Nano structured materials-synthesis, properties, self assembly and applications

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Module 3 Lecture 4, 5 and 6

Problem:

Nanowire 1:

1. What is nanowire? What is quantum wire?
2. Give an example of a molecular nanowire?
3. What is the size range quantum confinement can be observed?
4. What is the energy shift for a particular radius (R) of a quantum dot?
5. Define the remanence and coercivity.
6. How is thermal conductivity related to phonon transport?
7. What are the different methods for the synthesis of nanowires?
8. Give an example of evaporation condensation method for nanowire synthesis.

Nanowire 2:

1. What is the best method for large scale synthesis of nanofibers?
2. What is VLS method? Give an example.
3. What are the key steps for VLS growth mechanism?
4. How will you synthesize radial heterojunctions? How will you characterize heterojunctions?
5. Draw the phase diagram of the materials for VLS growth?
6. What size of the catalyst in VLS method will be good for nanowire synthesis?
7. Give an example of template based nanowire synthesis.
8. What is the step-edge growth mechanism for nanowire synthesis?

Nanowire 3:

1. Draw the schematic diagram of Laser ablation catalytic growth reactor.
2. What is supercritical fluid?
3. What are the applications of metal oxide nanowires?
4. How can metal nanowire be used as barcode?

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Solution:

Nanowire 1:

1. structure having nanometer width and unconstrained length with length: width ratio more than 1000.
   Nanowire having quantum mechanical effect are called Quantum wire.
2. DNA
3. diameter less than 20 nm.
4. $$\Delta E = \frac{\hbar^2}{2m^*}\left(\left(\frac{\alpha_{01}}{R}\right)^2 + \left(\frac{\pi}{L}\right)^2\right)$$
   $$-\left\langle \Psi(x_e)\Psi(x_h) \,|\, \frac{e^2}{\varepsilon |x_e - x_h|} \,|\, \Psi(x_h)\Psi(x_e) \right\rangle$$
5. The amount of magnetization it holds at zero driving field is called its remanence.
   The magnetic field strength required to demagnetize a ferromagnetic material after it has reached saturation is called Coercivity.
6. $\kappa = \frac{1}{3} c_v v l$, V is the phonon velocity. More boundary scattering in nanowire changes phonon dispersion.
7. evaporation-condensation, dissolution-condensation, VLS, electrochemical deposition, electrophoretic deposition, electro spinning, lithography etc.
8. ZnOnanobelts synthesis, where ZnO (s) to ZnO (g) to Zn (g) and 1/2O2 (g) decomposition process in evaporation-decomposition process.

Nanowire 2:

1. VLS
2. The growth species is evaporated and then diffuses and dissolves into a liquid droplet (catalyst) and the growth process takes place at the interface between the substrate and the liquid. Example: Si Nanowire.
3. Growth species in Catalyst droplet, supersaturating the droplet, Nanowire nucleation on the substrate and Nanowire growth on the substrate.
4. Axial growth of the material based on VLS method followed by radial growth of other materials for heterojunctions. STEM elemental mapping can be used to characterize.
5. It is pseudo binary phase diagram. See Module 2, lecture 5, 22:36 mins.
6. critical diameter of the catalyst in VLS method,
   $$d_c = \frac{4\alpha\Omega}{RT\ln\left(\frac{C}{C_\infty}\right)}$$
   a = surface free energy
   W = molar Volume
   R = gas constant
   T = absolute temperature

C = concentration of semiconductor component in liquid alloy
C¥ = equilibrium concentration

7. anodized aluminum oxide (AAO) as template and synthesis of Co, Pt, Ni nanowires etc.
8. electro-deposition of metal oxides on step edges of graphite substrate followed by reduction and then transfer to other substrate.

Nanowire 3:

1. see exact schematic on the slide at 13:10 mins of the module 3, lecture 6.
2. It is a phase above critical point where no distinct liquid or gas phase exists.
3. transparent electronics, detectors, UV light emitters, FET, magnetic storage etc.
4. stripped metal nanowires of alternative metals like Au and Ag can be used as barcode. Au as 0 and Ag as 1, so 0001010, 01011101, 11010001 these are all different barcodes.