190a Templated Synthesis of Compound Semiconductor Nanostructures Using Lyotropic Liquid Crystals

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Semiconductor nanostructures have been attracting a lot of attention by the research community over the past decade due to their unique size-tunable properties that can be useful for a variety of applications in clinical diagnostics, nanoelectronics, sensors and photovoltaics [1-3]. The size-dependent tunability of the properties arises when at least one of the nanocrystal's dimensions becomes smaller than the corresponding de Broglie wavelength or Bohr radius (mean separation of an optically excited electron-hole pair) causing quantum confinement of the exciton by the grain boundary. Several liquid- and vapor-phase techniques for growing such nanostructured materials have been reported in the literature.

The use of templates in the synthesis of nanostructured materials allows precise control of shape and size, scalability, and stabilization for long-term storage. Our group has demonstrated the development of stable microemulsion templates consisting of a polar continuous phase, a non-polar dispersed phase and an amphiphilic block copolymer surfactant, and their subsequent use in th synthesis of nearly monodisperse quantum dots of zinc selenide with excellent optical properties, including size-dependent luminescence [4].

This presentation will focus on simultaneous size and shape control of compound semiconductor nanostructures using liquid crystal templates formed by self-assembly of a poly (ethylene oxide)-poly (propylene oxide)-poly (ethylene oxide) (PEO-PPO-PEO) amphiphilic block copolymer in the presence of a polar and a non-polar solvent. The growth of ZnSe nanocrystals is used as an example. Two different template systems have been developed and employed for growing the nanocrystals: (a) the formamide / PEO-PPO-PEO / heptane system, in which the nanocrystals are synthesized in the heptane dispersed phase, and (b) the water / PEO-PPO-PEO / p-xylene system, in which the nanocrystals are synthesized in water. The formation of the nanomaterial starts with a direct nucleation reaction between a Zn precursor that has been dissolved in the appropriate solvent and hydrogen selenide gas that is allowed to diffuse through the template. For the first type of templates the Zn precursor used was diethylzinc dissolved in heptane and for the second type zinc acetate dihydrate dissolved in water. The concentration of the Zn precursor in the respective solvent is a crtical parameter that can been used for tuning the size of the nanocrystals. The zinc selenide nuclei that are formed in the nanodomains containimg the Zn precursor grow by surface reactions with unreacted precursors and by cluster-cluster coalescence to yield nanocrystals of various sizes and shapes, depending on the geometry of the template. In addition to quantum dots grown in the dispersed spherical nanodomains of cubic phase liquid crystals, we have also demonstrated the growth of nanowires in the cylindrical nanodomains of hexagonal phase liquid crystals, free-standing quantum wells (nanoplates or nanolaminates) in lamellar liquid crystals, as well as hollow spheres and hollow tubes around the dispersed nanodomains of the cubic and hexagonal phases. The synthesized nanocrystals have been characterized by HR-TEM, XRD, EDS, and optical spectroscopy (Raman, photoluminescence and absorption). The shape and size of the nanocrystals can be precisely controlled by selecting the structure of the templating phase, and by tuning the size of the nanodomains and the concentration of the zinc precursor in them.

References

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