

Quantum dot composition profiles: mechanisms, thermodynamics and effects on the electron spin

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For many lattice-mismatched systems, a small amount of one material deposited onto a single-crystal surface of another will yield coherently strained heteroepitaxial nanocrystals that can have atomic-like electronic properties. Over the past several years, many theoretical and experimental investigations have interpreted this nanocrystal formation and evolution as either a thermodynamic or kinetic process. More recently, several groups have discovered that the island Ge content was not only different from the nominally deposited material, but it was also non-uniform [1-3]. The observed Ge distributions have been associated with different alloying mechanisms [4], which may provide a clue to the island formation process. If the formation mechanism can be controlled, it may be possible to tailor the composition profile and thus the electronic confining potential. We determined the enthalpic and entropic contributions to the thermodynamics of coherently strained nanocrystals grown via deposition of pure Ge on Si(001) surfaces at 600°C and 700°C by analyzing their local Ge content and strain. We found that the free energy associated with the entropy of mixing, which drives $\text{Ge}_x\text{Si}_{1-x}$ alloy formation, was significantly larger than the relaxation enthalpy that produces the islands [5]. Thus, entropy plays an important role in the evolution of the size and shape of the islands during growth through the strong thermodynamic drive to form an alloy. Finally, it will be shown how the electron spin properties are affected by a composition profile for III-V quantum dots [6].

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