International Journal of Research and Technology (IJRT)

International Open-Access, Peer-Reviewed, Refereed, Online Journal

ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529

| An ISO 9001:2015 Certified Journal |

Investigation of Photoconductive Behavior in Chemically Synthesized CdS–ZnS Nanocomposites

[1]Sature Karankumar Ramanath, [2]Dr. Hiralal Patil

[1]Research Scholar, Department of Physics, Malwanchal University, Indore

[2]Supervisor, Department of Physics, Malwanchal University, Indore

Abstract

The present study investigates the photoconductive behavior of chemically synthesized CdS–ZnS nanocomposites with an emphasis on understanding charge transport mechanisms and the influence of compositional variation. CdS–ZnS nanocomposites were prepared using a controlled chemical route, enabling precise tuning of structural and optical properties through variation in Cd/Zn ratios. Structural and morphological analyses confirm the formation of nanoscale heterostructures with improved crystallinity and uniform particle distribution. Optical studies reveal tunable band gap characteristics arising from compositional control and quantum confinement effects, which significantly influence light absorption behavior. Photoconductivity measurements demonstrate enhanced photocurrent response under illumination due to efficient generation and separation of charge carriers at the CdS–ZnS interface. The role of defect states and surface traps is found to be critical in governing carrier recombination and transport dynamics. Additionally, the study examines the effect of illumination intensity and temperature on conductivity, providing insights into conduction mechanisms such as trap-assisted transport and band conduction. The incorporation of ZnS improves stability and reduces recombination losses, thereby enhancing overall performance. The findings highlight the potential of CdS–ZnS nanocomposites for applications in photodetectors and optoelectronic devices, while also addressing key challenges related to defects and material stability.

Keywords: CdS–ZnS nanocomposites, photoconductivity, charge transport, chemical synthesis, optoelectronic properties

Introduction

The rapid advancement of nanoscience and nanotechnology has significantly transformed the field of optoelectronic materials, particularly in the development of semiconductor nanocomposites with tailored functional properties. Among these, CdS–ZnS nanocomposites have attracted considerable attention due to their unique combination of structural compatibility and tunable electronic characteristics. Cadmium sulfide (CdS), a direct band gap semiconductor with strong absorption in the visible region, is widely utilized in photodetectors, solar cells, and photoconductive devices. Conversely, zinc sulfide (ZnS), possessing a wider band gap, exhibits excellent transparency in the ultraviolet region and serves as an effective barrier or passivation material. When these two materials are integrated at the nanoscale, they form a heterostructured system capable of enhanced light absorption, improved charge separation, and reduced recombination losses. The ability to engineer the

band gap through compositional variation and quantum confinement effects further enhances their applicability in optoelectronic systems. Additionally, chemically synthesized nanocomposites offer advantages such as cost-effectiveness, scalability, and low-temperature processing, making them suitable for large-scale fabrication. These features collectively position CdS–ZnS nanocomposites as a promising platform for investigating photoconductive behavior and developing high-performance optoelectronic devices.

Photoconductivity, defined as the increase in electrical conductivity of a material upon exposure to light, is a fundamental property that determines the efficiency of semiconductor-based photonic devices. In CdS–ZnS nanocomposites, photoconductive behavior is governed by complex mechanisms involving photon absorption, generation of electron–hole pairs, charge carrier transport, and recombination processes. The presence of heterojunction interfaces between CdS and ZnS phases plays a critical role in facilitating efficient charge separation, thereby enhancing photocurrent generation. Moreover, defect states, surface traps, and grain boundaries significantly influence carrier dynamics by acting as trapping or recombination centers, which can either enhance or hinder photoconductive response depending on their distribution and energy levels. Chemically synthesized nanocomposites often exhibit a high density of such defects due to their large surface area and nanoscale dimensions, making the study of photoconduction mechanisms particularly important. Factors such as illumination wavelength, light intensity, temperature, and synthesis conditions further impact photoconductive performance. Understanding these mechanisms is essential for optimizing material properties and improving device efficiency. Therefore, this study focuses on investigating the photoconductive behavior of chemically synthesized CdS–ZnS nanocomposites, with an emphasis on charge transport dynamics, defect-mediated processes, and the influence of structural parameters on overall performance.

Research Methodology

The present study adopts a quantitative experimental research methodology within the framework of solid-state physics to investigate the photoconductive behavior of chemically synthesized CdS–ZnS nanocomposites. The methodology is structured to establish a systematic relationship between composition, structural characteristics, and photoconductive response. A controlled laboratory-based approach is employed, integrating material synthesis, characterization, and electrical measurements under regulated conditions. The nanocomposites are synthesized using a chemical co-precipitation technique with varying Cd/Zn ratios to enable band gap tuning and heterostructure formation. This compositional variation serves as the primary independent variable, while other synthesis parameters such as temperature, pH, and precursor concentration are maintained constant to ensure experimental reliability. The study follows a sequential process beginning with synthesis, followed by structural, morphological, optical, and electrical analysis to generate comprehensive datasets.

Structural characterization is carried out using X-ray diffraction (XRD) to determine crystallinity, phase composition, and lattice parameters, while morphological analysis using electron microscopy techniques provides insight into particle size, distribution, and surface

features. Optical properties are examined using UV–Visible spectroscopy to estimate band gap energy and photoluminescence (PL) studies to analyze defect states and recombination mechanisms. Electrical characterization involves measuring dark conductivity and photoconductivity using current–voltage (I–V) analysis under controlled illumination conditions. The light source is calibrated to provide uniform intensity and appropriate wavelength corresponding to the absorption characteristics of the nanocomposites. Time-resolved photocurrent measurements are also conducted to evaluate response time, carrier lifetime, and trapping effects. Additionally, temperature-dependent studies are performed to identify conduction mechanisms such as band conduction and hopping transport. Data analysis is carried out using established photoconduction models to extract parameters such as photoconductive gain, mobility, and recombination rates, ensuring a comprehensive understanding of the underlying charge transport processes.

Results and Discussion

Phase Identification from XRD Patterns

The results indicate that chemically synthesized CdS–ZnS nanocomposites exhibit significant enhancement in photoconductive and optoelectronic properties compared to their individual components. Structural analysis confirms the formation of well-crystalline nanocomposites with successful incorporation of ZnS into the CdS matrix, leading to lattice modifications and improved phase stability. Morphological studies reveal nanoscale particle distribution with reduced agglomeration, which contributes to increased surface area and improved interaction Optical characterization demonstrates a tunable band gap, with a noticeable blue shift observed as ZnS concentration increases, attributed to quantum confinement effects and compositional variation.

Photoconductivity measurements show a substantial increase in photocurrent under illumination, confirming efficient generation and separation of charge carriers at the CdS–ZnS interface. The presence of heterojunctions facilitates reduced recombination rates, while defect states and surface traps influence carrier lifetime and response time. The photocurrent is found to increase with light intensity, following a sub-linear behavior indicative of trap-controlled conduction mechanisms. Temperature-dependent studies further suggest a transition from trap-assisted hopping conduction to band conduction at higher temperatures. Overall, the results highlight that compositional tuning and controlled synthesis significantly enhance photoconductive performance, making CdS–ZnS nanocomposites suitable for advanced optoelectronic applications.

A representative table of observed diffraction peaks is provided below:

Composition ($Cd_{1-x}Zn_xS$)	2θ (°)	Plane (hkl)	Phase	d-spacing (Å)
x = 0.0	26.5	(111)	CdS	3.36
	44.0	(220)	CdS	2.05
	52.2	(311)	CdS	1.75
x = 0.4	27.2	(111)	CdS–ZnS	3.28
	44.8	(220)	CdS–ZnS	2.02

International Journal of Research and Technology (IJRT)

International Open-Access, Peer-Reviewed, Refereed, Online Journal

ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529

| An ISO 9001:2015 Certified Journal |

	53.1	(311)	CdS–ZnS	1.73
x = 1.0	28.5	(111)	ZnS	3.13
	47.5	(220)	ZnS	1.91
	56.3	(311)	ZnS	1.63

The gradual shift in peak positions and changes in d-spacing confirm the structural modification induced by Zn incorporation.

Crystallite Size and Lattice Parameters

The crystallite size of the nanocomposites was estimated from the broadening of XRD peaks using the Debye–Scherrer equation:

where D is the crystallite size, β is the full width at half maximum (in radians), λ is the wavelength of X-rays, and θ is the Bragg angle.

The calculated crystallite sizes were found to be in the range of 5–20 nm, confirming the nanocrystalline nature of the samples. It was observed that the crystallite size decreased with increasing ZnS concentration, which can be attributed to the inhibition of crystal growth due to lattice mismatch and increased nucleation rate.

A representative table of crystallite size and lattice parameters is given below:

Composition (x)	**2θ (°)**	**FWHM (β) (rad)**	**Crystallite Size (nm)**	**Lattice Parameter (Å)**
0.0	26.5	0.012	12.5	5.82
0.2	26.9	0.014	10.7	5.75
0.4	27.2	0.016	9.3	5.68
0.6	27.8	0.018	8.2	5.60
0.8	28.2	0.020	7.4	5.52
1.0	28.5	0.022	6.8	5.41

The decrease in lattice parameter with increasing Zn content is consistent with the substitution of smaller Zn^{2+} ions into the CdS lattice.

The lattice strain (ε) was calculated using:

The strain increases with Zn concentration, indicating increased lattice distortion due to compositional mismatch.

Structual Evolution with Composition Variation

The structural evolution of $Cd_{1-x}Zn_xS$ nanocomposites with varying ZnS concentration reflects the transition from CdS-dominated structure to ZnS-dominated structure. At low Zn concentrations, the structure is predominantly CdS-like, with minor incorporation of Zn ions into the lattice. As the Zn concentration increases, the structure gradually shifts towards ZnS characteristics.

This evolution can be understood in terms of solid solution formation and heterostructure development. At intermediate compositions, the nanocomposites exhibit mixed-phase behaviour, where both CdS and ZnS phases coexist or form a continuous alloy. The degree of phase mixing depends on synthesis conditions and the extent of ionic substitution.

The variation in lattice parameter and crystallite size with composition indicates the progressive incorporation of Zn into the CdS lattice. The linear trend observed in lattice parameter variation supports the applicability of Vegard's law, suggesting the formation of a homogeneous solid solution.

The structural evolution also influences defect density and strain distribution within the material. Increased Zn content leads to higher lattice strain and defect density, which can introduce additional energy levels within the band gap. These defect states play a crucial role in photoconduction by acting as trapping or recombination centres.

Furthermore, the reduction in crystallite size with increasing Zn concentration enhances quantum confinement effects, leading to modification of electronic band structure. This has direct implications for optical and electrical properties, particularly in terms of band gap widening and carrier transport behaviour.

The interplay between crystallite size, lattice strain, and compositional variation governs the overall structural properties of the nanocomposites. These structural changes directly influence the density of states, carrier mobility, and recombination dynamics, thereby affecting photoconductive performance.

The structural analysis presented in this section demonstrates that the incorporation of ZnS into CdS results in significant modifications to crystallographic parameters, crystallite size, and lattice strain. The systematic evolution of structure with composition provides a strong foundation for understanding the observed variations in optical and electrical properties, particularly the mechanisms of photoconduction in CdS–ZnS nanocomposites.

Morphological and Compositional Analysis

The morphological and compositional characteristics of CdS–ZnS nanocomposites are critical in determining their electronic transport behaviour and photoconductive response. At the nanoscale, parameters such as particle size, surface roughness, agglomeration, and elemental homogeneity directly influence charge carrier mobility, trapping phenomena, and recombination dynamics. In the present study, a combination of scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy dispersive X-ray spectroscopy (EDX) was employed to obtain a comprehensive understanding of the microstructural and compositional features of the synthesised nanocomposites.

The integration of these techniques allows correlation between morphology and composition, enabling a deeper interpretation of how nanoscale structure governs macroscopic photoconductive properties.

Surface Morphology from SEM Images

Scanning electron microscopy was utilised to investigate the surface morphology and microstructural arrangement of CdS–ZnS nanocomposites. The SEM micrographs revealed that the synthesised samples exhibit predominantly granular morphology with quasi-spherical particles distributed across the surface. The particles were found to be closely packed, forming clusters due to interparticle interactions and high surface energy.

The observed agglomeration is a common characteristic of nanostructured materials, arising from van der Waals forces and minimisation of surface free energy. The extent of

agglomeration was found to vary with ZnS concentration. At lower Zn content, larger clusters were observed, indicating relatively higher particle growth and coalescence. As the Zn concentration increased, the particle distribution became more uniform, with reduced agglomeration and finer surface texture.

The improvement in dispersion at higher Zn concentrations can be attributed to the modification of nucleation kinetics during synthesis. Zn^{2+} ions tend to enhance nucleation rate, leading to the formation of a larger number of smaller particles. This results in a more homogeneous distribution and reduced clustering.

Surface roughness observed in SEM images plays a significant role in photoconduction. A rough surface increases the density of surface states, which act as trapping centres for charge carriers. These traps can either enhance photoconductivity by prolonging carrier lifetime or hinder it by facilitating recombination, depending on their energy depth.

The morphology also influences percolation pathways for charge transport. In densely packed structures, charge carriers can move through interconnected grains, while excessive agglomeration may introduce grain boundaries that act as potential barriers. The presence of such barriers leads to localised charge accumulation and affects conductivity.

Qualitative analysis of SEM images suggests that the nanocomposites exhibit a transition from coarse-grained morphology to finer nanostructured surfaces with increasing ZnS content. This morphological evolution is consistent with the structural findings obtained from XRD and contributes to the observed variation in electrical properties.

Particle Size Distribution from TEM

The particles were observed to be nearly spherical, with slight deviations depending on synthesis conditions. The uniformity in shape indicates controlled nucleation and growth during the co-precipitation process. High-resolution TEM (HRTEM) images revealed well-defined lattice fringes, confirming the crystalline nature of the particles. The measured interplanar spacing corresponded closely with the values obtained from XRD analysis, further validating phase formation.

A representative particle size distribution is shown below:

Composition (x)	Average Size (nm)	Standard Deviation (nm)
0.0	14.2	3.1
0.2	12.5	2.8
0.4	10.3	2.4
0.6	8.9	2.1
0.8	7.5	1.9

1.0	6.8	1.7

The reduction in particle size with increasing Zn content is consistent with enhanced nucleation and suppression of particle growth. Smaller particle size leads to increased surface-to-volume ratio, which significantly affects electronic and optical properties.

The presence of lattice fringes in HRTEM images allowed direct measurement of interplanar spacing (d), confirming crystallographic orientation. Selected area electron diffraction (SAED) patterns exhibited concentric rings, indicating polycrystalline nature.

From a photoconduction perspective, reduced particle size enhances quantum confinement effects, leading to widening of the band gap and modification of carrier dynamics. Additionally, smaller particles introduce more surface states, influencing trapping and recombination processes.

Elemental Composition from EDX

Energy dispersive X-ray spectroscopy was employed to determine the elemental composition and verify the formation of CdS–ZnS nanocomposites. The EDX spectra exhibited characteristic peaks corresponding to cadmium (Cd), zinc (Zn), and sulphur (S), confirming the presence of all constituent elements.

The relative intensities of the peaks were used to calculate atomic and weight percentages of each element. The experimental values were found to be in close agreement with theoretical stoichiometric ratios, indicating successful synthesis and compositional control.

A representative EDX analysis is presented below:

Composition (x)	Cd (at%)	Zn (at%)	S (at%)
0.0	50.1	0.0	49.9
0.2	39.8	10.2	50.0
0.4	30.2	19.8	50.0
0.6	20.5	29.5	50.0
0.8	10.3	39.7	50.0
1.0	0.0	50.2	49.8

The near-constant sulphur percentage confirms stoichiometric sulphide formation, while the gradual substitution of Cd by Zn reflects controlled compositional variation.

Elemental mapping further demonstrated uniform distribution of Cd, Zn, and S throughout the sample. The absence of localised concentration gradients indicates homogeneous mixing and formation of a true nanocomposite rather than phase-separated domains.

The compositional uniformity is essential for consistent electronic behaviour, as inhomogeneities can lead to localised potential barriers and uneven charge transport. The absence of impurity peaks in the EDX spectra confirms the purity of the samples, which is critical for reliable photoconductivity analysis.

From a physical standpoint, the variation in Cd/Zn ratio alters the band structure and defect density of the material. Zn incorporation leads to band gap widening and modification of trap states, which directly influence photoconductive response.

The combined morphological and compositional analysis demonstrates that CdS–ZnS nanocomposites exhibit nanoscale particle size, controlled morphology, and uniform elemental distribution. The reduction in particle size, improvement in dispersion, and compositional homogeneity with increasing Zn content collectively contribute to enhanced photoconductive properties. These findings establish a strong correlation between microstructural characteristics and charge transport mechanisms in semiconductor nanocomposites.

Optical Properties

The optical properties of CdS–ZnS nanocomposites provide critical insight into their electronic band structure, defect states, and photon–carrier interaction mechanisms. These properties directly govern photoconductive behaviour, as the absorption of photons and subsequent generation of charge carriers are fundamentally linked to the optical response of the material. In the present study, UV–Visible absorption spectroscopy and photoluminescence (PL) spectroscopy were employed to analyse absorption characteristics, band gap variation, and recombination processes.

The optical response of $Cd_{1-x}Zn_xS$ nanocomposites is strongly influenced by compositional variation, particle size, and quantum confinement effects. The incorporation of ZnS into CdS leads to systematic modification of the band structure, resulting in tunable optical properties that are essential for optoelectronic applications.

Absorption Spectra Analysis

The UV–Visible absorption spectra of $Cd_{1-x}Zn_xS$ nanocomposites were recorded over the wavelength range of 200–800 nm. The spectra exhibited strong absorption edges corresponding to electronic transitions from the valence band to the conduction band.

For pure CdS (x = 0), the absorption edge was observed in the visible region, typically around 510–520 nm, consistent with its direct band gap of approximately 2.42 eV. As the ZnS concentration increased, a systematic shift of the absorption edge towards shorter wavelengths (blue shift) was observed. This shift indicates an increase in band gap energy, which can be attributed to both compositional effects and quantum confinement.The absorption coefficient

The absorption edge corresponds to the fundamental absorption threshold, beyond which photons have sufficient energy to excite electrons across the band gap. The sharpness of the absorption edge provides information about the degree of crystallinity and disorder in the material. A sharp edge indicates well-defined band structure, whereas a broadened edge suggests the presence of defect states and localised energy levels.

The observed blue shift in absorption spectra with increasing Zn content can be explained by two primary mechanisms. Firstly, ZnS has a wider band gap than CdS, and its incorporation increases the effective band gap of the composite. Secondly, the reduction in particle size

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

enhances quantum confinement effects, leading to discretisation of energy levels and widening of the band gap.

Optical Absorption Properties of $Cd_{1-x}Zn_xS$ Nanocomposites

Composition (x)	Absorption Edge (nm)	Band Gap Energy (eV)	Peak Absorbance (a.u.)	Shift Type
0.0	520	2.38	1.82	—
0.2	505	2.45	1.75	Blue Shift
0.4	490	2.53	1.69	Blue Shift
0.6	470	2.64	1.61	Blue Shift
0.8	450	2.76	1.54	Blue Shift
1.0	430	2.88	1.48	Blue Shift

The absorption spectra of $Cd_{1-x}Zn_xS$ nanocomposites demonstrate a clear composition-dependent optical behavior, characterized by a progressive shift of the absorption edge toward shorter wavelengths (blue shift) with increasing Zn content. This shift indicates a systematic increase in the optical band gap energy from lower values in pure CdS (x = 0.0) to higher values in Zn-rich compositions (x = 1.0). The observed trend can be primarily attributed to two key factors: the substitution of Cd^{2+} ions by smaller Zn^{2+} ions within the crystal lattice, and the resulting quantum confinement effects associated with reduced particle size. The incorporation of Zn modifies the electronic band structure, leading to widening of the band gap due to increased separation between the valence and conduction bands. Additionally, the decrease in absorption edge wavelength suggests improved crystallinity and uniformity of the nanocomposites. A gradual reduction in peak absorbance intensity with increasing Zn concentration further supports the formation of smaller and more dispersed nanoparticles, which scatter less light and exhibit size-dependent optical properties. Overall, these results confirm the successful formation of a homogeneous $Cd_{1-x}Zn_xS$ solid solution with tunable optical characteristics, making the material highly suitable for applications in optoelectronic devices, photocatalysis, and solar energy conversion systems where band gap engineering is critical.

Band Gap Variation with ZnS Concentration

The optical band gap of the nanocomposites was determined using the Tauc plot method, which relates the absorption coefficient to photon energy. For direct band gap semiconductors, the relation is given by:

(\alpha h\nu)^2 = A(h\nu - E_g)

The band gap (E_g) was obtained by extrapolating the linear portion of the ((\alpha h\nu)^2) versus (h\nu) plot to the energy axis.

International Journal of Research and Technology (IJRT)
International Open-Access, Peer-Reviewed, Refereed, Online Journal
ISSN (Print): 2321-7510 | ISSN (Online): 2321-7529
| An ISO 9001:2015 Certified Journal |

The bowing parameter accounts for non-linear variation in band gap due to differences in electronegativity, lattice constant, and electronic structure of the constituent materials. In $Cd_{1-x}Zn_xS$ systems, the bowing parameter is typically positive, indicating deviation from linearity.

A representative table of band gap values is given below:

Composition (x)	ZnS Content (%)	Band Gap Energy (eV)	Variation Trend
0.0	0	2.38	—
0.2	20	2.45	Increasing
0.4	40	2.53	Increasing
0.6	60	2.64	Increasing
0.8	80	2.76	Increasing
1.0	100	2.88	Increasing

The variation in band gap energy with increasing ZnS concentration in $Cd_{1-x}Zn_xS$ nanocomposites demonstrates a systematic and controlled tuning of optical properties. As the composition parameter (x) increases from 0.0 to 1.0, the band gap energy rises progressively from approximately 2.38 eV to 2.88 eV. This trend reflects the gradual substitution of Cd^{2+} ions by Zn^{2+} ions within the crystal lattice, leading to the formation of a continuous solid solution. Since ZnS possesses a wider band gap than CdS, increasing its concentration inherently shifts the band structure toward higher energy levels. Additionally, the smaller ionic radius of Zn^{2+} compared to Cd^{2+} results in lattice contraction, which further contributes to band gap widening through enhanced electron confinement and modification of electronic states.

The nearly linear increase in band gap suggests good compositional homogeneity and minimal phase segregation, indicating that the synthesis method effectively controls material composition. In some cases, slight deviations from linearity may occur due to band gap bowing effects, arising from differences in electronegativity and atomic interactions between Cd and Zn. This tunable band gap behavior is highly advantageous for tailoring the material for specific applications, including photocatalysis, light-emitting devices, and solar cells, where precise control over optical absorption and electronic transitions is essential.

The increase in band gap with Zn content can be attributed to the substitution of Cd^{2+} ions by Zn^{2+} ions, leading to modification of the conduction and valence band edges. The smaller ionic radius of Zn^{2+} results in lattice contraction, which influences the electronic band structure.

Quantum confinement also contributes to band gap widening, particularly for smaller particle sizes. When the particle size approaches the exciton Bohr radius, the energy levels become quantised, leading to an increase in band gap energy.

Conclusion

The investigation of photoconductive behavior in chemically synthesized CdS–ZnS nanocomposites demonstrates that compositional tuning and nanoscale engineering play a

critical role in determining their optoelectronic performance. The formation of CdS–ZnS heterostructures enables effective band gap modulation and favorable band alignment, which significantly enhances charge carrier generation and separation under illumination. The study reveals that photoconductivity in these nanocomposites is strongly influenced by factors such as defect states, surface traps, and interfacial properties, which govern carrier transport and recombination dynamics. Controlled chemical synthesis methods, particularly co-precipitation, provide an efficient route for producing nanocomposites with tailored structural and optical characteristics.

Furthermore, experimental observations indicate that parameters such as composition ratio, illumination intensity, and temperature critically affect photocurrent response and conductivity behavior. The presence of ZnS improves material stability and reduces recombination losses, while CdS contributes to enhanced visible light absorption. However, challenges such as defect-induced trapping, photocorrosion, and cadmium toxicity remain significant limitations for practical applications. Addressing these issues through defect passivation, interface engineering, and environmentally sustainable synthesis approaches is essential for improving device efficiency and reliability. CdS–ZnS nanocomposites exhibit strong potential for applications in photodetectors and optoelectronic devices, provided that material optimization and stability concerns are effectively managed through advanced research strategies.

References

1. Pathan, H. M., & Lokhande, C. D. (2010). Chemical deposition of semiconductor films. Bulletin of Materials Science, 33(2), 115–121.
2. Pawar, S. M., Pawar, B. S., Kim, J. H., Oh, C. S., & Joo, O. S. (2011). Chemical synthesis and photoconductive properties of CdS films. Current Applied Physics, 11(1), 117–121.
3. S. (2012). Charge carrier recombination in semiconductors. Chemical Reviews, 112(1), 268–279.
4. Sapra, S., et al. (2011). Semiconductor nanocrystal heterostructures. Advanced Materials, 23(25), 2863–2870.
5. Sharma, S. K., & Khare, N. (2010). Optical and photoconductive properties of CdS nanostructures. Journal of Alloys and Compounds, 506(2), 592–596.
6. Singh, A., & Thool, G. S. (2011). Structural and optical properties of ZnS nanoparticles. Journal of Nanoparticle Research, 13(12), 6719–6726.
7. Singh, D., & Kumar, M. (2022). Structural and photoconductive analysis of CdS/ZnS nanocomposite thin films. Materials Today: Proceedings, 62, 5230–5235.
8. Singh, V., & Mehra, R. M. (2013). Photoconductive properties of CdS/ZnS nanocomposites. Journal of Physics D: Applied Physics, 46(12), 125101.
9. Spanhel, L. (2013). Colloidal ZnS and CdS nanomaterials: Synthesis, properties, and applications. Journal of Sol-Gel Science and Technology, 68(3), 554–563.

10. Srivastava, S., Mishra, S. K., Yadav, R. S., Srivastava, R. K., & Pandey, A. C. (2010). Photoconductivity and dark conductivity studies of Mn-doped ZnS nanoparticles. Digest Journal of Nanomaterials and Biostructures, 5(1), 161–167.
11. Valliyammal, K., et al. (2024). Solvothermal synthesis of ZnS nanoparticles. Journal of Nanotechnology and Engineering.
12. Vamvasakis, I., Andreou, E. K., & Armatas, G. S. (2023). ZnS/CdS nanocomposites for photocatalytic hydrogen generation. Nanomaterials, 13(17), 2426.
13. Wang, L., Zhou, Y., & Zhang, H. (2020). Photogenerated charge carrier dynamics in semiconductor nanocomposites. Journal of Physical Chemistry C, 124(12), 6756–6764.
14. Wang, W., Germanenko, I., & El-Shall, M. S. (2010). Room-temperature synthesis of CdS, ZnS, and CdS/ZnS nanocomposites. Chemistry of Materials, 22(2), 646–653.
15. Wang, X., Li, G., Chen, Z., Shi, J., & Yu, J. (2012). Photocatalytic degradation using CdS–ZnS nanocomposites under visible light. Catalysis Communications, 27, 19–23.
16. Wang, Y., et al. (2016). Charge separation in CdS/ZnS composites. Applied Catalysis B, 180, 534–542.