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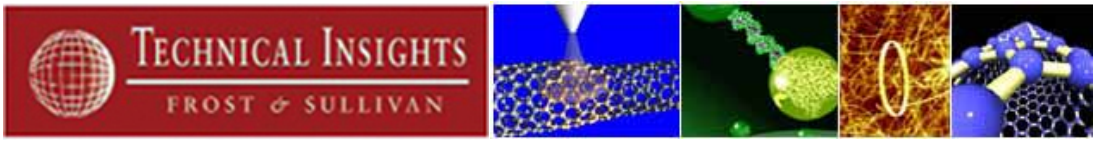

2. TECHNIQUE TO ENHANCE THE INTENSITY OF LIGHT EMITTED BY QUANTUM DOTS

Quantum dots or nanocrystals find utility in a number of sectors, such as energy and power supplies, healthcare and electronics, and security. Solar cells composed of copper indium gallium selenide (CIGS) nanoparticles are comparatively cheaper than the traditional solar cells and also operate at high efficiencies even under low-lighting conditions. In the electronics sector, they are used in solid state lighting and electroluminescent displays. In the healthcare sector, they can be utilized for drug delivery, diagnostics, and other surgical procedures. Technique to enhance the intensity of light that is emitted by individual quantum dots is expected to have a huge impact on the utilization of these quantum dots in various applications.

A team of scientists led by Micrea Cotlet, physical chemist, Brookhaven's Center for Functional Nanomaterials (CFN) at the US Department of Energy's Brookhaven National Laboratory, have achieved a means to enhance the intensity of light emitted by individual quantum dots by up to 20 times. It involves linking of individual semiconductor quantum dots with gold nanoparticles. This technique of manufacturing light emitting particle clusters is expected to facilitate the study and modification of the optical properties of quantum dots.

The amount of light emitted by the quantum dots is greatly influenced by various factors. It is also difficult to sort out the contributions by each of these factors in large samples owing to the inherent ensemble averaging. The team from Brookhaven has developed a precision technique to build nanosized structures using short strands of DNA as specific glue to link the particles together. The construction of individual nanoclusters can be controlled precisely by varying the length of the individual DNA strands, by attaching complementary pieces to the particles that needs to be joined and by anchoring the entire process on an assembly surface.

Metallic materials, however, affect the optical properties of quantum dots either by inhibiting or enhancing the photoluminescence, which in turn is governed by a range of factors including the shape and size of the materials, the wavelength of light that is used to induce photoexcitation, and the distance between the quantum dots. The scientists followed the precision assembly technique to control the shape, size, and distance to a high degree of precision and also test the effect of wavelength in an isolated environment. For this purpose, two specific wavelengths were chosen--one close to the plasmon resonance of the gold nanoparticles and another one outside this range. It was observed that the wavelength within the plasmon resonance range enhanced the photoluminescence of the quantum dots approximately four times when compared with the photoluminescence achieved by the wavelength that lies outside the plasmon resonance range. When comparing the photoluminescence of quantum dots linked to gold nanoparticles with that of the individual quantum dots not linked to the metallic nanoparticle, the resonant wavelength enhanced photoluminescence of the linked quantum dots by an order of magnitude.

The ability to control the excitonic properties present in plasmonic fluorescent quantum dots plays a key role in the development of devices, such as light emitting diodes, solar cells, and other optical circuits. It also helps to improve the sensitivity of quantum dot-based biosensing assays. These modified quantum dots currently find utility in solar energy conversion devices, biosensors, and light-controlled electronics. The commercialization of this technique is expected to happen in the next five years.

The study was conducted at the Center for Functional Nanomaterials, Brookhaven National Laboratory and was funded by the Office of Science of the US Department of Energy.

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