Microwave Synthesis Connects With the (Quantum) Dots

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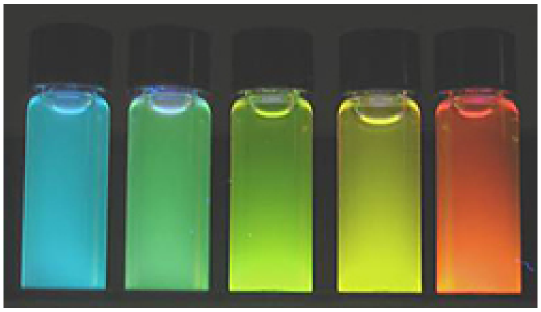

Brightly glowing vials of highly luminescent, water soluble quantum dots produced by the new NIST microwave process span a wavelength range from 500 to 600 nm. Credit: NIST

Materials researchers at the National Institute of Standards and Technology have developed a simplified, low-cost process for producing high-quality, water-soluble “quantum dots” for biological research. By using a laboratory microwave reactor to promote the synthesis of the widely used nanomaterials, the recently published NIST process avoids a problematic step in the conventional approach to making quantum dots, resulting in brighter, more stable dots.

Quantum dots are specially engineered nanoscale crystals of semiconductor compounds. The name comes from the fact that their infinitesimal size enables a quantum electronics effect that causes the crystals to fluoresce brilliantly at specific, sharply defined colors.

Bright, stable, tiny and tunable across a broad spectrum of colors, quantum dots that are engineered to attach themselves to particular proteins have become a popular research tool in areas such as cancer research for detecting, labeling and tracking specific biomarkers and cells.

Making good quantum dots for biological research is complex. First a semiconductor compound—typically a mixture of cadmium and selenium—must be induced to crystallize into discrete nanocrystals of just the right size. Cadmium is toxic, and the compound also can oxidize easily (ruining the effect), so the nanocrystals must be encapsulated in a protective shell such as zinc sulfide. To make them water soluble for biological applications, a short organic molecule called a "ligand" is attached to the zinc atoms. The organic ligand also serves as a tether to attach additional functional molecules that cause the dot to bind to specific proteins.

The accepted commercial method uses a high-temperature reaction (about 300 degrees Celsius) that must be carefully controlled under an inert gas atmosphere for the crystallization and encapsulation stages. An intermediate ligand material that can tolerate the high temperature is used to promote the crystallization process, but it must be chemically swapped afterwards for a different compound that makes the material water soluble. The ligand exchange step—as well as several variations on the process—is known to significantly alter the luminescence and stability of the resulting quantum dots.

Seeking a better method, NIST researchers turned to microwave-assisted chemistry. Microwaves have been employed in a variety of chemical reactions to reduce the required times and temperatures. Working at temperatures half those of commercial processes, the group developed a relatively simple two-stage process that requires no special atmospheric conditions and directly incorporates the water-soluble ligand into the shell without an exchange step. Using commercially available starting materials, they have synthesized highly uniform and efficient quantum dots for a range of frequencies and shown them to be stable in aqueous solutions for longer than four months.

Citation: M.D. Roy, A.A. Herzing, S.H. De Paoli Lacerda and M,L. Becker. Emission-tunable microwave synthesis of highly luminescent water soluble CdSe/ZnS quantum dots. *Chemical Communications*, 2008, 2106-2108.

Source: NIST

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