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High Temperature Solution-Phase Synthesis of Silicon and Germanium Nanocrystals and Nanowires

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Nanocrystals in the 2 to 10 nm size range, also called quantum dots due to their unique size dependent optical and electronic properties can be synthesized in solution with controlled size using an approach called arrested precipitation.

In"this method, organic ligands coat the nanocrystals to stabilize their size. We have developed methods for synthesizing Group IV nanocrystals in high temperature supercritical solvents. Silicon nanocrystals are grown using diphenylsilane thermally degraded in hexane at 450 oC and 370 bar in the presence of octanol. The long chain alcohol bonds to the silicon surface. Silicon nanocrystals synthesized using this approach exhibit remarkable optical properties with size tunable photoluminescence ranging from blue to red with quantum yields as high as 38% at room temperature.

The nanocrystals are chemically robust and exhibit electrogenerated chemiluminescence for example. The high temperature of the solvent also enables silicon and germanium nanowire synthesis under the appropriate conditions. Using gold nanocrystals as seeds, the nanowires crystallize through a fluid-liquid-solid (FLS) growth mechanism. In this process, silicon atoms dissolve into the gold nanocrystals rather than nucleating homogeneously into particles. After saturating the gold, a wire crystallizes as more silicon adds to the seed particle. One requirement for this process is a reaction temperature exceeding the Au:Si (or Au:Ge) eutectic temperature, which is approximately 360C. The high temperature environment produces single crystal nanowires ranging from 4 to 20 nm in diameter and micrometers in length. The nanowires can be isolated and deposited onto electrodes for electrical measurements. The nanowires can also be resuspended in solution to form liquid crystals. One key component to these studies is the ex situ chemical surface modification of the nanowires. We will discuss the synthesis, processing, and properties of silicon and germanium nanocrystals and nanowires grown in high temperature high pressure solvents.