5.4 May 4, 2005: Coherent/epitaxial films, nanostructure formation

Coherent films, strained epitaxial films. Epitaxy basically means growing new material with the same lattice spacing. Applications:

- High-quality films of various types: early giant magnetoresistance (GMR) films were alternating Fe/Cr on Al_2O_3 sapphire substrates.
- Heterojunction lasers: deposit together GaAs, AlAs, AlAs layers pump electrons and holes, GaAs has smaller bandgap in middle to let them in in an inverted state. Single crystal really helps conduction. GaAs and AlAs have very close lattice spacing, different band gap.
- III-IV devices on Si-Ge: (Ga,Al)As has lattice spacing between Si and Ge; Si and Ge form solid solution with varying lattice spacing between the two. Eugene Fitzgerald (MIT DMSE) pioneered this.

If deposition is *really* slow, and entropy of roughness really high, and temperature pretty high then can use RHEED to determine when each layer completes, and make alternating layers in a superlattice; pretty cool!

Making nanostructures Different ways to make nano-structured materials:

- Fancy deposition: vapor-liquid-solid, anything from alumina whiskers to GaN nanowires. Start with high-surface energy metal which beads up, nucleates whisker and moves with it as it grows. GaN: JMR 18:2 2003 p. 245; ZnO: JMR 18:3 2003 p. 714. Question: is it really liquid? Nature Materials piece shows good data fitting from a solid diffusion model: Nature Materials Nature Materials 3:10 2004 p. 677.
- Catalytic thermal vapor deposition: CNTs catalyzed by nickel particles.
- Very large strains on small scales: ball milling, friction stir processing. Low temperature keeps it solid, large deformation results in nanoscale grains.
- Surface deformation: surface mechanical attrition. JMR 19 p. 1623 2004.
- Self-assembly: proteins have bits that fit, just fall into place. Microtubule formation by a protein pair. Nanoparticles too: chemical function on the surface can attach them together in ways which form structure.
- Templated self-assembly of block copolymers: Nature Materials 3:11 2004 p. 823 (Anne Mayes, Caroline Ross; Ned Thomas does some of this too).

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