Research Highlights

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Aerosol flow synthesis of nanoparticles

Nanocrystalline colloidal semiconductors are of current scientific and commercial interest owing to their tuneable optical and electronic properties and resulting applications in electronic devices and biosensors. The physical characteristics of nanocrystallites are determined primarily by spatial confinement effects with properties such as the optical band gap often differing considerably from the bulk semiconductor. As these properties are ultimately determined by the physical dimensions of the crystallites, there is considerable interest in synthetic routes that can yield nanoparticles of well defined size and shape. In practice, deviations about the mean particle radius should be lower than one percent. Unfortunately, this is beyond the tolerance of most standard syntheses and in general it is necessary to employ some form of post-treatment to extract the desired particle size and sample size distribution. Using such *post hoc* approaches, it is possible to obtain nanoparticles with extremely narrow size distributions, however processing can be complex and yields are generally low. Accordingly, it is preferable to use direct techniques, requiring no post-treatment, to prepare the crystals. Recently, a number of studies have indicated that the use of continuous flow, microfluidic devices may provide a direct route to the production of metal, metal-oxide and compound semiconductor nanoparticles. Such devices have the advantage of eliminating local variations in reaction conditions such as concentration and temperature and of allowing rapid, reproducible changes in these conditions should they be desired. An interesting alternative to these methods has recently been described by Yuri Didenko and Kenneth Suslick at the University of Illinois at Urbana-Champagne.[1] In these studies a continuous chemical aerosol flow is used to synthesize both CdSe and CdTe nanoparticles. The authors create a dense mist by ultrasonic nebulization of solutions containing appropriate precursors (Fig. 1). Reactions are then initiated within individual sub-micron droplets by motivating the mist in a gaseous argon stream into a furnace. Initially, aerosols are formed using an ultrasonic transducer taken from a home humidifier. These aerosol droplets contain reactants dissolved in both a high-boiling point solvent and a lower boiling point solvent (toluene). When the aerosol droplets enter the furnace they are rapidly heated. This causes the toluene to evaporate above 111 °C and leave submicron droplets which contain the reactants within the high boiling point solvent. At high temperatures nanoparticles are formed and upon exiting the furnace they are rapidly cooled and collected in a solvent bubbler. Importantly, the authors demonstrate that the approach can be used in a variety of synthetic schemes. For example, for CdSe nanoparticle synthesis a variety of Cd sources (including CdO, $CdCO_3$ and $Cd(CH_3CO_2)_2$), Se sources (including trioctylphosphine selenide) and surfactants (including hexadecylamine and oleic acid) were used to generate highly luminescent particles of well-defined size. In addition, variation of the furnace temperature provides a simple way of controlling average particle size and emission across a wide wavelength range. Interestingly, the authors show that the method can be applied to the synthesis of highly luminescent CdTe nanoparticles, which in turn can be directly deposited onto planar substrates to form CdTe solar cells and LEDs.

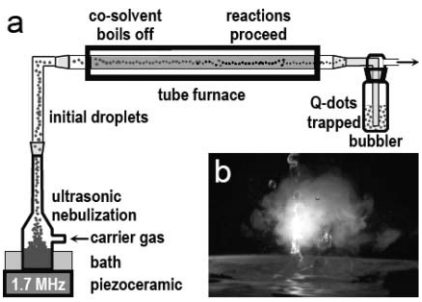

Fig. 1 Experimental apparatus for chemical aerosol flow synthesis. a. Solutions of high boiling liquids containing appropriate precursors are diluted and then atomized by an ultrasonic nebulizer. The volatile solvent boils off, leaving submicron liquid droplets that are carried through the tube furnace by a gas flow. Reactions inside the heated liquid droplets result in the preparation of narrow distributions of quantum dot semiconductor particles, which are trapped in a liquid-filled bubbler. b. Photograph of nebulized mist produced by the ultrasonic fountain. (Adapted with permission. Copyright 2005, The American Chemical Society.)

One of the key features of this new approach to nanoparticle synthesis is the ability to produce high-quality nanoparticles in relatively large amounts. For example, using their low-end nebulizer Didenko and Suslick generate a system throughput of over 100 mg h^{-1} and estimate significantly higher yields if ultrasonic horn atomizers are adopted in future systems.[1]

Rapid prototyping of glass microstructures

A cursory glance through the literature illustrates that the majority of early microfluidic systems were constructed from glasses or silicon as the substrate material. This is not surprising since standard photolithography and wet-etching techniques could be used to efficiently structure these materials to produce microchannel networks. In addition, much of the early work in the field focused on transferring separation methods to planar chip formats, and in particular the development of electrophoretic separation technology. Although silicon-based CE chips have been reported, the conductivity of silicon proved problematic when applying high voltages necessary for the generation of electroosmotic flow and consequently, the vast majority of early microfluidic systems were sculpted from glassy materials. Glasses possess other beneficial properties such as well-defined surface chemistries, excellent optical characteristics and good electroosmotic