Scientists age quantum dots in a test tube

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Aging quantum dots. Credit: Daria Sokol/MIPT

Researchers from MIPT and the RAS Institute of Problems of Chemical Physics have proposed a simple and convenient way to obtain arbitrarily sized quantum dots required for physical experiments via chemical aging. The study was published in *Materials Today Chemistry*.

Colloidal quantum dots are nanosized crystals whose size determines the frequency at which they emit and absorb electromagnetic radiation. They are used in solar cells, TV sets, fire alarm systems and more.

The MIPT Laboratory for Photonics of Quantum Nanostructures conducts research using lead sulfide quantum dots. The conventional approach to their synthesis, known as hot injection, involves mixing two so-called precursors—compounds containing lead and sulfur—under particular conditions. This process is controlled using special reagents and equipment to create quantum dots of desired size. However, the synthesis is complex, costly and does not yield dots of all requisite sizes.

"If a physicist needed some quantum dots but had no equipment to manufacture them, they used to spend quite a lot of money to commission synthesis or order the products from abroad through a catalog. And you could not buy dots of arbitrary size," said Ivan Shuklov, deputy head of the MIPT Laboratory for Photonics of Quantum Nanostructures. "So we searched for a simple and affordable way to obtain lead sulfide quantum dots that would not require any specialized equipment or skills and would produce dots of any size and therefore precisely the properties needed."

Experimenting with various compounds, the researchers found the quantum dot spectrum to change in the presence of a mixture of oleic acid and oleylamine. Electron microscopy afforded a closer look at what was going on, showing that mixture of the two chemicals to actually reverse the standard synthesis, causing sulfur and lead atoms to retreat back into the solution, gradually reducing dot size. More importantly, the dot size distribution remained the same. In other words, you get basically the same dots you had before introducing the mixture, just that they get smaller and therefore alter their properties.

The standard approach to synthesizing quantum dots also employs oleic acid and oleylamine, but the chemicals are used at different stages. It is their simultaneous application and mutual interaction that turned out to enable controlled crystal aging. That is, the predictable long-term change in crystal properties over time.

"We have proposed a solution that allows an experimenter who has 10-nanometer quantum dots to predictably reduce them to 8 nanometers tomorrow, to 6 nanometers the day after that, and so on. Accordingly, the absorption frequency will change from 2 micrometers to 1.8 micrometers the first time and then to 1.5 micrometers," explained Vladimir Razumov, the head of the Laboratory for Photonics of Quantum Nanostructures at MIPT. "Basically, from one batch of generic colloidal quantum dots, you can produce those with precisely the right size and properties for your needs. With our technique, a physicist with no special equipment other than some test tubes can convert one sample of quantum dots into any size. All it takes is waiting for the dots to 'age' to the appropriate size."

More information: I.A. Shuklov et al. Controlled aging of PbS colloidal quantum dots under mild conditions, *Materials Today Chemistry* (2020). DOI: 10.1016/j.mtchem.2020.100357

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