Baku State University Journal of Chemistry and Materials Science, 2026, v. 3 (2), p.63-68

journal homepage: http://bsuj.bsu.edu.az/en
https://doi.org/10.30546/209501.201.2026.03.002.229

SYNTHESIS OF PHOTOCATALYTIC CdS NANOPARTICLES BASED ON OLEASTER EXTRACT BY CHEMICAL PRECIPITATION METHOD

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Received: 28 February 2026
Accepted: 29 June 2026
Published: 30 June 2026

In this study, photocatalytic CdS nanoparticles were synthesized via a chemical precipitation method using Elaeagnus angustifolia (oleaster) fruit extract as a green bio-assisted agent. The use of plant-derived extract provided an environmentally friendly synthesis route, where naturally occurring phytochemicals acted as reducing and stabilizing agents, influencing the size and surface characteristics of the nanoparticles. The synthesized CdS nanoparticles exhibited strong absorption in the visible light region, indicating their suitability for photocatalytic applications. The photocatalytic performance of the obtained nanomaterials suggests their potential effectiveness in the degradation of organic pollutants present in air and water environments. Moreover, the integration of nanomaterial synthesis with the ecological utilization of oleaster, a salt- and drought-tolerant plant widely used in soil restoration, highlights a sustainable approach combining environmental remediation and green nanotechnology. This work demonstrates the potential of bio-assisted CdS nanomaterials for advanced environmental purification applications.

Keywords: CdS nanoparticles, photocatalysis, green synthesis, oleaster (elaeagnus angustifolia) extract, chemical precipitation, environmental remediation.

INTRODUCTION

In recent years, the increasing global demand for energy and the escalating level of environmental pollution have become critical challenges for sustainable development. Chemical materials play a fundamental role in scientific, technological, agricultural and industrial advancements and are deeply integrate into modern lifestyles. Synthetic chemicals are extensively used in consumer products such as furniture, clothing, electrical appliances, food packaging and cleaning agents. While these materials have significantly improved the quality of human life, their uncontrolled production and disposal have contributed to severe environmental pollution, posing a serious threat to global ecosystems.

Semiconductor-based nanomaterials have emerged as promising candidates for addressing environmental and enery-related challenges. Among them, cadmium sulfide (CdS) nanoparticles have gained considerable attention due to their direct band gap, high absorption coefficient in the visible region and excellent photocatalytic performance. These properties make CdS nanomaterials suitable for applications such as solar energy conversion, photocatalysis and environmental remediation.

Recently, green synthesis approaches utilizing biological resources such as plant extracts and microorganisms have attracted increasing interest as environmentally benign alternatives to conventional chemical methods. Biological synthesis offers several advantages, including low toxicity, cost-effectiveness, simplicity and effective control over

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nanoparticle size and morphology without the use of additional stabilizing agents. Such eco-friendly synthesis routes align with the principles of sustainable chemistry.

CdS nanoparticles exhibit unique size- and shape-dependent properties that enable their application in a wide range of nanotechnological fields, including photovoltaic solar cells, light-emitting diodes, surface acoustic wave devices, biosensors and bioimaging. Furthermore, their antimicrobial activity has positioned CdS nanoparticles as potential alternatives to traditional antibiotics, while ongoing studies explore their applications in molecular pathology and targeted drug delivery. Despite these advantages, insufficient assessment and management of chemical pollutants remain a serious global concern, highlighting the importance of developing efficient and environmentally friendly nanomaterials.

EXPERIMENTAL

CdS nanoparticles in thin-film form were synthesized via an eco-friendly chemical precipitation route assisted by a plant extract. A 10% Oleaster (Elaeagnus angustifolia) leaf extract was employed as a natural reducing, capping and stabilizing agent, owing to its rich content of polyphenols and flavonoids.

For the synthesis process, 10ml of 0,05M $CdCl_2 \cdot 2,5H_2O$ and 10ml of 0,1M $Na_2S \cdot 9H_2O$ aqueous solutions were prepared separately using distilled water under ambient conditions. The plant extract üas continuously stirred prior to the addition of the metal precursor to ensure a homogeneous reaction environment. The cadmium precursor solution was introduced slowly in a dropwise manner in order to control the initial nucleation process and to avoid the formation of large agglomerates. This gradual addition allowed uniform interaction between cadmium ions and the bioactive compounds present in the extract, which acted as natural chelating and stabilizing agents.

After achieving a stable dispersion, the sulfur precursor solution was added gradually under constant stirring. The controlled introduction of sulfide ions promoted regulated CdS nucleation and growth, leading to the formation of well-dispersed nanoparticles. Continous stirring throughout the process ensured uniform mass transfer and prevented localized supersaturation. The plant extract was first placed on a magnetic stirrer and the cadmium precursor solution was slowly introduced dropwise under continuous stirring to ensure homogeneous mixing and controlled nucleation. Subsequently, the sodium sulfide solution was gradually added to the reaction mixture, facilitating the formation of CdS nuclei through controlled precipitation.

The reaction mixture was maintained at 25°C for 48h under constant stirring to ensure complete growth and stabilization of CdS nanoparticles (Figure 1).

Figure 1. Aqueous extract solution of Elaeagnus angustifolia used in a nanoparticle synthesis.

Maintaining the reaction at room temperature minimized thermal stress and preserved the functional integrity of the phytochemicals present in the plant extract. The extended reaction time allowed sufficient growth and stabilization of CdS nanoparticles, ensuring completion of the precipitation process. Constant stirring during this period facilitated uniform particle growth and enhanced colloidal stability. After completion of the reaction, the precipitated product was collected and thoroughly washed several times with distilled water to remove unreacted precursors and residual organic compounds. Repeated washing with distilled water was performed to eliminate unreacted precursors and excess organic residues originating from the plant extract. This purification step was essential to obtain chemically stable nanoparticles with reproducible optical properties. Drying at room temperature prevented structural alteration and aggregation that may occur at elevated temperatures. The obtained material was then dried at room temperature to yield the final CdS nanoparticle product.

The optical properties of the synthesized CdS nanoparticles were investigated using UV-Visible spectroscopy. The absorption spectra were recorded in the wavelength range of 200-300nm. The optical band gap energy (Eg) of the CdSnanoparticles was estimated using the Tauc plot method. The band gap energy was determined by extrapolating the linear portion of the plot to the photon energy axis (Figure 2).

The optical band gap energy of the synthesized CdS nanoparticles was calculated from UV-Vis absorption data using the tauc relation for a direct band gap semiconductor. The photon energy was determined from the corresponding absorption wavelengths obtained from the UV-Vis spectrum.

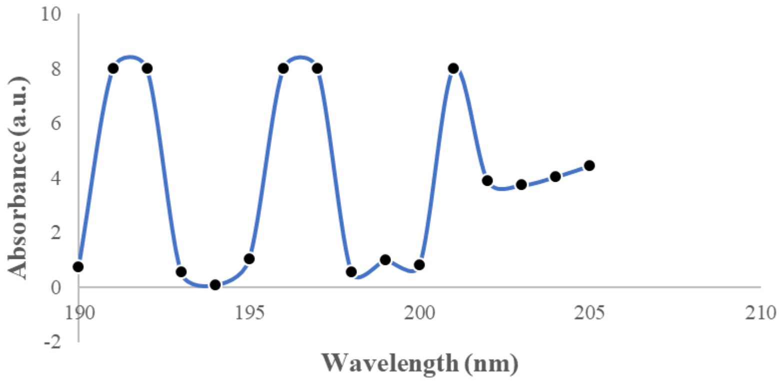

Figure 2. UV-Vis absorption spectrum of CdS nanoparticles.

RESULTS AND DISCUSSION

The formation of CdS nanoparticles via a plant-assisted green synthesis route was clearly confirmed through both visual observation and optical characterization. During the reaction, the gradual appearance of a yellow coloration indicated the successful conversion of cadmium ions into cadmium sulfide nanostructures. This color evolution reflects the initiation of nucleation followed by controlled growth, which was effectively regulated by biomolecules present in the plant extract.

The plant extract served a dual function in the synthesis process. In addition to facilitating the reduction of metal ions, naturally occurring phytochemicals adsorbed onto the nanoparticle surface and acted as stabilizing agents. This bio-capping effect limited particle aggregation and promoted uniform growth, which is essential for achieving consistent optical behavior. The mild reaction conditions functional groups responsible for nanoparticle stabilization.

The optical response of the synthesized CdS nanoparticles was evaluated using UV-Visible spectroscopy within the wavelength range of 200-300nm. The obsorption spectrum displayed a distinct absorption onset in the ultraviolet region, which is characteristic of semiconductor CdS nanomaterials. Compared to bulk CdS, the absorption edge was shifted toward shorter wavelengths, confirming the reduced particle dimendions.

This blue shift arises from quantum confinement, where spatial restriction of charge carriers modifies the electronic structure of the material. As particle size decreases, the separation between energy levels increases, leading to an enlarged optical band gap. The observed spectral behavior aligns well with reported trends for nanoscale CdS synthesized through environmentally benign methods.

The band gap energy of the CdS nanoparticles was determined using the Tauc formalism, based on the UV-Vis absorption results, the optical band gap energy of the CdS nanoparticles was estimated using the Tauc approach, assuming a direct allowed electronic transition. The band gap value was determined to be 2,47±0,05eV, which is slightly higher than that of bulk CdS (2,42ev). Thins minor blue shift is attributed to quantum confinement effects arising from particle size reduction, as well as the bio-capping action of phytochemicals present in the Elaeagnus angustifolia extract. The obtained band gap value confirms the nanoscale nature of the synthesized CdS nanoparticles and supports their suitability for visible-light-driven photocatalytic applications. This enhancement in band gap energy provides additional evidence of nanoscale formation and confirms effective size control during synthesis.

An enlarged band gap is particularly advantageous for photocatalytic systems, as it can improve charge carrier mobility and suppress electron-hole recombination. Moreover, surface functionalization by plant-derived molecules may introduce additional active sites, further enhancing interaction with target species in catalytic and environmental applications.

The combination of controlled optical properties and green synthesis methodology highlights the functional potential of the prepared CdS nanoparticles. The absence of toxic reducing agents and the presence of bio-derived surface modifiers make these nanoparticles attractive for sustainable technological applications. Their optical characteristics suggest suitability for photocatalytic degradation processes, optoelectronic components and light-harvesting systems.

CONCLUSION

In this study, CdS nanoparticles were successfully synthesized via an eco-friendly green synthesis. A synthesis route using plant extract as a reducing and stabilizing agent. The chemical precipitation method enabled controlled nucleation and growth of nanoparticles under mild experimental conditions without the use of toxic chemicals.

UV-Vis spectroscopic analysis confirmed the formation of CdS nanoparticles, showing a characteristic absorption edge and a noticeable blue shift compared to bulk CdS. The calculated optical band gap using the Tauc method revealed an increased band gap energy, attributed to quantum confinement effects at the nanoscale. These findings clearly indicate the successful synthesis of nanosized CdS with enhanced optical properties.

The green synthesis approach offers several advantages, including simplicity, cost-effectiveness, environmental sustainability and improved nanoparticle stability due to natural surface capping by phytochemicals. The synthesized CdSnanoparticles exhibit promising potential for applications in photocatalysis, environmental remediation, optoelectronic devices and solar energy conversion.

Overall, this work demonstrates that plant-mediated green synthesis is a viable and efficient strategy for producing high-quality CdS nanoparticles, aligning well with the growing demand for sustainable nanomaterial fabrication in advanced technological applications.

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