Semiconductor Nanoparticles, Nanorods, and Nanowires:
Properties and Applications

Recent review:
H. M. Mansur, *WIREs: Nanomed. Nanobiotechnol.* 2010, 2, 113
Cell uptake of lipid-encapsulated Q-dots


Uptake rate: 50 nm > 15 nm >> 5 nm
Other photophysical properties of Q-dots

1) Intermittent “blinking” emission


Nonradiative photoionization produces temporary “off” state

2.1-nm CdSe QDs, TOPO-coated CdSe/ZnS core-shell QDs

2) Fluorescent resonant energy transfer (FRET) in mixed QD solids


460 nm excitation  \( \rightarrow \) FRET

620 nm emission

540 nm emission

3.85 and 6.2-nm CdSe NPs
Anisotropic Q-dots: quantum rods

Linearly polarized emission from wurtzite CdSe nanorods:


Nanorod emission as a function of aspect ratio

Emission of single quantum rod as a function of polarization angle

Change in HOMO with aspect ratio:

Se(p_{x,y})  Se(p_z)
Quantum nanorods: photovoltaic applications


Inorganic solar cells: up to 10% power efficiency
Organic (conducting polymer) solar cells: ~2.5% efficiency

Hybrid nanorod-polythiophene solar cell: 6.9% efficiency at 515 nm irradiation
Semiconductor nanowires: synthesis


Laser-catalyzed vapor-liquid-solid (VLS) growth of nanowires (NWs)


Laser ablation (high temps.) Liquid particle growth Si NW growth above eutectic temp.


Au nanoparticle as ‘solvent’:
Semiconductor nanowire heterostructures

**GaAs/GaP “striped” nanowires:**

**Si/SiGe superlattice nanowires:**

**InAs/InP superlattice nanowires**
by chemical-beam epitaxy:
Core-shell nanowires and nanotubes

Co-axial nanowires by VLS/CVD:

Templated synthesis of GaN nanotubes:

GaN has a wide band gap (3.42 eV); near-UV lasing capabilities

Semiconductor nanowires: optoelectronic properties


Oxygen adsorption creates depletion layer in dark current: \[ O_{2}(g) + e^{-} \rightarrow O_{2}^{-} \text{(ad)} \]

Photocurrent produces hole-electron dissociation, discharges adsorbed \( O_2 \): \[ O_2^{\text{(ad)}} + h^{+} \rightarrow O_2(g) \]

Zn-doped InP nanowire: $p$-type
Te-doped InP nanowire: $n$-type