SAND2008-4970P

Soft Nanomaterials, Nanocomposites, and Interfaces

Erik D. Spoerke

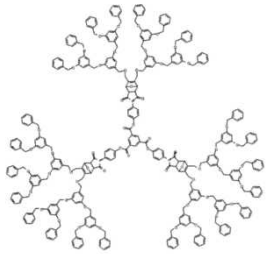
Sandia National Laboratories

Technical Workshop for the National Institute for Nano Engineering (NINE)
Albuquerque, NM
July 29-30, 2008

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000

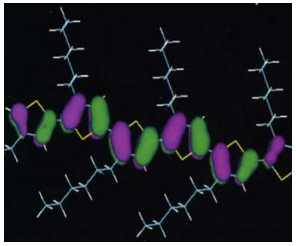
Soft Nanomaterials at Sandia

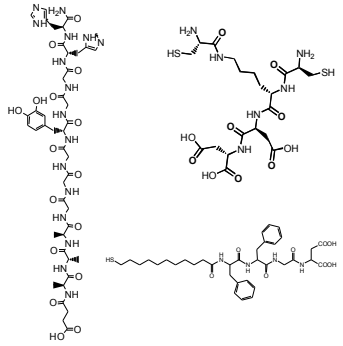
Organic materials at Sandia mediate critical elements of assembly, integration, and communication between active nanomaterials across multiple length scales.



Soft nanomaterials are integrated across a broad set of disciplines at Sandia:

- Biomaterials and Active Assembly
- Surface Functionalization and Modification
- Self-Assembly and Nanoscale Templating
- Nanoparticle Integration
- Active Material Composites

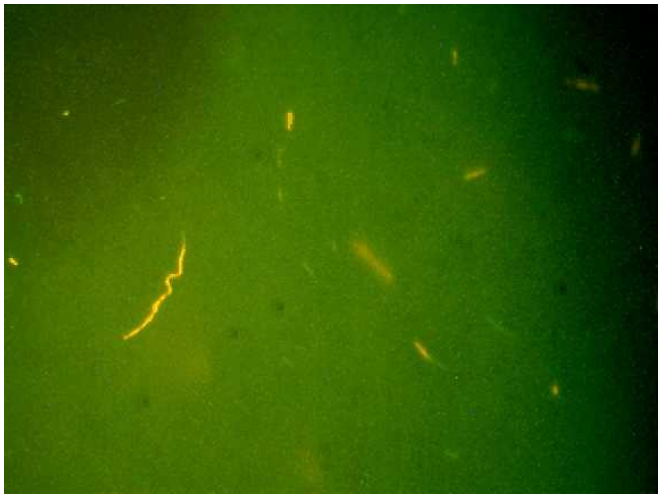




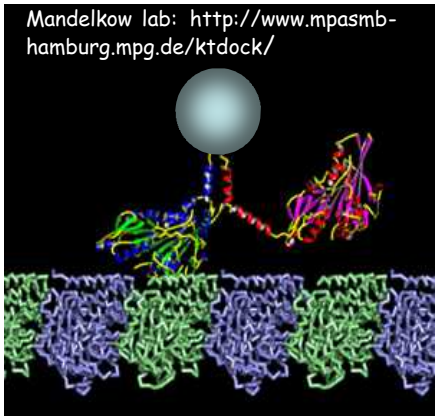
Biomaterials and Active Assembly

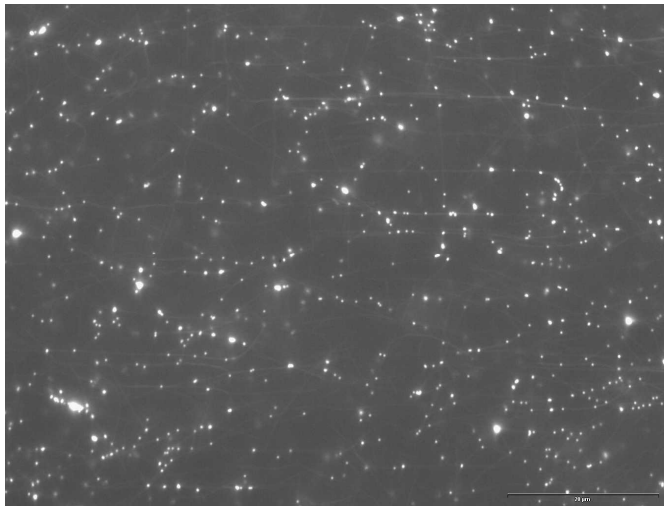
Active Assembly With Microtubules and Motor Proteins

Microtubules and kinesin motor proteins are dynamic nanostructured biomaterials that can be adapted for *in vitro* study and application.

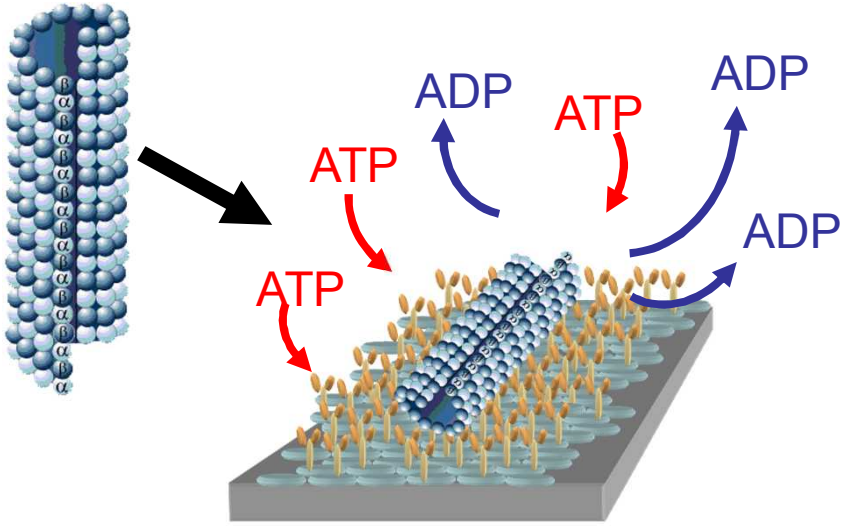


"Standard Motility" involves motor proteins moving, often carrying cargo, over an array of surface-bound MTs





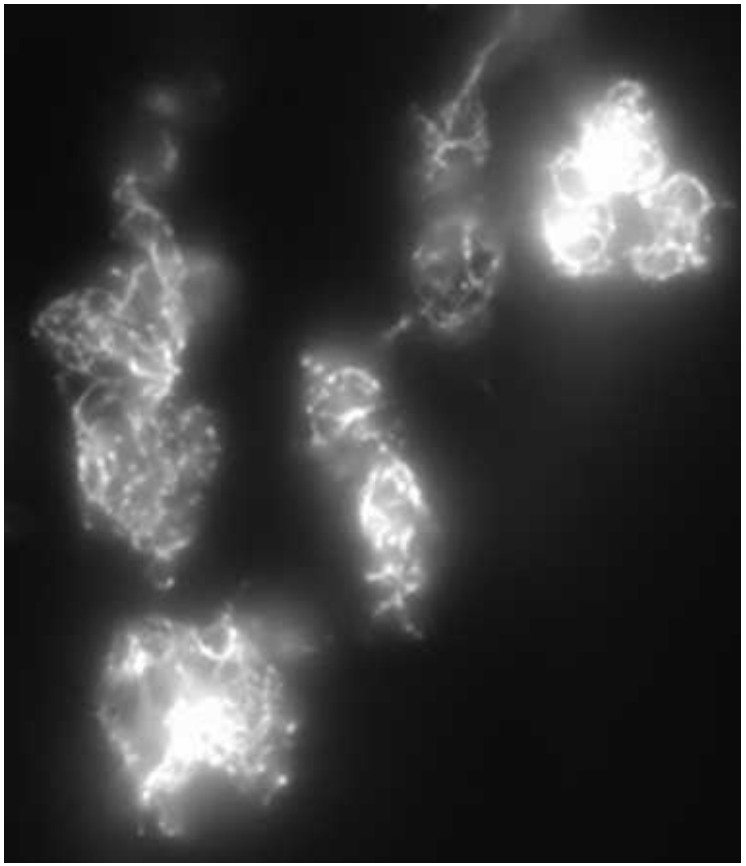
"Inverted (Gliding) Motility" relies on array of surface-bound inverted kinesins to capture and transport MTs over a surface



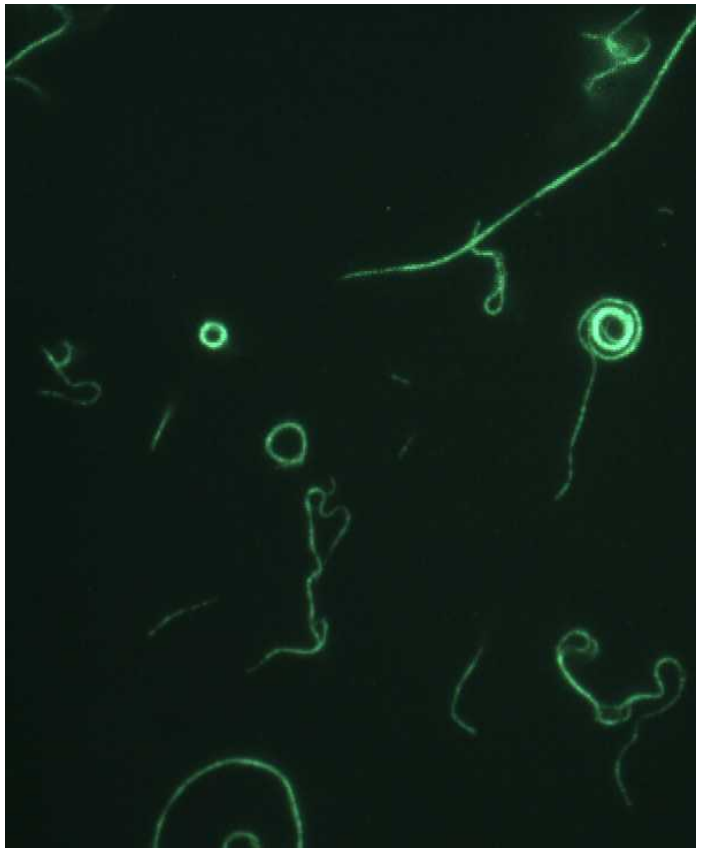
Non-Equilibrium Biocomposites

Active Assembly can profoundly affect nanocomposite morphology

Random Assembly

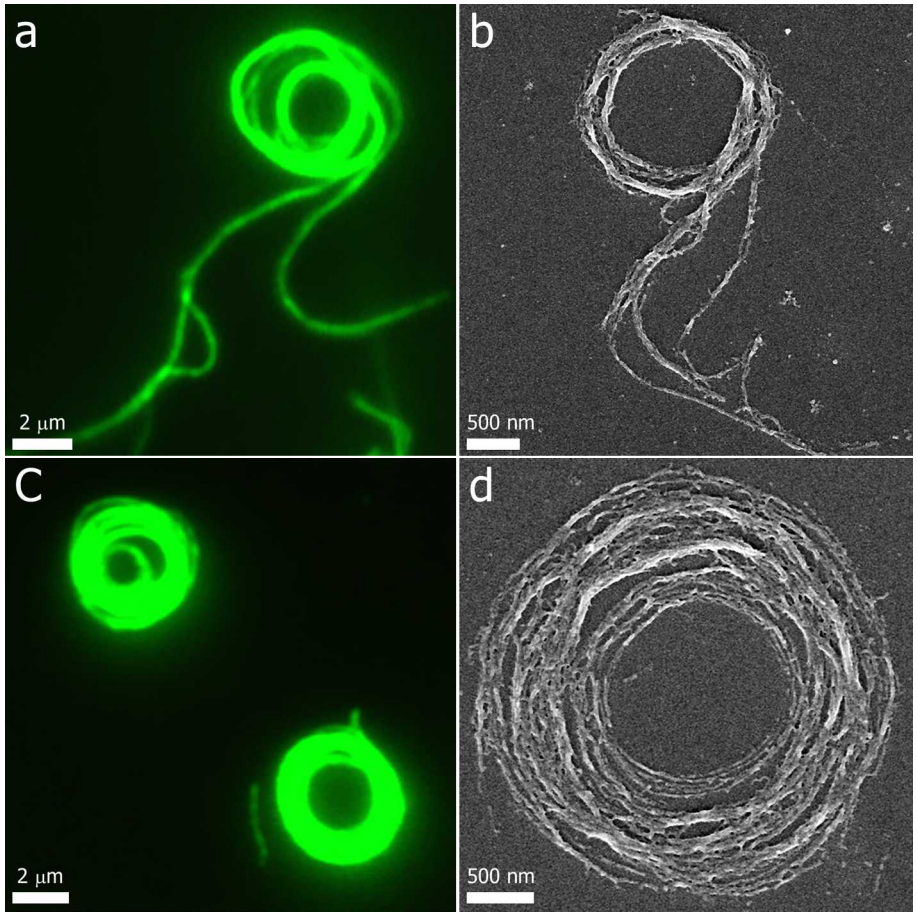


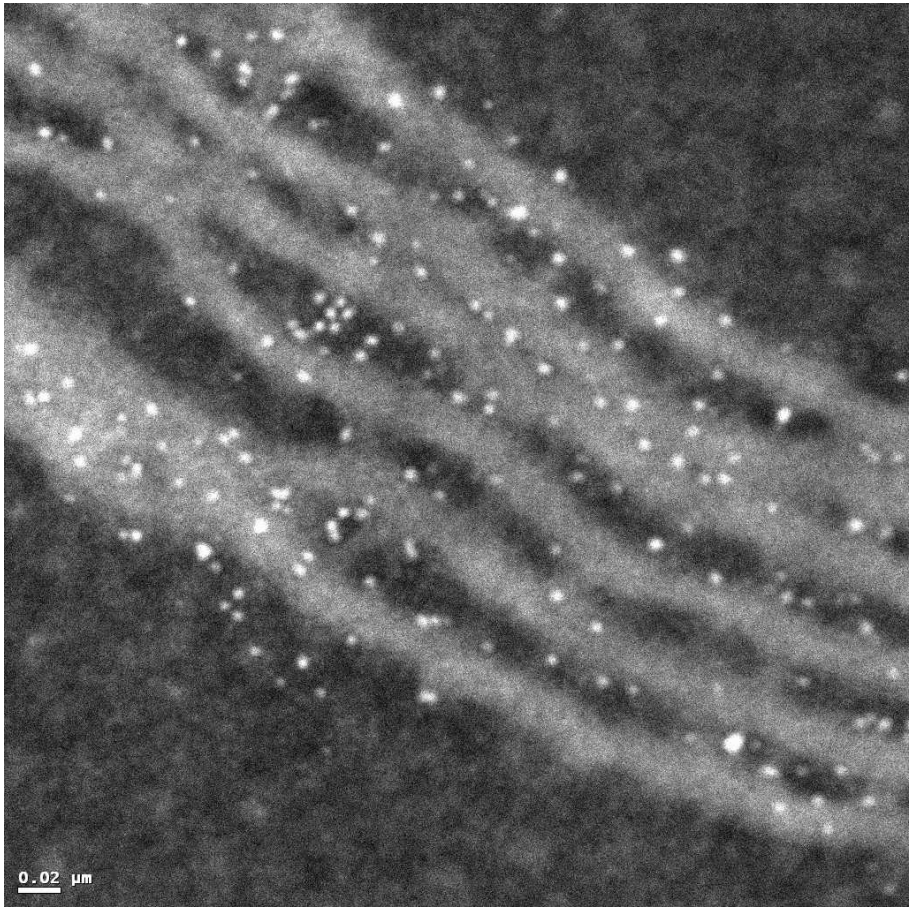
Kinesin-driven Active Assembly



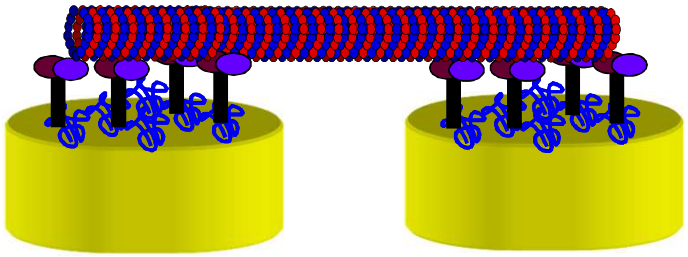
Dynamic Composite Structure

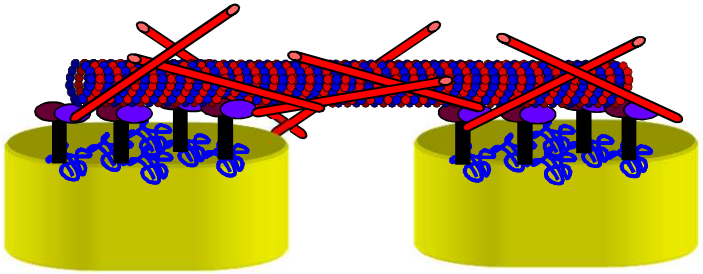
Intimate component interactions drive the formation of these unusual structures.

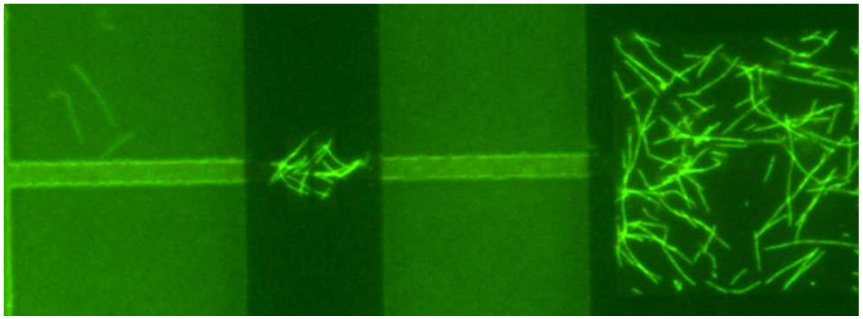


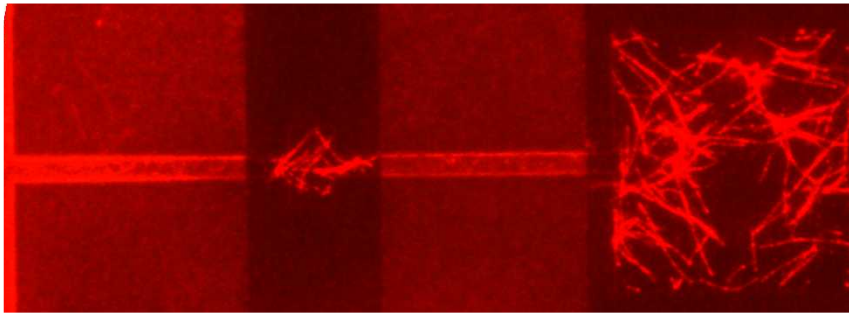


Nanomaterials Biotemplating







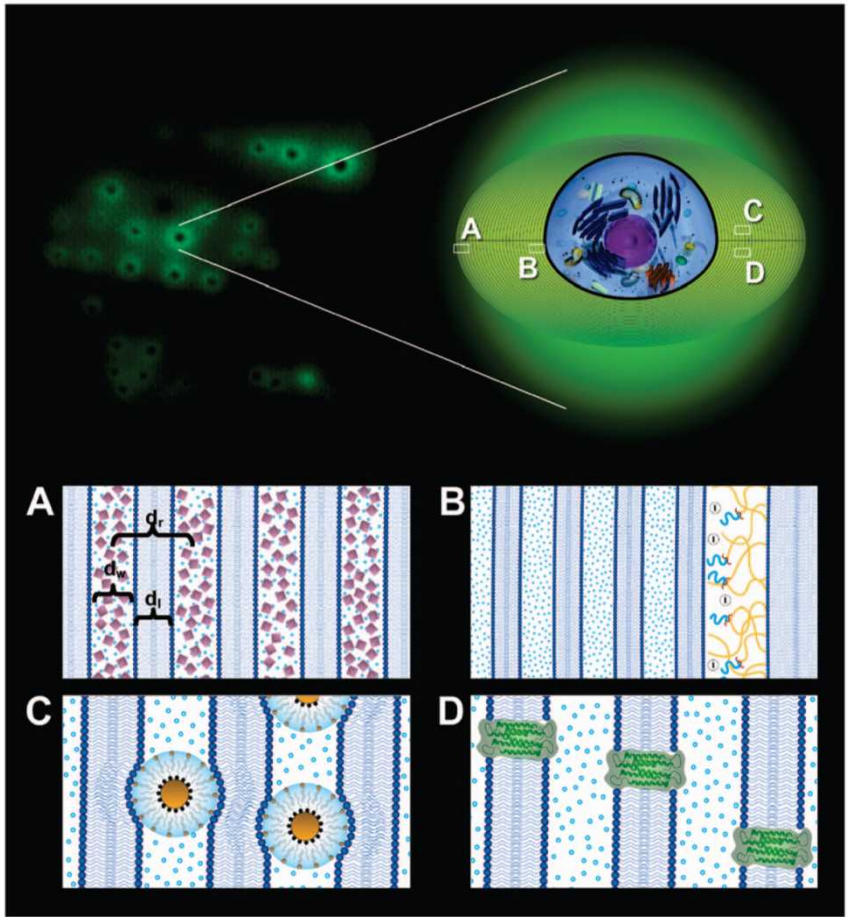


Kinesin-captured MTs will selectively bind to gold platforms, forming bridges between gold electrodes

Using Biotin-Streptavidin linkages, SWNTs may be templated on MT bridges *without degrading MT/kinesin interactions*

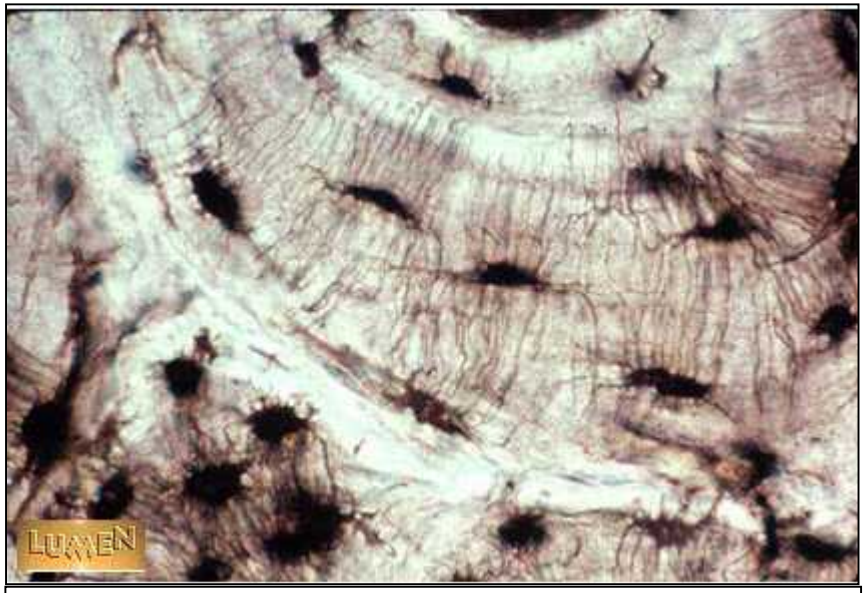
Living Composites

Live yeast cells encapsulated in a silica matrix surround themselves in nanostructured lipid vesicles to preserve cell viability (Cell Directed Assembly).



Baca, et al. *Acc. Chem. Res.* **2007,** *40,* 836–845

These living cells, encapsulated in a complex composite matrix draw parallels to osteocytes en,capsulated in the complex nanostructure of bone.

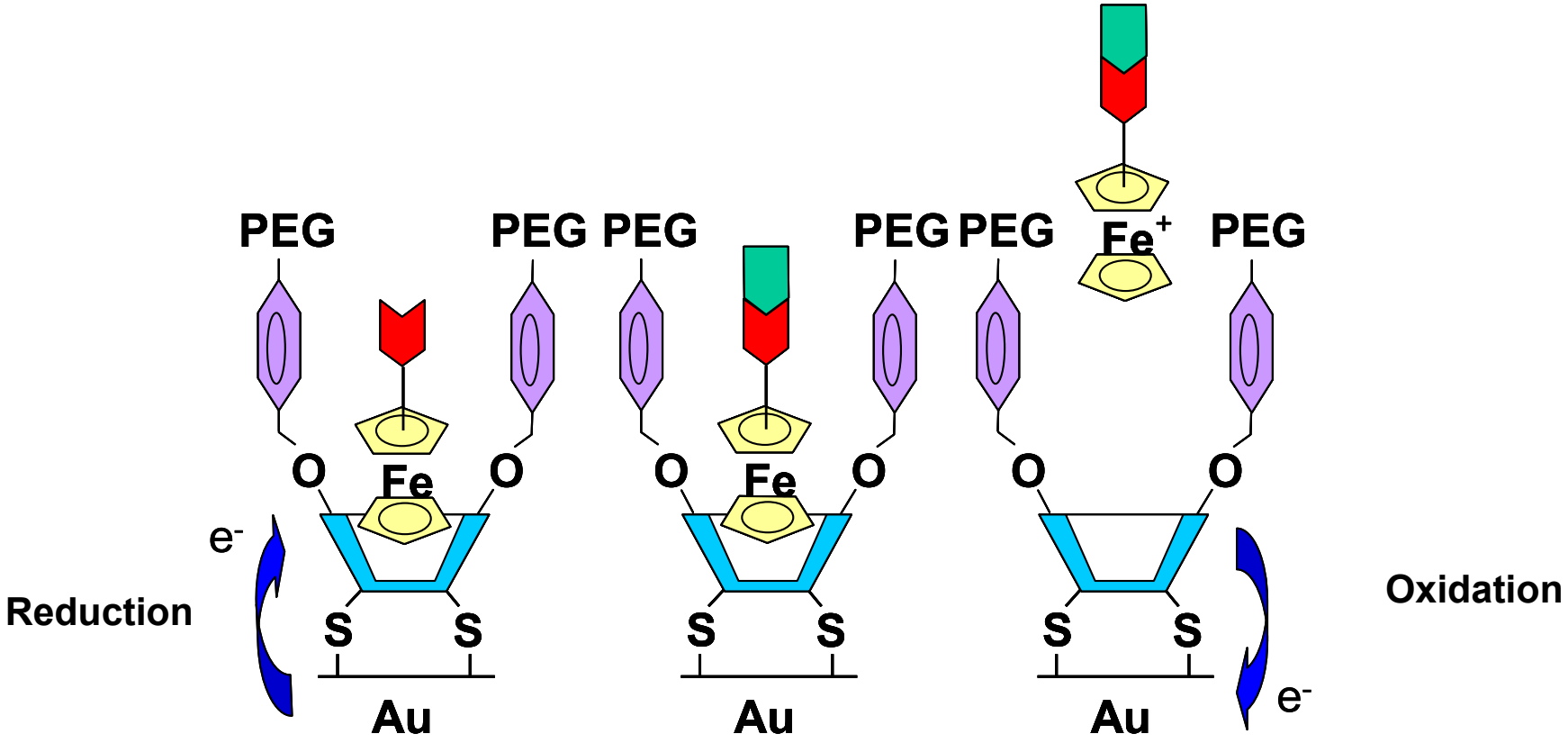


http://www.meddean.luc.edu/lumen/MedEd/Histo/frames/h_frame9.html

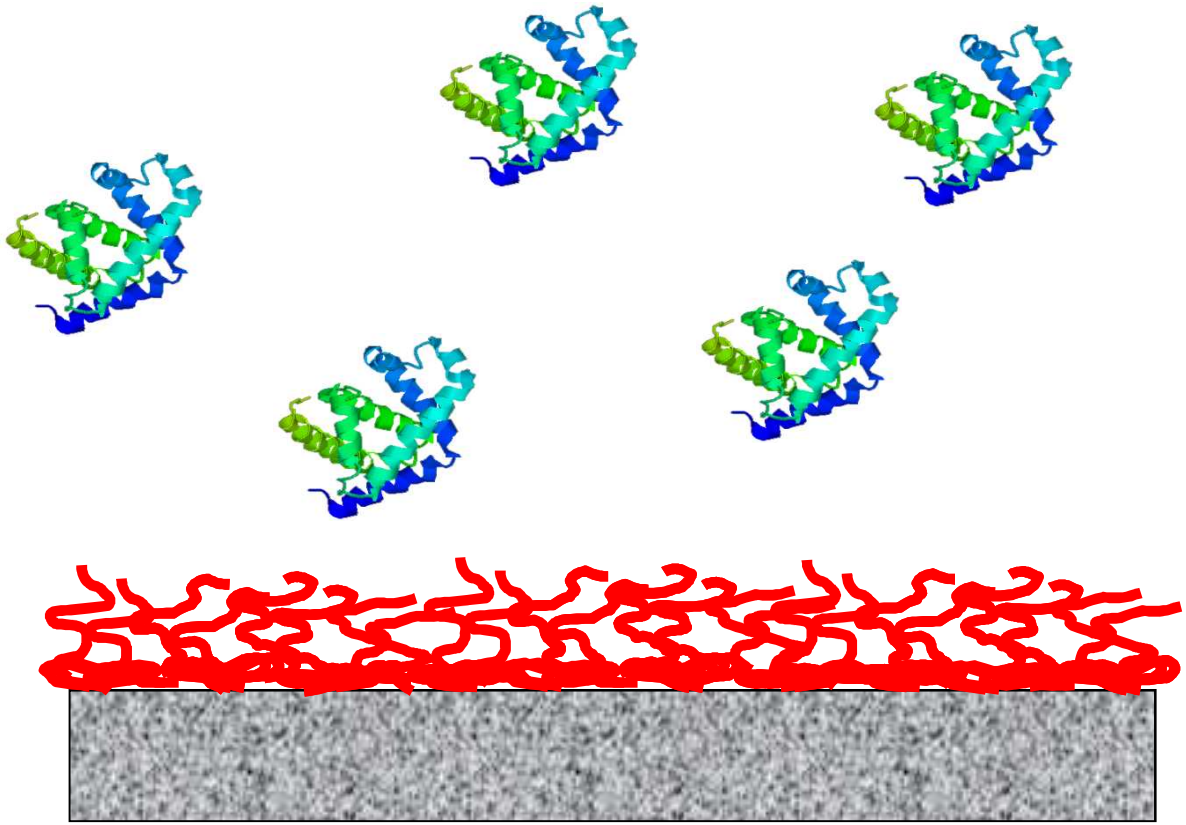
Surface Functionalization and Modification

Surface Modifications

Electrochemical activation of Redox-active molecular interfaces mediate molecular capture on surface.



Thermally Variable Systems

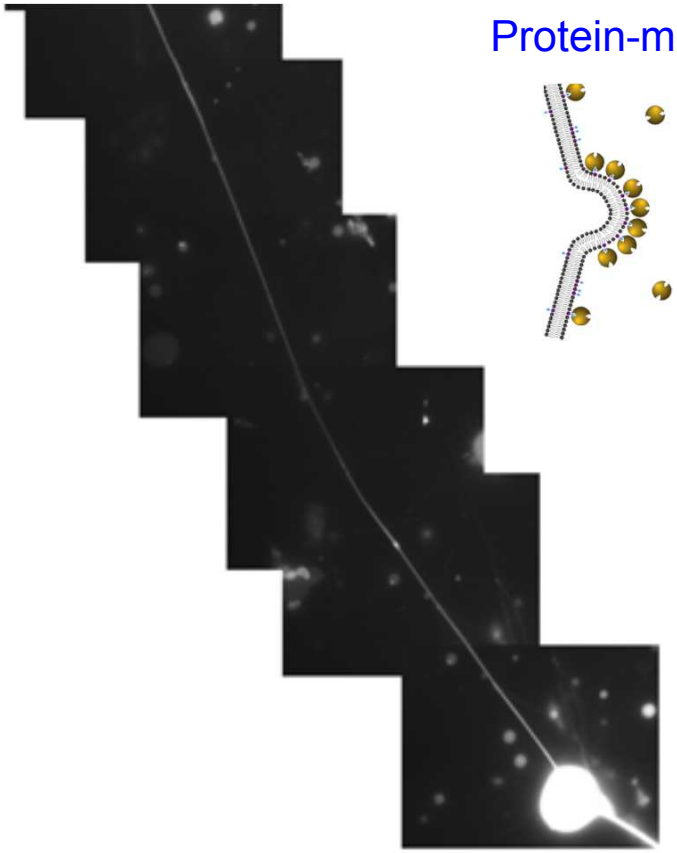


Poly(NIPAM) polymerized from the substrate surface

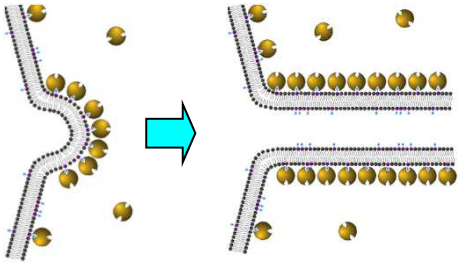
Self-Assembly and Nanoscale Templating

Lipid Nanotubes

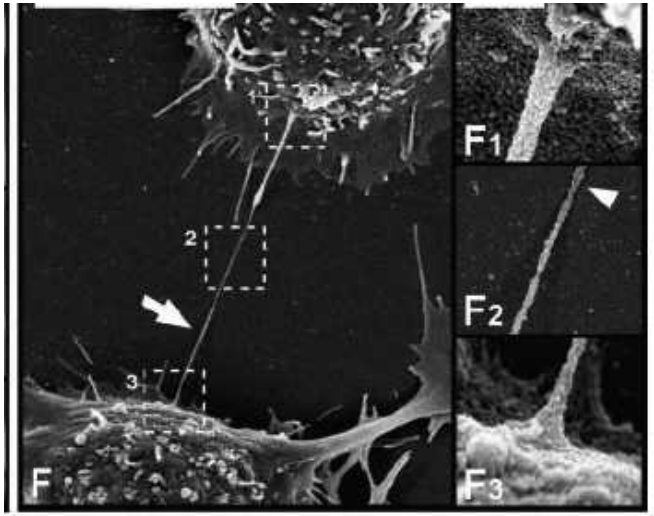
Interactions between streptavidin and biotinylated lipid vesicles induces spontaneous nanotubulation.



Protein-membrane tubulation

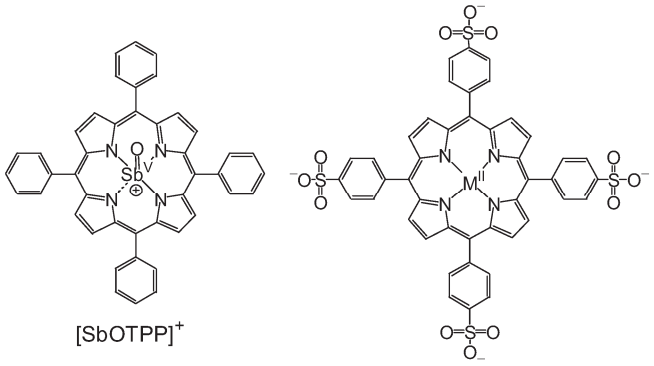


These nanotubes resemble lipid tubules formed between communicating cells in biology

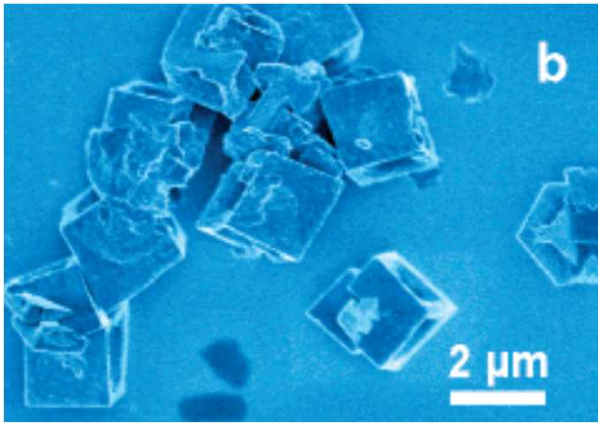


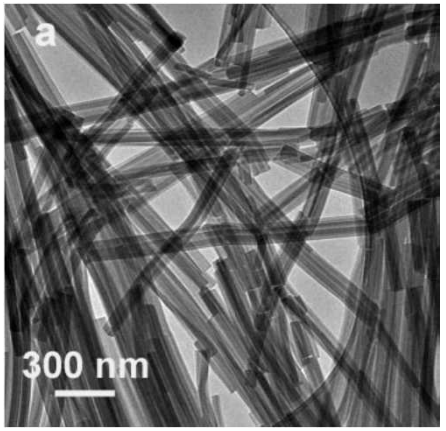
Porphyrin-based Assemblies

Molecular building blocks (porphyrins) can be used to assemble diverse geometries with complex molecular function.



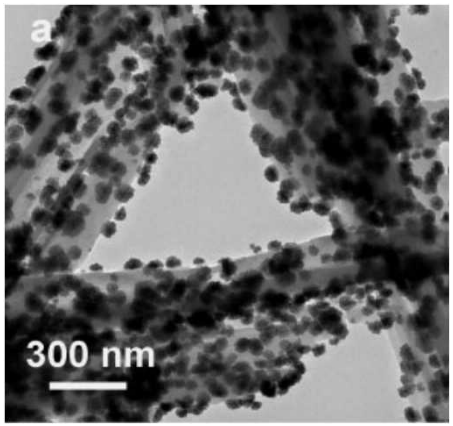
Cubes





Nanobundles

Irradiation with incandescent light in metal precursor solution induces catalytic self-metallization



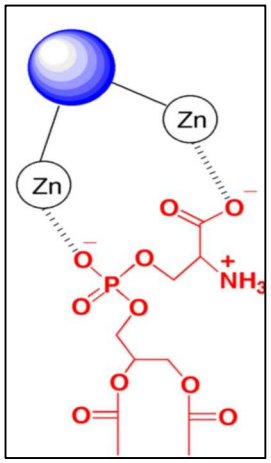
Metallized Nanobundles

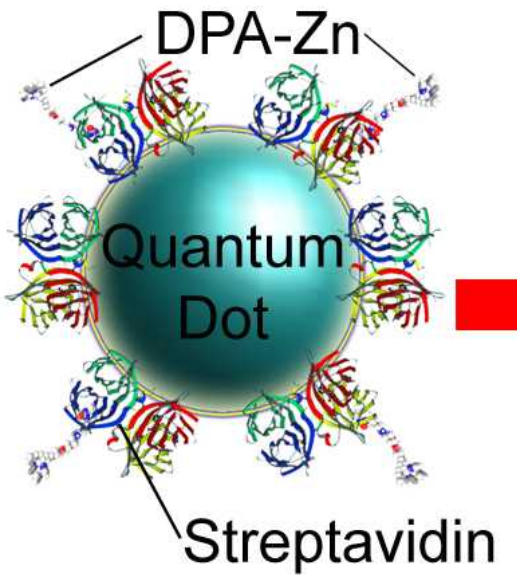
Nanoparticle Integration

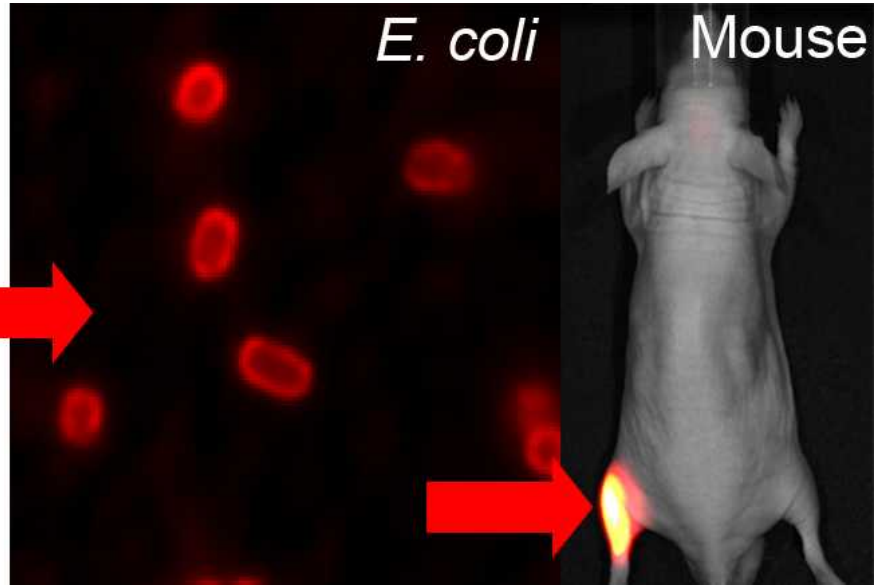
Nanoparticle Biocomposites

Nanoparticle biocomposites engineered for sensitivity to phosphatidylserine enable detection of dying cells (apoptosis)

DPA-Zn

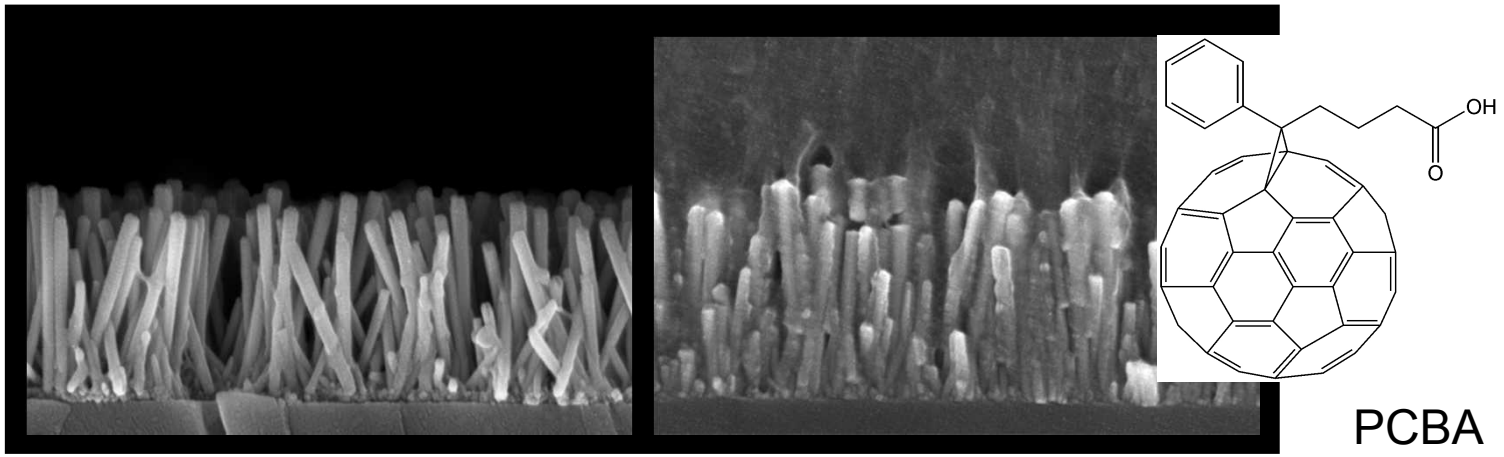


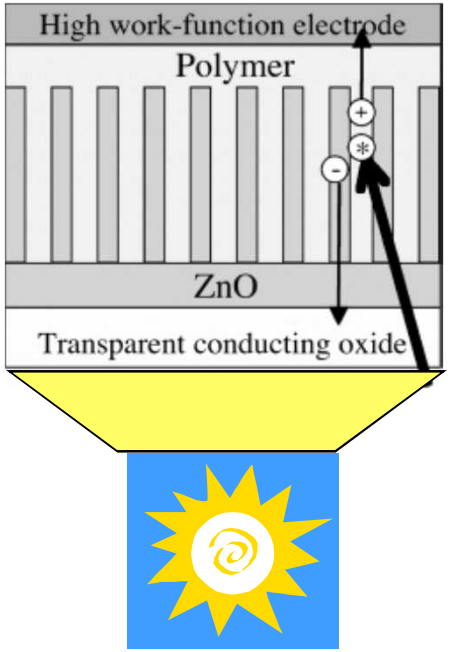


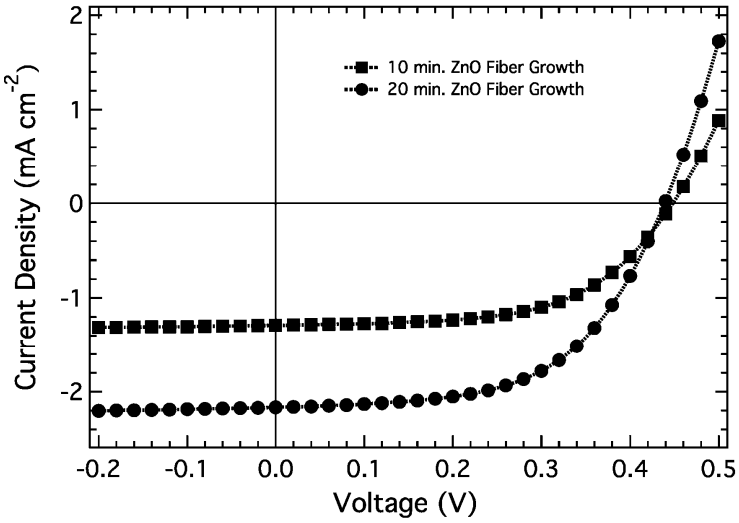


Active Material Composites

Hybrid Organic Photovoltaics







Looking Forward

Project “Composites”

Integration of personnel, capabilities, and materials technologies to drive the next generation of functional composite materials.

Introduce project idea?