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Quantum dots and their applications in television display technologies

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Abstract
Quantum dots (QDs) are the best emissive materials ever made something that may revolutionize the display industry and lead to a new generation of low cost and high-performance displays. Due to the low absorption cross-section, conventional phosphor colour conversion cannot support high-resolution displays. This gap will be filled by QDs materials because of their remarkable photoluminescence, narrow bandwidth emission, color tunability, high quantum yield and nanoscale size providing a powerful full-colour solution for display technology. QDs based display technology to position itself at the forefront of next-generation display technology competition. The purpose of this paper is to present an overview of QDs based display technology's research progress and application prospects in overseas.

Keywords: Quantum dots; Display; High resolution; LEDs; LDs

1. Introduction
The semiconductor quantum dots (QDs) are nanoscale material clusters made up of 10^2-10^5 atoms. In all three spatial dimensions, QDs provide quantum confinement of electrons and holes because their size is orders of magnitude larger than typical atomic radiuses. Therefore, they are also called artificial atoms. In semiconductor QDs, the size, shape, and composition of the quantum confined states can be controlled to tailor their energies and wave functions. Semiconductor QDs have gained a lot of attention in recent years as potential replacements for small molecules and polymers in optoelectronic devices application such as light-emitting diodes (LEDs) and Laser diodes (LDs) [1-3].

In spite of being part of mature technologies, QD synthesis, characterization, and applications remain active research areas. Initially, the focus of QD research was on compounds of groups IV and III, however, progress in the synthesis has enabled the composition of the compounds to be expanded over time. Currently, QDs are also based on II – VI, I–III–V and I–IV–VI compounds, as well as transition-metal dichalcogenides, perovskites, and carbon, among others. In QD applications, light emission, conversion, and detection are mostly based on their exquisite optical properties. Thus, QDs can be applied to a wide variety of applications [4-8], as illustrated in Figure 1.

Typically, semiconductor QDs are fabricated by chemical synthesis or epitaxial growth. Despite the fact that chemical fabrication methods are less expensive, epitaxial QDs offer several significant advantages, including direct integration in crystalline matrixes, providing high optical quality as well as the possibility of fabricating optical and electrical devices utilizing epitaxial heterostructures [9].

Optical and electronic properties are influenced by quantum size effects in semiconductor nanocrystals. The ability to generate tunable and efficient photoluminescence (PL), with narrow emission and photochemical stability and core-

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shell structures is a common characteristic of modern QDs materials systems. Increasing the size of quantum dots reduces the energy band gap and causes large wavelength photons to be emitted (red-shift). Small quantum dots have a greater energy band gap and emit short wavelength light (blue shift). Quantum dot solutions emit differing colors when exposed to UV light of different particle sizes [10].

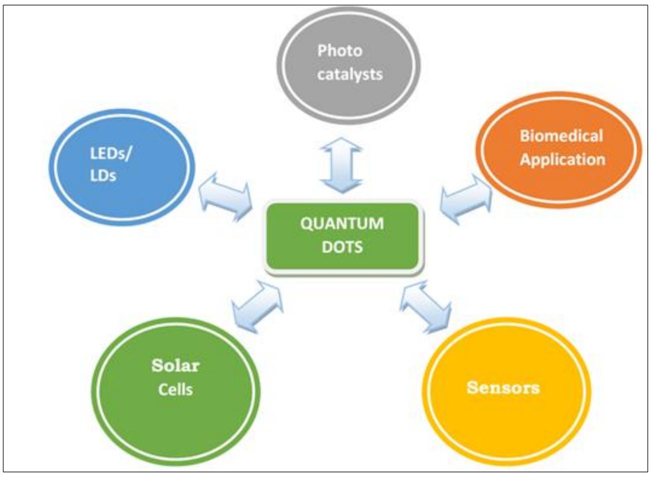

Figure 1 Various applications of QDs

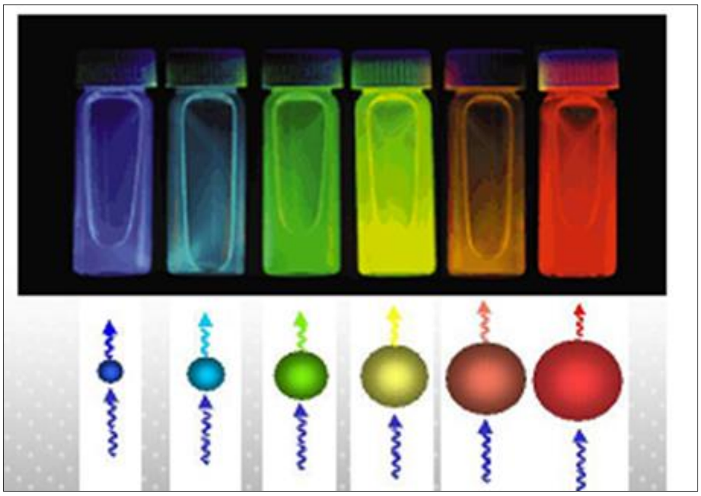

Figure 2 QDs size-dependent emission color and wavelength

Therefore, QDs have been incorporated into a wide range of devices and applications. Today, many of these applications are commercially available and are integrated into our everyday lives, such as QDs-based displays.

2. Role of QDs in Display

Compared with conventional displays, modern displays offer higher brightness, contrast ratios, higher resolutions, and consume less power. As a result of improved specifications, display manufacturers aim to strengthen their market position. As QDs offer high color resolutions, better color purity, a highly immersive high-dynamic range (HDR) experience, and higher energy efficiency compared with conventional displays, these QDs are being increasingly used in display devices. QDs narrow emission spectra and wide excitation profiles make it more efficient to convert light into any color within the visible spectrum. Display manufacturers utilize QDs extensively because of their enhanced properties.

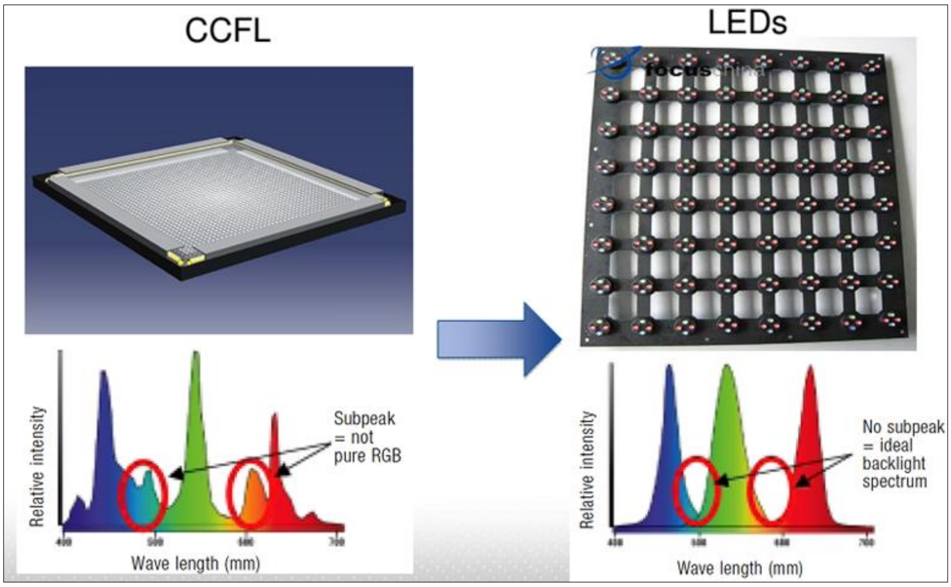

Figure 3 Conventional display vs. QDs LED display wavelength

LCD TVs use CCFLs (Cold Cathode Fluorescent Lamps) for backlighting. LCD TVs are typically bigger than LEDs (Light-Emitting Diodes), which is why they were bulkier than LED TVs today. As compared to CCFLs, LEDs are small, consume less power, and are brighter. The longer their lifespan, the more reliable LED TVs are. A LED TV's backlighting technology is also important to consider when buying. The most common LED solutions available these days are edge-lit and full array [11].

It is likely that we have seen QLED models before. A QLED indicates quantum technology, which sounds high-tech and futuristic. It is similar to traditional LED TVs, but with some advantages. Quantum dots provide a more accurate colour and brightness due to the additional filter. A QLED TV's backlighting also contributes to its bigger changes. In contrast to LED TVs with white backlights, QLED TVs have blue backlights. A quantum dot filter consists of red and blue dots that interact with this blue light.

A colour filter glass and LCD filter pass RGB light from the Quantum filter through the screen to render images. Dots allow precise light control, which results in a more accurate rendering of colors. Furthermore, they deliver higher brightness levels without losing colour saturation. Sony introduced QLED technology in 2013, but Samsung brought it to the masses. To make this technology more affordable, Samsung has also formed a licensing partnership with other TV manufacturers. TCL and Hisense, two affordable TV manufacturing brands, now offer more QLED TVs.

QDs materials offer unique performance and compositions for insertion of LED backlights in Liquid Crystal Displays (LCDs). In today's world, LEDs provide most of the backlighting for televisions, tablets, laptops, and mobile phones. Numerous prominent analyses now predict that most wide color gamut displays of the next generation will be QD-enabled due to the advantages of QDs material as down conversion material for LCDs. According to the NTSC (National Television System Committee) Standard for color gamut, QD backlit LED LCDs can have more than 100 percent efficiency whereas conventional LED LCDs often have less than 70 percent efficiency. In addition to being able to perform better than conventional television displays in terms of color gamut, QD-enabled LCDs are more cost-effective to produce as well. Similar QD enhanced PDs operate in both the visible and infrared spectrums. This device offers higher response times and exceptional sensitivity up to 1×10^{13} jones [12].

3. QDs displays: future trends

As of 2022, nearly 300 transmissive LCD displays are using quantum dot technology, up from a mere handful in 2013. It includes tablets, notebooks, computer monitors, and even 98" TVs. It is expected that the number of QDs shipped in 2022-2023 will surpass 50 million units. In the near future, consumers can expect to see more innovative displays and smart phones using quantum dots and LCDs. Also, technology is progressing rapidly in emissive displays: the first emissive displays with quantum dots are expected to ship in early 2023, and consumers can now purchase them. Through QDs manufacturing companies is powering unprecedented visually immersive experiences and paving the future of cost-effective digital displays. We are literally looking forward to a brighter future with quantum dot technology

4. Conclusion

In summary, QDs are an active area of nanomaterial research that continues to grow at a rapid pace in display technologies. QDs will be used in a new LED (light-emitting diode) variation called QD-LEDs. The manufacturing of blue emitting QDs is, however, a difficult process. In order to detect the same signal with the human eye, it must be smaller and have a stronger emission than the rest of the color emitting dots.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

References

[1] Irshad Ahamed, M. and Sathish Kumar, K. (2019) "Studies on cu2sns3 quantum dots for O-band wavelength detection," Materials Science-Poland, 37(2), pp. 225–229. Available at: https://doi.org/10.2478/msp-2019-0022.

[2] Ahamed, M.I., Ahamed, M. and Muthaiyan, R. (2021) "Modelling of density of states and energy level of chalcogenide quantum dots," International Review of Applied Sciences and Engineering, 13(1), pp. 42–46. Available at: https://doi.org/10.1556/1848.2021.00288.

[3] Irshad Ahamed et al. (2022) "Comparative energy bandgap analysis of zinc and tin based chalcogenide quantum dots," Revista Mexicana de Física, 68(4 Jul-Aug). Available at: https://doi.org/10.31349/revmexfis.68.041601.

[4] J. L. Alonso J. C. Ferrer, F. Rodr´ıguez-Mas, and S. Fernandez´ de Avila, Improved P´ 3HT: PCBM photovoltaic cells with twofold stabilized PbS nanoparticles, Optoelectron. Adv. Mater. Rapid Commun. 10 (2016) 634.

[5] C. Kloeffel and D. Loss, Prospects for Spin-Based Quantum Computing in Quantum Dots, Annu. Rev. Cond. Matter Phys. 4 (2013) 51, https://doi.org/10.1146/annurev-conmatphys-030212-184248.

[6] Pugazhendhi, T. N. Edison, I. Karuppusamy, and B. Kathirvel, Inorganic nanoparticles: A potential cancer therapy for human welfare, Int. J. Pharm. 25 (2018) 104, https: //doi.org/10.1016/j.ijpharm. 2018. 01. 034 .

[7] Irshad Ahamed, Mansoor Ahamed, K. Sathish Kumar, and A. Sivaranjani. "Comparative Energy Bandgap Analysis of Zinc and Tin Based Chalcogenide Quantum Dots." Revista Mexicana de Física 68, no. 4 Jul-Aug (2022). https://doi.org/10.31349/revmexfis.68.041601.

[8] M. I. Ahamed , M. Ahamed, A. Sivaranjani, S. Chockalingam Energy bandgap studies on copper chalcogenide semiconductor nanostructures using cohesive energy, Chalcogenide Letters Vol. 18, No. 5, May 2021, p. 245 – 253

[9] P. J. S. Babu, T. S. Padmanabhan, M. I. Ahamed, A. Sivaranjani, Studies on copper indium selenide/Zinc sulphide semiconductor quantum dots for solar cell applications Chalcogenide Letters Vol. 18, No. 11 , November 2021, p. 701 – 715

[10] M. I. Ahamed, K. S. Kumar, E. E. Anand, A. Sivaranjani, optical attenuation modelling of pbsexs1-x quantum dots with vegard's law and brus equation use Journal of Ovonic Research, Vol. 16, No. 4, July - August 2020, p. 245 – 252

[11] Ahamed, M.I. and Kumar, K.S. (2019) "Modelling of electronic and optical properties of Cu2Sns3 Quantum dots for Optoelectronics applications," Materials Science-Poland, 37(1), pp. 108–115. Available at: https://doi.org/10.2478/msp-2018-0103.

[12] https://nanosys.com/blog/building-our-digital-future-one-quantum-dot-at-a-time, accessed on: 2022.12.08.