Directed Assembly and Strain Engineering of SiGe Films and Nanostructures

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The lattice-mismatch-induced strain in growth of Ge on Si produces a host of exciting scientific and technological consequences, both in 2D film growth and in 3D nanostructure formation. The excitement and novelty are enhanced if silicon-on-insulator (SOI) is used as a substrate. The strain driven self-assembly of faceted Ge nanocrystals during epitaxy on Si(001) to form quantum dots (QDs) is by now well known. A simple templating process allows us to direct the assembly of Ge QDs and provides an understanding of the mechanism of directed assembly. [1] Using silicon-on-insulator (SOI) as a substrate, we discovered that nanostructures can provide sufficient stress to distort the Si layer and causes the oxide underneath to flow, with significant implications for electrical properties of the Si template layer.[2] These measurements led us to new theoretical insights on bending of nanoscale thin substrates during heteroepitaxial growth that may also impact 2D film growth and devices made from strained films. For example, recently, we have been able to fabricate gated quantum dots in silicon/silicon-germanium two-dimensional electron gases. The spins of electrons in such silicon dots are excellent candidates for quantum information processing. Their advantages include long coherence times and the integrability of silicon-germanium within the present microelectronics infrastructure.

Growth of films on SOI rather than Si also brings with it unique defect generation mechanisms that are distinct from the behavior on bulk Si, for example, dislocation formation. We use low-energy electron microscopy (LEEM) as a tool to investigate dislocation formation and dislocation core spreading in SiGe heteroepitaxy on SOI(001). LEEM is the only technique that allows analysis of dislocation core spreading in these systems. We also use LEEM to observe the defect initiated dewetting and thermal decomposition of the thin Si template layer of SOI. Combined with first-principles total-energy calculations, these observations provide a quantitative understanding of the unique pattern formation that results from this decomposition. [3] Finally we fabricate thin membranes and free-standing structures to investigate the effect of added uniaxial stress on adatom diffusion and the nucleation and coarsening of 2D and 3D structures.

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