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Quantum Dots- Tiny Semiconductor Nanodots

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Abstract

Quantum dots can be defined as semiconductor nanostructures which are artificial in nature and ranges from 2-10 nm in size. These tiny nanocrystals become excited under illumination and emits colors of different wavelength. Quantum dots possess unique properties determined by their structure (hollow or solid), size, shape and composition. Fabrication of Quantum dots is achieved by several methods such as electron beam lithography, epitaxy or by means of colloidal synthesis.

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Introduction

The word 'Quantum' itself is derived from a Latin word meaning 'amount' and can be defined as small unit of physical property like energy or matter [1]. In 1900 physicist Max Planck discovered that like matter radiation existed in discrete units of energy, hence named these units as "quanta" [2]. Similarly, quantum dots can be defined as semiconductor nanostructures which are artificial in nature and ranges from 2-10 nm in size [3, 4].These tiny nanocrystals become excited under illumination and emits colors of different wavelength [5]. Quantum dots possess unique properties determined by their structure (hollow or solid), size, shape and composition [6].Sometimes these are also referred as artificial atoms [7]. Quantum dots have different crystalline lattice structures so when pressure is applied they form very thin semiconductor films [8]. As a result, the flat film later due to stress tends to separate into dots in three dimensions [9].

Physiochemical Properties of Quantum dots is mentioned in Table 1

Types of Quantum Dots

There are 3 types of Quantum dots on the basis of their composition and structure [17].

Core-Typed Quantum Dots

Quantum dots that have internally uniform structures which is composed of a single material [18]. They have variable electro/photo luminescence e.g. Metal chalcogenides [19].

Core-shell Quantum Dots

Also known as Core-Shell semi-conducting nanoparticles having variable photophysical properties e.g ZnS[20]

Alloyed Quantum Dots

Multicomponent semiconductor nanoparticles e.g. CdS-Se/ZnS [21]

Fabrication of Quantum Dots

There are 3 main approaches through which quantum dots can be prepared

1. Electron beam lithography [22]
2. Colloidal synthesis [23]
3. Epitaxy such as Vapor Phase epitaxy, liquid phase epitaxy,molecular beam epitaxy etc [24,25]

Applications of Quantum Dots

- Used in Solar cells and photo-voltaic e.g. Graphene quantum dots [26].
- Used as fluorophores which helps in bio-sensing and bio-tagging [27].
- Used as a catalyst to form hydrocarbons [28]
- Luminescent quantum dots (LQD) are used in high quality displays and lighting systems [29]
- Quantum computing uses quantum computer that store information in quantum bits [30].

Table 1. Physiochemical Properties of Quantum dots

S.no	Physiochemical Properties	
1	Size	Microscopic, 2-10nm (10-50 atoms) [10]
2	Configuration	Confined in three-dimensions [11]
3	Highly tunable	Variable core sizes make them give off different colors by tuning/ changing the characteristic wavelength of emitted light [12].
4	Excitable	Can excite to higher energy level to emit light of respective wavelength [13]
5	Shapes	Various including cubes, spheres and pyramids [14]
6	Resistance	Resistance to photo-bleaching, photo-degradation and chemical- degradation [15, 16].

- Magnetic quantum particles are used in memory chips [31]
- Used in communication devices like lasers [32].
- Have biological applications including in vivo and invitro imaging, DNA assays and microar-rays,labelling tumors , diagnosis /treatment of cancer , drug delivery [33,34,35,36]
- Quantum dots have many exceeding rewards, but they do have drawbacks like they are costly, toxic, may cause environmental pollution etc [37].

Conclusion

Due to their excellent intrinsic and extrinsic properties, Quantum dots continues to amaze researchers with their immense applications.

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