Nobel Prize in Chemistry 2023: Quantum Dots

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Three researchers, Moungi G. Bawendi, Louis E. Brus, and Aleksey Yekimov, were awarded the Nobel Prize in Chemistry 2023 for their discovery and method of synthesizing quantum dot nanoparticles.

Quantum dots are extraordinarily small semiconductor nanoparticles, ranging in size between 1.5 nanometers (nm) and 10.0 nm (Maxwell et. al, 2020). That's up to ten million times smaller than a millimeter! These nanocrystals, distinguished from regular crystals because of their minute size, are made of silicon and other semiconductor materials, ones that fall between the conductivity levels of conductors and insulators (Saplakoglu, 2023). At the nanoscale, these 'dots' exhibit quantum properties similar to individual atoms, while still being composed of up to a few thousand atoms themselves.

The Nobel laureates' work to harness these properties goes back decades. As shown by Edwin Schrödinger's equation, as particles become extremely small, electrons have less space within these particles, causing them to squeeze together (The Nobel Prize in Chemistry 2023). In the 1970s, researchers succeeded in creating a nanostructure, making a nano-thin coating layer on top of a material. They showed that the coating's optical properties changed with the thickness of the layer. By the end of the decade, scientists were using colored glass to study the optical properties of light. They demonstrated that the differences in the glass' color were due to changes in the size of particles forming inside the glass (The Nobel Prize…). Bawendi, Brus, and Yekimov then built on this knowledge.

In 1981, Aleksey Yekimov published a work in a Soviet scientific journal covering his creation of quantum dots while examining colored glass. He observed that the "glass' light absorption was affected by the size of the particles," which he recognized as a quantum effect (The Nobel Prize…). Concurrently and unbeknownst to both scientists, Louis Brus, in 1983 in the U.S., published his discovery of quantum dots while working with solar energy. Both researchers had noted the same phenomenon: "the smaller the particles, the bluer the light they absorbed" (The Nobel Prize…).

These discoveries were revolutionary. The emission of light by a particle is controlled by its electrons. These electrons control many other properties of the particle, such as its

conductivity and ability to catalyze chemical reactions. An electron's wave function gets compressed as it is forced into a smaller place. If a particle's optical properties are changing, so are the electrons, which would also change the particle's other properties. A new metric influencing a particle's properties had emerged.

Throughout the following decade, researchers were unable to fully control the size and quality of the nanocrystals Yekimov and Brus had created. They were riddled with defects and of unpredictable sizes, making experiments and developments difficult. Then came Bawendi.

Moungi Bawendi began his postdoctoral training at Brus' laboratory in 1988. The researchers were attempting to improve the production of quantum dots. They used various substances, solvents, temperatures, and methods, but the progress was slow. In 1993, working as a research leader at the Massachusetts Institute of Technology, Bawendi's team found a major breakthrough. They injected nanocrystal-forming substances into a heated solvent. Nanocrystals of cadmium selenide began to form immediately. The injection cooled the solvent, however, prohibiting their further growth and leaving them as crystal "embryos" (The Nobel Prize…). By slowly reheating the solvent, the MIT scientists could control the growth of the quantum dots.

Not only had Bawendi created a method to reliably synthesize quantum dots, their size could be easily controlled and the crystals were smooth and almost free of defects. Depending on the temperature to which the solvent was reheated, different sizes of crystals could be created. The different sized quantum dots emitted distinct colors of light. Although they conducted their research separately, the joint efforts of Yekimov, Brus, and Bawendi revolutionized nanotechnology and the study of quantum dots. These nanocrystals can be used in a plethora of ways; they range from usage in QLED television screens (the 'Q' stands for quantum dot!) to biomedical imaging. They can be used in cancer research as fluorescent markers and in drug delivery. Quantum dots are changing parts of our lives, and the 2023 Nobel Laureates in Chemistry played a key role in their creation and usage.

Bibliography

Maxwell, T., Campos G.N.M., Smith, S., Doomra, M., Thwin, Z., Santra S.. (2020). Chapter 15 - Quantum Dots. In Nanoparticles for Biomedical Applications (pp. 243-265). https://www.sciencedirect.com/topics/materials-science/quantum-dot

Saplakoglu, Yasemin. (2023, October 4). Nobel Prize Honors Inventors of 'Quantum Dot' Nanoparticles. Retrieved from https://www.quantamagazine.org/nobel-prize-honors-inventors-of-quantum-dot-nanoparticles-20231004/

The Nobel Prize in Chemistry 2023. (n.d.). Retrieved from https://www.nobelprize.org/prizes/chemistry/2023/popular-information/