Controlled Synthesis of Semiconductor Nanocrystals and Nanorods using Microemulsion and Liquid Crystal Templates

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Nanostructured materials, i.e. materials consisting of structures that have at least one dimension between 1 and 100 nm, are attracting great attention due to their fascinating properties and applications, that cannot be obtained from the same materials in bulk [1]. Semiconductor nanocrystals (quantum dots), with size smaller than the corresponding de Broglie wavelength or Bohr radius (mean separation of an optically excited electron-hole pair), exhibit optical and electronic properties that can be manipulated by changing their size or composition, such as size-dependent luminescence [2,3]. In addition to playing an important role in fundamental studies on solid-state physics, materials science, and thermodynamics [4], quantum dots can be used in a wide range of applications including photovoltaic devices [5], photodetectors [6], and as fluorescent biological labels [7]. Furthermore, one-dimensional nanostructures (nano-wires, -tubes, -rods, and -belts) are envisioned to play an important role as both interconnects and functional units in fabricating electronic, optoelectronic, electrochemical, and electromechanical devices with nanoscale dimensions [1].

This presentation will focus on a scalable method for controlled synthesis of zero- and one-dimensional compound semiconductor nanostructures at room temperature using microemulsion and liquid crystal templates. ZnSe quantum dots were synthesized by reacting hydrogen selenide gas with diethylzinc dissolved in the heptane nanodroplets of a microemulsion formed by self-assembly of a poly (ethylene oxide)-poly (propylene oxide)-poly (ethylene oxide) (PEO-PPO-PEO) amphiphilic block copolymer in formamide. Inside each nanodroplet, ZnSe nuclei grow by surface reactions with unreacted precursors and through cluster-cluster coalescence, leading to single nanocrystal formation. The nanocrystals exhibit size-dependent luminescence and excellent photostability [8]. The technique is currently being expanded to synthesize ZnSe nanowires through contact between hydrogen selenide gas and hexagonal liquid crystals of heptane/formamide/PEO-PPO-PEO, containing diethylzinc dissolved in the heptane cylindrical nanodomains. Reactions between group-II alkyls and group-VI hydrides are employed, similar to those used by the microelectronics industry for metalorganic vapor phase epitaxy (MOVPE) of thin films [9]. The microemulsion nanodroplets or the liquid crystal nanocylinders are used as identical nanoreactors, thus allowing precise control of particle size by manipulation of the initial diethylzinc concentration in the heptane.

References

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