, **226**, 164-170 (2017). https://doi.org/10.1016/j.synthmet.2017.02.012
[22] Y. Liu, J. Hua, K. Zhang, J. Zhao, and H. Li, “Effect of MgO shell on electron transfer from Cu doped ZnInS quantum dots to FePt nanoparticles.,” Materials Research Bulletin, **103**, 242-246 (2018). https://doi.org/10.1016/j.synthmet.2017.02.012
[23] H.S. Al-Rikabi, M.H. Al-Timimi, and W.H. Albanda, “Morphological and optical properties of $MgO_{1-x}ZnS_x$ thin films,” Digest Journal of Nanomaterials and Biostructures, **17**(3), (2022). https://doi.org/10.15251/DJNB.2022.173.889
[24] V.S.G.Krishna, S.R. Maidur, P.S. Patil, and M.G. Mahesha, “Role of copper dopant in two-photon absorption and nonlinear optical properties of sprayed ZnS thin films for optical limiting applications,” Physics Letters A, **398**, 127276 (2021). https://doi.org/10.1016/j.physleta.2021.127276
[25] M. Ostadebrahim, and H. Dehghani, “$ZnS/CdSe_{0.2}S_{0.8}/ZnSSe$ heterostructure as a novel and efficient photosensitizer for highly efficient quantum dot sensitized solar cells,” Applied Surface Science, **545**, 148958 (2021). https://doi.org/10.1016/j.apsusc.2021.148958
[26] L. Ma, X. Ai, and X. Wu, “Effect of substrate and Zn doping on the structural, optical and electrical properties of CdS thin films prepared by CBD method,” Journal of Alloys and Compounds, **691**, 399-406 (2017). https://doi.org/10.1016/j.jallcom.2016.08.298
[27] Z.M. Kakhaki, A.A. Youzbashi, P. Sangpour, N. Naderi, and Y. Orooji, “Influence of Cd salt concentration on the photoconductivity of CdS thin films prepared by chemical bath technique,” Materials Science in Semiconductor Processing, **148**, 106773 (2022). https://doi.org/10.1016/j.mssp.2022.106773
[28] T.A. Wassner, B. Laumer, S. Maier, A. Laufer, B.K. Meyer, M. Stutzmann, and M. Eickhoff, “Optical properties and structural characteristics of ZnMgO grown by plasma assisted molecular beam epitaxy,” Journal of Applied Physics, **105**(2), 023505 (2009). https://doi.org/10.1063/1.3065535
[29] I. Marozau, A. Shkabko, M. Döbeli, T. Lippert, D. Logvinovich, M. Mallepell, *et al.,* “Optical properties of nitrogen-substituted strontium titanate thin films prepared by pulsed laser deposition,” Materials, **2**(3), 1388-1401 (2009). https://doi.org/10.3390/ma2031388
[30] R Bairy, and K.N. Narasimhamurthy, “Effect of annealing temperature on optimizing the structural, linear–nonlinear optical properties of $Cd_{1-x}Zn_xS$ nanocrystalline thin films,” Optical and Quantum Electronics, **53**(10), 579 (2021). https://doi.org/10.1007/s11082-021-03215-0
[31] R. Suganya, A. Revathi, D. Sudha, V. Sivaprakash, and E.R. Kumar, “Evaluation of structural, optical properties and photocatalytic activity of Ag_2O coated ZnO nanoparticles,” Journal of Materials Science: Materials in Electronics, **33**(29), 23224-23235 (2022). https://doi.org/10.1007/s10854-022-09086-9
[32] S. Yasmeen, F. Iqbal, T. Munawar, M.A. Nawaz, M. Asghar, and A. Hussain, “Synthesis, structural and optical analysis of surfactant assisted ZnO–NiO nanocomposites prepared by homogeneous precipitation method,” Ceramics International, **45**(14), 17859-17873 (2019). https://doi.org/10.1016/j.ceramint.2019.06.001
[33] M.H. Saeed, M.H. Al-Timimi, and O.A.A. Hussein, “Structural, morphological and optical characterization of nanocrystalline WO_3 thin films,” Digest Journal of Nanomaterials and Biostructures, **16**(2), 563-569 (2021). https://chalcogen.ro/563_SaeedMH.pdf
[34] H. Ghasemi, M.H. Mozaffari, and R. Moradian, “Effects of deposition time on structural and optical properties of ZnS and ZnS/Au thin films grown by thermal evaporation,” Physica B: Condensed Matter, **627**, 413616 (2022). https://doi.org/10.1016/j.physb.2021.413616
[35] H. Ali, A. Falak, M.A. Rafiq, U. Khan, S. Karim, A., Nairan, *et al.,* “Temperature dependent dielectric and electric modulus properties of ZnS nano particles,” Semiconductor Science and Technology, **32**(3), 035008 (2017). https://doi.org/10.1088/1361-6641/aa539c
[36] W.D. Park, “Optical constants and dispersion parameters of CdS thin film prepared by chemical bath deposition,” Transactions on Electrical and Electronic Materials, **13**(4), 196-199 (2012). https://doi.org/10.4313/TEEM.2012.13.4.196
[37] J. Tauc, R. Grigorovici, and A. Vancu, “Optical properties and electronic structure of amorphous germanium,” Physica Status Solidi (b), **15**(2), 627-637 (1966). https://doi.org/10.1002/pssb.19660150224

ВПЛИВ ZnS ТА CdS НА ДЕЯКІ ФІЗИЧНІ ВЛАСТИВОСТІ ПЛІВОК MgO

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У цій статті повідомляється про виготовлення та характеристику наноструктурованих плівок MgO та вплив ZnS і CdS на їхні структурні, оптичні та електричні властивості. Тонкі плівки MgO, MgO: ZnS і MgO: CdS були нанесені за допомогою техніки піролізу хімічним розпиленням. на скляні підкладки при 673 K. Рентгенограми показали, що тонкі плівки MgO мають переважну (111) орієнтацію з чистою кубічною кристалічною структурою, тоді як шари ZnS і CdS мають гексагональну структуру. Зображення FE-SEM показали, що плівки MgO мають наноструктуровану морфологію із середнім розміром частинок ~50 нм. Результати УФ-видимої спектроскопії показали, що додавання шарів ZnS і CdS до плівок MgO призвело до зміщення краю поглинання у бік видимої області електромагнітного спектру, що вказує на покращення їх оптичних властивостей. Ці знахідки свідчать про те, що плівки MgOZnS і MgOCdS можуть мати потенційне застосування в оптоелектронних пристроях.

Ключові слова: *плівки MgO; допінг ефект; ZnS; CdS; хімічний розпилювальний піроліз; фізичні властивості*