Producing Quantum Dots by Spray Pyrolysis

Sizes of quantum dots are determined by sizes of sprayed drops.

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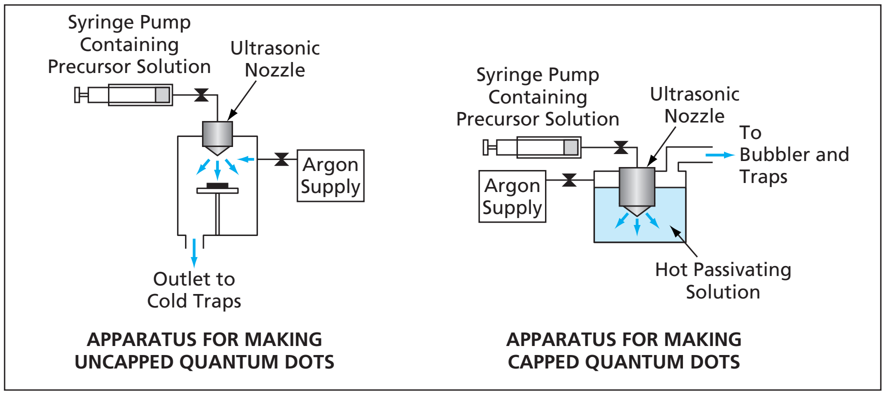
An improved process for making nanocrystallites, commonly denoted quantum dots (QDs), is based on spray pyrolysis. Unlike the process used heretofore, the improved process is amenable to mass production of either passivated or non-passivated QDs, with computer control to ensure near uniformity of size.

The extraordinary optical properties that make QDs useful can be tailored via the chemical compositions and sizes of the QDs. Heretofore, QDs have been made by *in situ* pyrolysis of molecular reagents that contain all the elemental ingredients. In order to make all QDs in a batch have the same or nearly the same size, it is necessary to prevent nucleation with adjacent QDs by passivating the surfaces of the QDs soon after they have formed. Passivation is effected by use of a passivating coordinating solvent/ligand compound as one of the ingredients. This compound both serves as a medium for the formation of the QDs via pyrolysis and readily coordinates to the surfaces of the QDs, thereby preventing further nucleation. Covering of the surfaces of the QDs with the coordinating molecular groups is known in the art as capping. The capping groups can be organic or inorganic. The solvent/ligand can be formulated to tailor the surface properties of the QDs for a specific application. For example, they can be made hydrophilic or hydrophobic. Unfortunately, this *in situ* pyrolysis process cannot readily be scaled up to mass production, and the QDs produced exhibit excessive nonuniformity.



These Two Apparatuses serve to illustrate the basic principles of two variants of the spray-pyrolysis process for making uncapped or capped QDs of controlled size.

The improved process also includes pyrolysis, but differs from the prior process in the pyrolysis conditions and in the manner in which the ingredients are prepared for pyrolysis. In addition, one has an option to form QDs of controlled size without or with capping. Unlike in the prior process, one does not rely on formulation and pyrolysis process conditions to cause the QDs to form spontaneously in the desired size range. Instead, one forces the QDs to form in a desired relatively narrow size range by spraying a solution of QD-precursor material through an ultrasonic nozzle to form drops of controlled size. The average size of the drops can be tailored via the surface tension and density of the solution. Even more conveniently, the average size can be tailored via the frequency of ultrasonic agitation. Experiments have shown that for a given formulation, the average size is inversely proportional to frequency to the 2/3 power.

The basic concept of the improved process admits of variations. For example, in a simple embodiment of the process for making non-capped QDs, a precursor solution is sprayed into a cold-wall reactor that contains a substrate that is electrically heated to the desired reaction temperature (see figure). The drops falling on the substrate become pyrolized into QDs. In a slightly more complex example, capped QDs are made by similar spraying of a precursor solution into a hot passivating solvent.

This work was done by Kulbinder Banger, Michael H. Jin, and Aloysius Hepp of **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

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