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Introduction

Quantum dots (QDs) are a class of nanomaterials that have gained signi cant attention due to their unique optical and electronic properties. ese nanometer-si ed semiconductor particles, t picall ranging from 2 to 10 nanometers in diameter, exhibit quantum mechanical behaviors that di er from bulk materials. eir si e and composition directl in uence their electronic properties [1], including light absorption, emission, and conductivit . Quantum dots have demonstrated remarkable potential in various elds, including optoelectronics, biomedicine, and solar energ , owing to their tunable properties and versatilit . is article explores the structure, properties, s nthesis methods, applications, and challenges of quantum dots, o ering an overview of their transformative role in modern technolog .

Structure and Properties of Quantum Dots

At the core of a quantum dot lies its nanoscale structure. ese materials consist of a semiconductor core, o en surrounded b a shell to improve their stabilit and performance [2]. e core material is t picall made of elements from groups II-VI, III-V, or IV-VI of the periodic table, such as cadmium selenide (CdSe), cadmium telluride (CdTe), or indium phosphide (In). e shell, usuall composed of a higher-bandgap material like inc sul de (ZnS), serves to protect the core from environmental factors and enhance its optical properties.

Quantum dots are characteri ed b several unique features:

Quantum con nement: Due to their tin si e, quantum dots exhibit quantum con nement, a phenomenon in which the electronic properties of the material are signi cantl altered. Electrons within the quantum dot are restricted in movement, resulting in discrete energ levels instead of the continuous energ bands seen in bulk materials. is leads to si e-dependent properties [3], particularl in optical behavior.

Size-dependent optical properties: ne of the most remarkable features of quantum dots is their abilit to emit light at speci c wavelengths, which can be precisel tuned b controlling the si e of the dots. Smaller quantum dots emit light at shorter wavelengths (e.g., blue), while larger ones emit light at longer wavelengths (e.g., red). is tunabilit makes quantum dots highl attractive for various optoelectronic applications.

High brightness and photostability: Quantum dots are known for their high quantum e cienc , meaning the can emit a large number of photons per absorbed photon. Additionall , the exhibit superior photostabilit compared to conventional uorescent d es, making them ideal for long-term imaging and diagnostic applications.

Broad absorption spectrum

speci c biomolecules, allowing for targeted imaging and drug deliver .