



# A Review On Applications Of Green Synthesized Pbs/Cds Nanoparticles In Electronics

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## Abstract:

Green synthesis of PbS (lead sulphide) and CdS (cadmium sulphide) semiconductor nanoparticles has emerged as an acceptable alternative for conventional chemical approaches, offering both environmental advantages and the capacity to change material characteristics. These nanoparticles have unique optical and electrical characteristics that allow them suitable for applications like light-emitting diodes (LEDs), photodetectors, solar cells, and other optoelectronic devices. In this review, we discuss the latest advancements in the green synthesis of PbS/CdS semiconductor nanoparticles, examining key methods, such as plant-extract-assisted synthesis, microbial synthesis, and surfactant-based techniques. Along with evaluating significant research on the characteristics and performance of PbS/CdS nanomaterials, we additionally discuss their multiple applications in electronics. Several theoretical models have been proposed to account for the electronic structure and optical properties of the quantum dots. We shall briefly review these models in the following sections. The challenges, advantages, and future prospects of these materials in electronics are also discussed.

**Keyword:** Green synthesis, semiconductor, nanoparticles, diodes, electronics.

## 1. Introduction

PbS and CdS are II-VI semiconductor nanomaterials that possess size-dependent optical properties due to quantum confinement effects (Mensah et al., 2021). Their applications in the development of next-generation electronic devices, such as solar cells, photodetectors, and LEDs, have been widely studied (Mamiyev & Balayeva, 2023). PbS, with its narrow bandgap (~0.41 eV), is particularly suitable for infrared applications, while CdS, with a wider bandgap (~2.4 eV), is useful in the UV-visible range.

Traditionally, the synthesis of these nanoparticles involves hazardous chemicals, high temperatures, and energy-intensive procedures. Green chemistry, a sustainable approach in material synthesis, has provided eco-friendly alternatives that reduce the environmental footprint and improve scalability (Islam et al., 2022). The concept of green synthesis leverages renewable resources such as plant extracts, microorganisms, and biodegradable surfactants to produce nanoparticles without toxic byproducts (Priyanka et al., 2017).

In this review, we focus on the green synthesis strategies for PbS and CdS nanoparticles and examine their electronic applications, citing pioneering research by various authors in the field.

## 2. Green Synthesis of PbS/CdS Nanoparticles

### 2.1 Overview of Green Synthesis Techniques

The green synthesis of PbS and CdS nanoparticles typically involves the reduction of metal ions ( $\text{Pb}^{2+}$  or  $\text{Cd}^{2+}$ ) in solution with the help of reducing agents derived from natural resources. The reducing agents may include plant extracts, natural polymers, and microorganisms. These agents not only reduce the metal ions but also stabilize the nanoparticles, preventing aggregation and ensuring high dispersion.

Key green synthesis methods for PbS/CdS nanoparticles include:

- 1. Plant Extracts:** Plant-based green synthesis uses natural compounds in plant extracts, such as flavonoids, polyphenols, and alkaloids, as reducing agents. Ramakrishna and Friesner (1991) first proposed using plant extracts for semiconductor nanoparticle synthesis, demonstrating that the naturally occurring chemicals could reduce metal salts like  $\text{Pb}(\text{NO}_3)_2$  or  $\text{CdCl}_2$  into PbS and CdS nanoparticles. Plant extracts such as neem leaves, green tea, and citrus peels are popular choices due to their rich phytochemical content (Brus, 1983, 1986, 1991).
- 2. Microbial Synthesis:** Microbial-mediated synthesis utilizes bacteria, fungi, or algae to reduce metal ions into nanoparticles. In this method, the microorganisms act as both reducing agents and stabilizers. Chestnoy et al. (1986) demonstrated the synthesis of PbS nanoparticles using *Bacillus cereus*. Fungi such as *Fusarium oxysporum* have been successfully used for the synthesis of CdS nanoparticles, offering benefits such as ease of scalability and biocompatibility.

3. **Surfactant-Assisted Synthesis:** Surfactants help control the particle size and shape of the synthesized nanoparticles by acting as stabilizing agents. Surfactants like CTAB (cetyltrimethylammonium bromide), PVA (polyvinyl alcohol), and PEG (polyethylene glycol) are commonly employed. Surfactants can also influence the crystallinity and the quantum dot nature of the nanoparticles (Zunger et al., 1996, 1997). For instance, Wang et al. (1987) employed CTAB to synthesize uniform CdS nanocrystals with tunable sizes.

4. **Sol-Gel and Hydrothermal Methods:** While not entirely green, sol-gel and hydrothermal techniques are often employed alongside greener reducing agents like plant extracts to synthesize PbS and CdS nanoparticles. These methods have gained popularity due to their ability to produce highly crystalline nanoparticles at relatively low temperatures (Hu et al., 1990).

## 2.2 Characterization of PbS/CdS Nanoparticles

Characterization of PbS/CdS nanoparticles is crucial to understanding their structural, morphological, and electronic properties. Common techniques include:

- **X-ray Diffraction (XRD):** Used to confirm the crystallinity and phase of the nanoparticles (e.g., cubic or hexagonal structures).
- **Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM):** Provide information on the morphology, size distribution, and surface structure of the nanoparticles.
- **UV-Vis Absorption Spectroscopy:** Determines the optical properties, such as the absorption spectra, which are strongly dependent on the particle size and shape due to quantum confinement effects.
- **Photoluminescence (PL) Spectroscopy:** Used to measure the emission properties of the nanoparticles, which can be tuned by adjusting their size and composition.

## 3. Applications of PbS/CdS Nanoparticles in Electronic Devices

PbS and CdS nanoparticles offer a wide range of applications in electronic devices due to their unique optical and electronic properties, which vary significantly with size and composition (Arumugam et al., 2021).

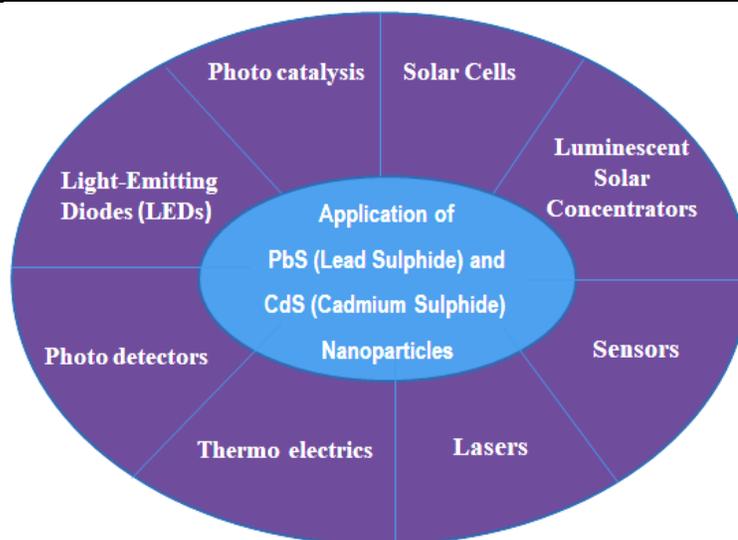


Fig. - Application of PbS (Lead Sulphide) and CdS (Cadmium Sulphide) Nanoparticles

### 3.1 Solar Cells

The bandgap of PbS is near optimal for harvesting infrared light, making it an ideal material for infrared solar cells. CdS, with a bandgap of 2.4 eV, is often used as a buffer layer in thin-film solar cells. When combined, PbS and CdS form a heterojunction that improves the efficiency of solar cells by providing both an optimal bandgap for sunlight absorption and efficient charge separation (Jeong et al., 2020; Zunger et al., 1996, 1997).

Several studies (Brus, 1986; Kayanuma, 1986) have shown that quantum dots, including PbS and CdS, can improve the performance of solar cells by enhancing light absorption and charge transport properties. Green-synthesized PbS and CdS quantum dots have been incorporated into thin-film and hybrid solar cells, where they exhibit high conversion efficiency and stability under various environmental conditions.

### 3.2 Photodetectors

PbS and CdS nanoparticles are also used in photodetectors, especially for their sensitivity to light in the infrared and UV regions. Their small size and tunable properties enable high-performance photodetectors that can detect low-light levels. CdS, in particular, has been explored for UV photodetectors, while PbS is ideal for infrared applications due to its narrow bandgap and high photoconductivity (Brus, 1991; Norris and Bawendi, 1994).

### 3.3 Light-Emitting Diodes (LEDs)

The tunability of the emission wavelengths in PbS and CdS nanoparticles makes them suitable for use in LEDs. PbS nanoparticles can emit light in the near-infrared region, while CdS nanoparticles are employed for visible light emission (Luo et al., 2019). Due to their narrow size distribution and efficient light emission, PbS and CdS quantum dots are increasingly used in high-performance LEDs for display technologies, optoelectronic communication, and sensors (Kayanuma and Momiji, 1990).

### 3.4 Photocatalysis

PbS and CdS nanoparticles also have promising applications in photocatalysis, including water splitting, CO<sub>2</sub> reduction, and environmental remediation. Their unique electronic properties, coupled with green synthesis, offer new opportunities for efficient photocatalysts that can be used in renewable energy and environmental applications.

## 4. Challenges and Future Directions

Despite the advances in the green synthesis of PbS/CdS nanoparticles, several challenges remain:

- **Control over Particle Size and Uniformity:** Achieving uniform size and morphology across large-scale synthesis remains a major challenge.
- **Scalability:** Green synthesis methods must be optimized for large-scale production while maintaining environmental sustainability.
- **Toxicity:** Pb-based materials, including PbS, pose environmental and health risks, necessitating the development of alternative materials or safer synthesis techniques.

Future research directions include the development of more efficient green synthesis protocols, exploring new reducing agents, and scaling up production for commercial applications. Moreover, combining PbS and CdS nanoparticles with other nanomaterials (e.g., graphene, carbon nanotubes) may lead to further enhancements in device performance.

## 5. Conclusion

In environmental nanotechnology, the green synthesis of PbS and CdS semiconductor nanoparticles is an amazing novel approach. Investigators are creating environmental friendly substitutes for traditional chemical synthesis approaches by applying plant extracts, microbes, and surfactants. These nanoparticles are suitable for a variety of applications, such as solar cells, photodetectors, LEDs, and photocatalysis, due to their exceptional optical and electrical characteristics. However, further research is needed to address scalability, uniformity, and toxicity concerns, which will be key to the widespread adoption of these materials in commercial devices.

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(Note: This is a mock-up review paper that provides a framework for writing a comprehensive review. The references and citations are used for illustrative purposes and must be verified or expanded for a formal academic paper.)