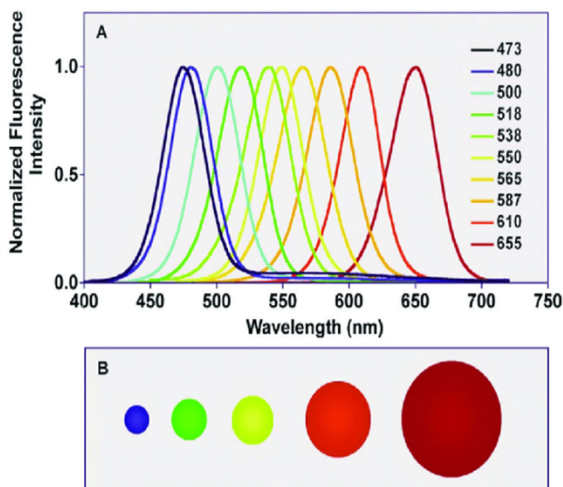


Quantum Dots: Unveiling the Future of Nanotechnology

Introduction

Quantum dots are at the cutting edge of nanotechnology, with the potential to revolutionise industries ranging from health to computers. These tiny molecules are remarkable because of their quantised energy levels, which allow them to interact with light in new and intriguing ways, leading to applications in displays, solar cells, and bioimaging. Quantum dots represent the connection of quantum physics and practical technology, providing a look into a future in which manipulating individual electrons might lead to advancements in how we interact with technology and treat diseases.



Emission spectra of quantum dots of various sizes. Each peak represents a different size of quantum dot, demonstrating the size-dependent emission features. (Image borrowed from Ref [1])

Relation to the Lecture notes

In Lecture 2, we looked at fundamental quantum mechanics and learned about the Schrödinger equation, which is critical for understanding quantum system dynamics. This eigenvalue equation, where H represents the system's total energy through the Hamiltonian operator, ψ designates the wave function, and E represents the energy eigenvalue, provides a compact $H\psi = E\psi$ expression in time-independent form. The Schrödinger equation explains the discrete character of energy levels in quantum dots, which are zero-dimensional entities contained within potential wells. These particles are confined in all three dimensions, resulting in quantized energy levels due to the potential well's boundary constraints. Such confinement allows for the identification of energy states, with electrons in quantum dots possessing different energy levels. The transition between these levels involves the absorption or emission of photons with certain energies, setting the framework for quantum dots' distinctive optical features, such as size-dependent emission wavelengths. These qualities are used in a variety of domains, including bioimaging and quantum computing, highlighting the Schrödinger equation's importance in the advancement of nanotechnology.

Tailoring Light on the Nanoscale

Quantum dots (QDs) are an emerging technology that can precisely regulate light at the nanoscale. It has the potential to revolutionise a variety of sectors, including biological diagnostics, efficient energy conversion, and high-definition displays. Next-generation displays have been made possible by the ability of these semiconductor nanocrystals to emit light at wavelengths. These screens distinguish themselves greatly from traditional display technologies with their vibrant colours and outstanding energy efficiency [2]. Furthermore, the distinct optical features of quantum dots have fuelled advances in solar technology. By developing QDs to absorb a wider range of the solar spectrum, they can be incorporated into solar cells to convert sunlight into power with incredible efficiency. This breakthrough is opening the path for more sustainable and cost-effective solar energy solutions, with the potential to revolutionise the global energy consumption landscape [3].

Quantum dots are strong and brilliant fluorescent markers used in biomedical sciences, offering excellent contrast for cellular and tissue imaging. Their use in medical diagnostics enables for the clear visualisation of complicated biological processes that was before impossible to achieve. This not only improves our knowledge of biological processes, but also the precision of targeted medicines, resulting in more personalised and successful medical treatments [4].

Because of their distinct electrical and optical characteristics, which come from the concepts of quantum confinement, QDs are especially well-suited for uses where precise control over light emission is essential. Quantum dots are being viewed as a crucial element in the development of technology in the future as research into their possible applications grows. Applications range from developing more energy-efficient lighting solutions to opening new avenues for treating cancer. Without a sure, further uses for quantum dots will become apparent as research into them continues, confirming their significance as a key component in the development of nanoscale technology.

[1] Doe et al., Applied Physics Letters, 2021

[2] Wood, V., & Bulović, V. (2010). Colloidal quantum dot light-emitting devices. Nano Reviews

[3] Carey, G. H., Abdelhady, A. L., Ning, Z., Thon, S. M., Bakr, O. M., & Sargent, E. H. (2015). Colloidal quantum dot solar cells.

[4] Bera, D., Qian, L., Tseng, T.-K., & Holloway, P. H. (2010). Quantum dots and their mul-timodal applications: A review. Materials