EMERGING APPLICATIONS OF QUANTUM DOTS

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ABSTRACT

Semiconductor particles of a few nanometre size which has the optical and electronic properties are called "Quantum dots" , and that will differ from larger particles due to the quantum mechanics. There might light of specific wavelength if the energy is applied to them. The quantum dots are important for their optical applications because of their bright and pure colours along with their ability to emit rainbow of colours which have higher efficiencies and long life. Quantum dots are the nanocrystals which will low when it is stimulated by an external source such as ultraviolet source and the size of the quantum dot determines the colour of the light emitted. The energy levels of a Quantum dot are judged by the size of the dot rather than the substance from which it is made. Quantum dots are made of silicon or germanium or from the compound semiconductors. Generally there are two approaches from which we can prepare the quantum dots the first one is formation of nanosized the semiconductor particles through colloidal chemistry and the second one is epitaxial growth technique with the help of lithography based technology. The applications of quantum dots include LED, solar technology, Quantum dot laser, military applications, satellite defence system and biomedical applications

Keywords: Quantum Dots , Colloidal methods, Epitaxial growth technique, solar cell technology, High photon source, lasers.

1. INTRODUCTION

Alexei Ekimov was the primary one to manifest about the Quantum Dot. He produced the primary Quantum Dot in a liquified glass matrix. Alexander Efros was the primary one to theorize the Quantum Dot. Joseph Louis Barrow Brus was the foremost to bring the concept of mixture Quantum Dot.

Quantum dots are considerably vital for optical applications as a result of their bright, pure colours together with their ability to emit rainbow of colours beside their high efficiencies, longer lifetimes and high extinction coefficient. quantum dots area unit used for labeling live biological material in vitro and in vivo in animals (other than humans) for analysis - they'll be injected into cells or connected to proteins so that it can trace, label or verify specific biomolecules. in this contex we tend to know about the fundamentals of Quantum dots.[1]

2. HOW DO QUANTUM DOTS WORK?

Generally as the electron jumps from lower energy state to higher energy state it gains the energy i.e the energy is absorbed. Likewise, when the electron jumps from higher energy state to lower energy state then the energy is liberated. The quantum dots can have quantized energy levels but the dots which are created from the identical material is silicon which will give out different colours of light depends on the size of the dots. The biggest Quantum dots will generate the longest wavelength with lower frequencies whereas the smallest dots makes shorter wavelengths with the higher frequencies such that the big dots make red colour light and the small dot make blue colour light but with the intermediary size dots show the green colour light. However, the smaller dots have the larger band gap thus it takes a lot of energy to excite itself because of the frequency of emitted light is proportional to the energy since the smaller dots with higher energy can produce higher frequencies with shorter wavelengths.

From Fig. 1: After captivating energy (1), an electron inside an atom is jumped to a high energy level further from centre of the nucleus(2). When it returns, the energy is given out as light quantum (3). The colour of the light depends on the energy levels and differs from one atom to another atom. Quantum dots produce light in a similar way because the electrons and holes stilted inside them give the similarly discrete, quantized energy levels. However, the energy levels are controlled by the size of the dot rather than the substance from which it is produced.

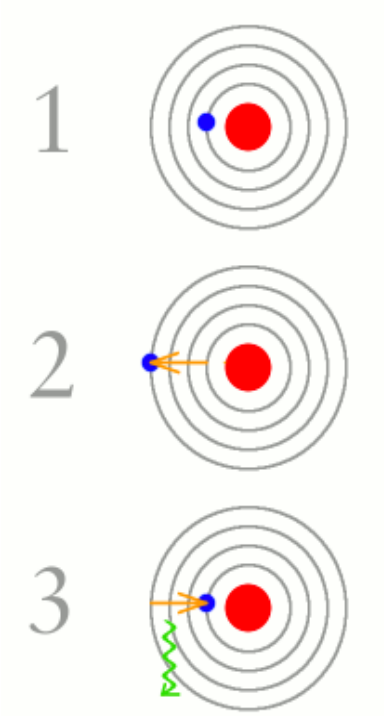

Fig.1: How atoms make light?

Adopted source: explainthatstuff.com/quantum-dots.html

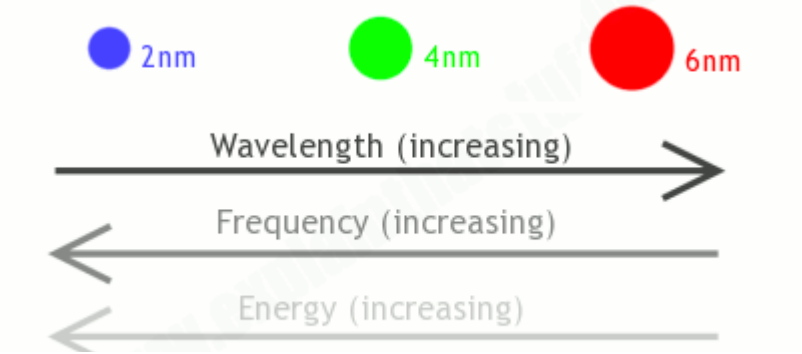

Fig.2: Determination of Quantum dots based on size & colour.

Adopted source: explainthatstuff.com/quantum-dots.html

PREPARATION METHODS OF QUANTUM DOTS

Quantum dots can be manufactured by many processes from collidal synthesis to chemical vapour deposition but the cheapest and the easiest way is benchtop colloidal synthesis and also we use electrochemical techniques and CVD to create ordered arrays of quantum dots on a substrate material and X-ray lithography (a kind of atomic-scale engraving technique with the assistance of X rays). [3]

Usually, there are two general approaches for the preparation of Quantum dots:

3.1 Formation of nanosized semiconductor particles through mixture chemistry

3.2 Epitaxial growth or nanoscale patterning i.e.., with the help of lithography-based technology [4]

3.1. Formation of nanosized semiconductor particles through mixture chemistry

There are two principal ways by which colloids will be prepared

- Dispersion of huge particles or droplets to the mixture dimensions by milling, spraying, or application of shear (e.g., shaking, mixing, or high shear mixing).
- Condensation of very little dissolved molecules into larger mixture of particles by precipitation, condensation, or oxidation-reduction reactions. Such processes are used in the preparation of silica mixture or gold.

3.2. Epitaxial growth or nanoscale patterning i.e.., employing lithography-based technology

Epitaxial technique of Quantum Dots composition are significantly used in optoelectronics (lasers, infrared photodetectors) and nanotechnologies. Epitaxial techniques are typically classified in accordance to phase origin into vapor phase epitaxy (VPE) or liquid phase epitaxy (LPE). Self-assembly techniques are a part of Epitaxial growth.

Self-assembly involves processes that may promote the disordered elements turning into ordered patterns by their internal interactions. It has three exceptional features:

(i) The elements could react directly toward a high ordered state;

(ii) The weak interactions like, van der Waals π–π, chemical bonds, etc., play a significant role in regulating their physical properties;

(iii) The building blocks are broad, and not exclusively embrace atoms and molecules, it contain Nano- and mesoscopic structures.

3. APPLICATIONS [5]

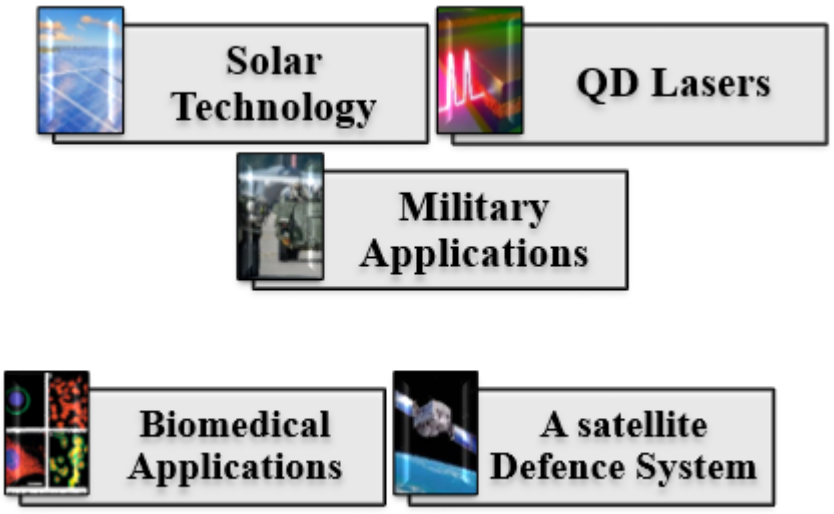

Fig.3: Applications of Quantum Dots

Adopted source: Use of Quantum Dots in real life

4.1 Solar Technology

The quantum dots solar cell is a cell which is used to absorb the photovoltaic material that uses Quantum dots and the quantum dots have band gaps that are flexible in wide range of energy levels by changing the size of a Quantum dot. The mechanism of a Quantum Dot Solar Cell occurs when the optical rays enters through a transparent electrode of a Quantum dots solar cell which will fall on the light absorbing layer of quantum dots in order to generate the electron hole pair. Then the charge particles are separated and they travel to their respective electrodes by producing the electric current. It is used to convert the solar energy to electricity by using the tiny nanoparticles called the quantum dots in which the electrons will pass from one another and generate electrical current when it is exposed to solar energy in a solar cell device. This also helps in supporting global renewable energy targets in the countries.

4.2 QD Lasers

Quantum dots laser technology are designed to provide high performance semiconductor lasers. Because of the rigidity of charge carriers within the quantum dots they exhibit electronic structures which are similar to atoms. Additionally, it has different wavelength by varying the dot size and its composition. The density of higher electronic States is useful for Quantum dot optical devices because it needs intense pumping of energy into a Quantum well laser to start out the lasing action. Besides that a Quantum well lasers show the improved the temperature stability and a narrower emission line. The rule of a Quantum dot laser is within the active region of a device is so narrow that the quantum confinement occurs and also the wavelength of light which is emitted by the quantum well laser it is determined by its thickness of the active region instead of just the band gap of the substance from which it is constructed. The energy levels in a Quantum well laser split apart by tens of milli-electron volts.

4.3 Military Applications

The tiny nanocrystal Quantum dots can be used for tagging, tracking and locating the targets. The nanocrystal quantum dots can be hidden in clear liquids and they can be seen only through a sensor like night vision goggles and these can be applied to an unknown person then he could be tracked using the night vision goggles from a distance apart without noticing him. This tiny dots can change the optical properties of a material by making them small on the order of a NM in size. And when the size is decreased they have Quantum confinement effects which causes absorption and emission properties the light they absorb and the light they emit and also by using the spectral barcodes that allows you to identify and track the enemy, so in this way Quantum dots can be used in military.

4.4 Biomedical Applications

Quantum dots that have broad excitation spectra, thin emission spectra, tunable emission peaks, long visible light lifetimes, negligible photobleaching, and capability to be conjugated to protiens, all the properties makes quantum dots a crutial application. Different colours of fluorescence imaging of cancer cells could be accomplished by inherent injection of quantum-dot-based multifunctional nanoprobes. Quantum Dots Cancer treatment will emit tiny light-emitting particles on millimicron. scale, are new sort of fluorescent probes for molecular and cellular imaging Compared with organic dyes and fluorescent proteins, Quantum Dots Cancer treatment have distinctive optical and electronic

properties in cellular imaging Wavelength-tunable emission, improved brightness of signal, resistance against photobleaching, etc.Such high optical properties were not noticed until the QD-based probes were equipped with tumor-targeted warheads.. Likewise they are also used in drug delivery, bioimaging biomonitoring, photocatalysis, Gene delivery in Vivo bioimaging, bioanalytical assays and etc.

4.5 Satellite Defence System

They have developed the decoy which is consisting of quantum dot of various sizes and shapes that are designed to emit the radiation having a radiation which is same to that of the asset. The decoy is found to be precise in imitating the radiation profile of the asset and thereby deviating the anti-satellite weapons from the target more accurately than the existing conventional counter measure systems that use pyrolytic materials. Magnesium-Viton-Teflon (MVT) glows to generate huge radiation by an exothermic reaction such, a conventional counter measure system are usually bounded by the availablity of oxygen in the space environment (for exothermic reaction) and they are insufficient in many aspects as you devices like long wavelength infrared detector are now able to easily differentiate between the Decoy and also the target spacecraft. Protection systems for growing number of satellites and different space assests against combative threats and collisions should have the ability to accurately replicate the spectral signature of the target to act as an effective decoy. Quantum dots are mainly known for their size-dependent electro-optical properties and by controlling the geometrical size shape and the strength of confinement potential there can be effortlessly tuned to emit radiation at desired wavelength.

5. CONCLUSION

We have seen about quantum dots, how quantum dots work do and the preparation methods of quantum dots. Quantum dots, which are nano-sized semiconductor crystals, are attractive materials in a variety of applications such as solar cell, single photon source, light- emitting diodes (LED), and biomedical applications. Quantum dots are made of durable inorganic materials that will not fade color for the life of the screen. The quantum dot is 60 million times smaller than a tennis ball and 10 times narrower than a human hair. This wide range of Quantum Dot applications makes it important.

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