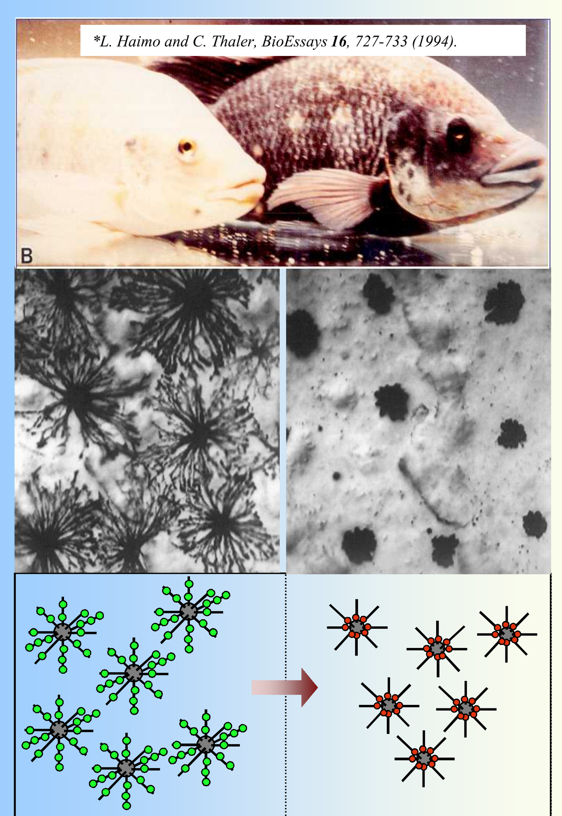
SAND2006-5038P

Developing Dynamic, Integrated Nanomaterials Using Active Biomolecules

The formation and nature of biological materials are intrinsically different from those of synthetic materials. Living systems utilize energy to assemble, organize, and disassemble materials in a dynamic, highly non-equilibrium manner. The goal of our work is to develop integrated nanomaterials that utilize active biomolecules for assembly, dynamic organization, and disassembly.

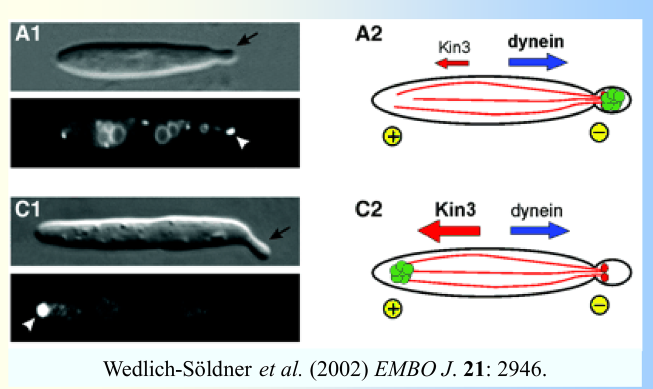


Some organisms such as fish have the ability to adaptively change color (macroscale) by actively reorganizing pigment granules (nanoscale).

Granule reorganization is driven by motor protein-based transport systems.

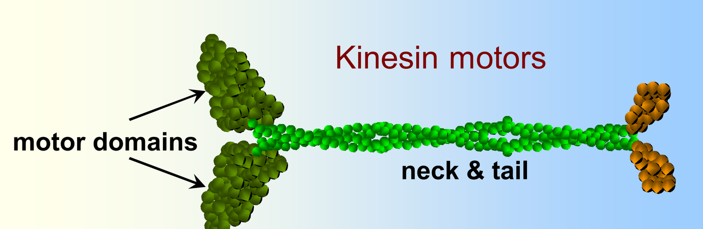
These systems can be reconstructed *in vitro*, with the goal of developing adaptive materials.

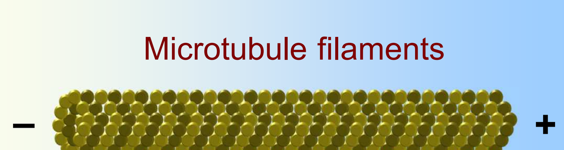
Intracellular, nanofluidic transport is achieved by active transport in which motor proteins move macromolecular cargo within the cell's cytoplasm.



Motor protein-based transport in artificial systems can be guided using combined physical (channels) and chemical (SAMs) barriers.

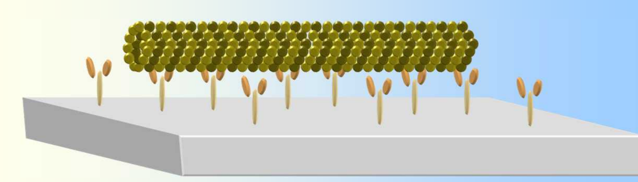
We have focused on the active transport system involving kinesin motor proteins and microtubule filaments. This transport system is key to a range of physiological processes (e.g., fish color change), and may be reconstructed *in vitro* for nanotechnological application.

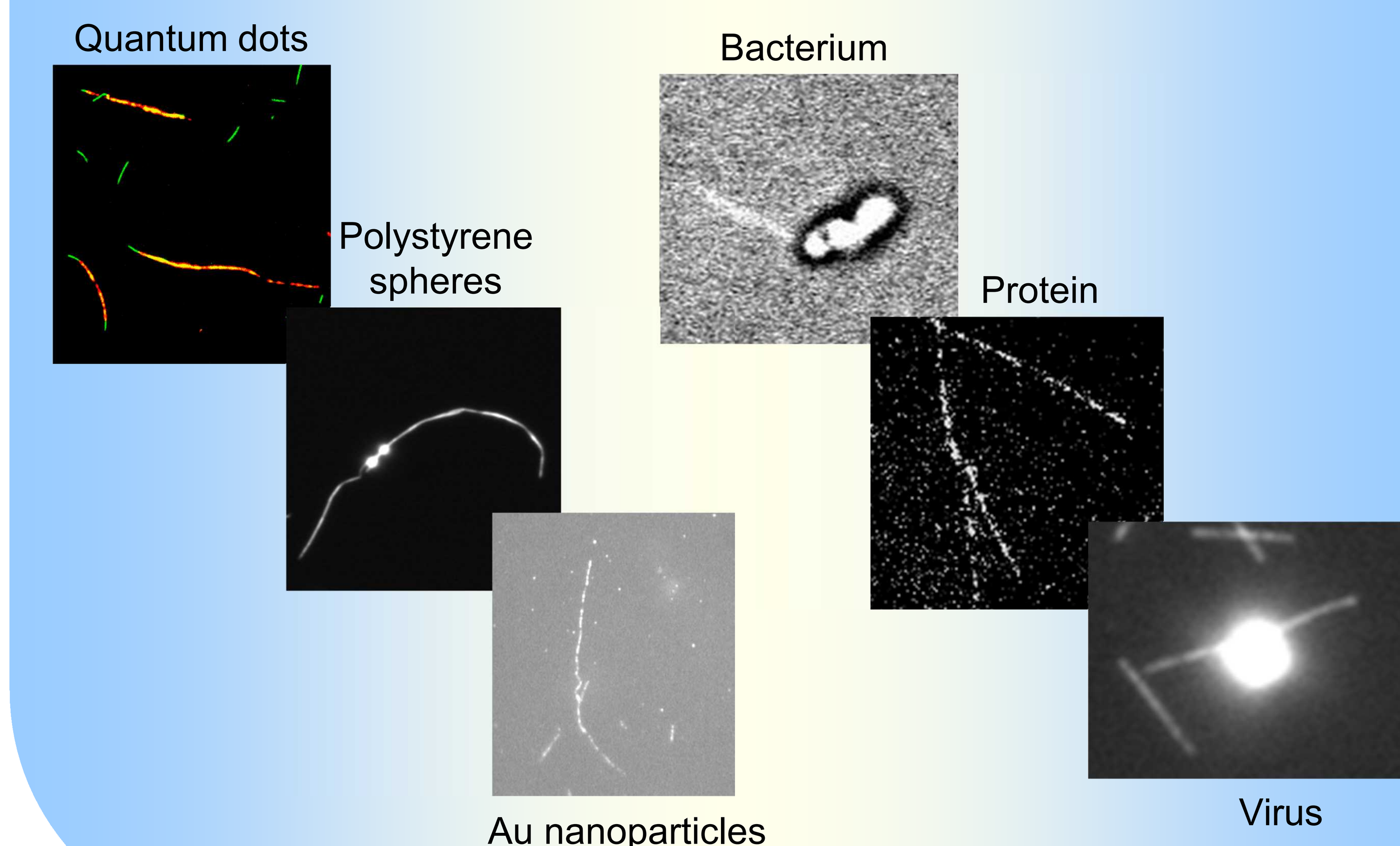




Motor Protein-Based Nanofluidic Transport

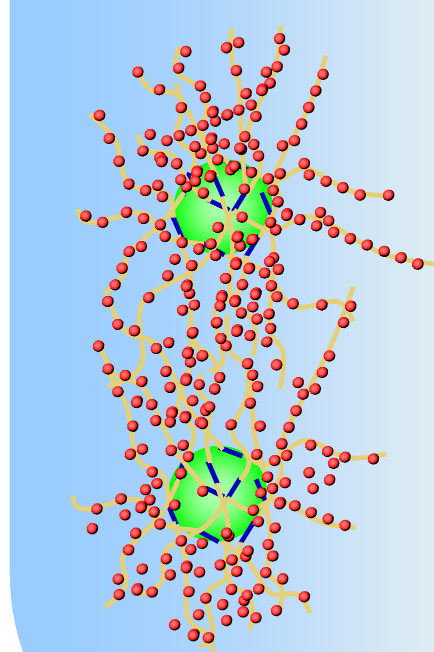
Molecular shuttles (microtubule filaments transported along a kinesin monolayer) can be used to transport a wide array of inorganic, polymer, and organic materials in nanofluidic environments.

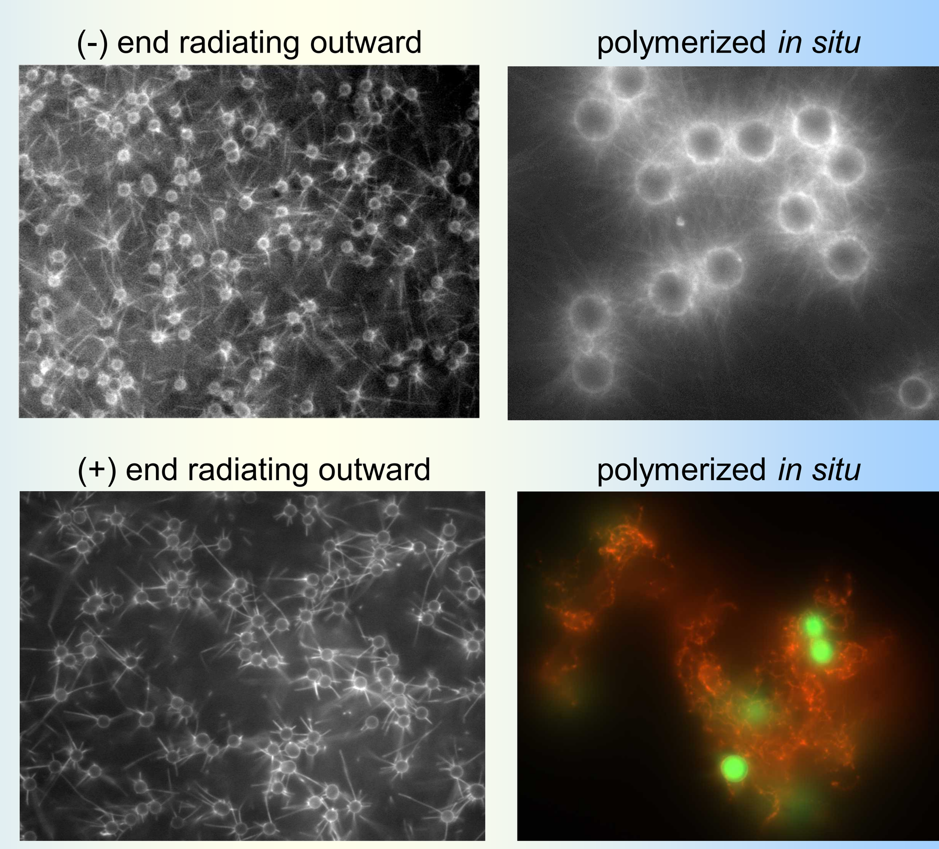




3D Nanocomposite Assemblies

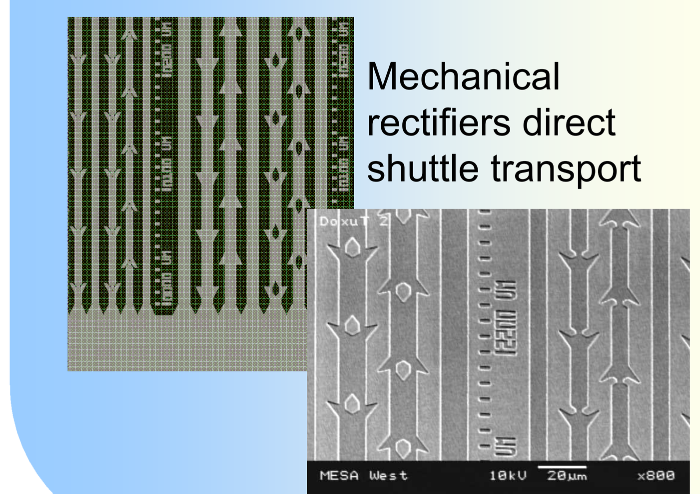
Microtubule filaments can be assembled into 3D structures mimicking the centrosomes in living systems. These 3D structures may be used to organize nanoparticles as shown below, or serve a transportation networks on which kinesin motor proteins can transport nanoscale cargo.



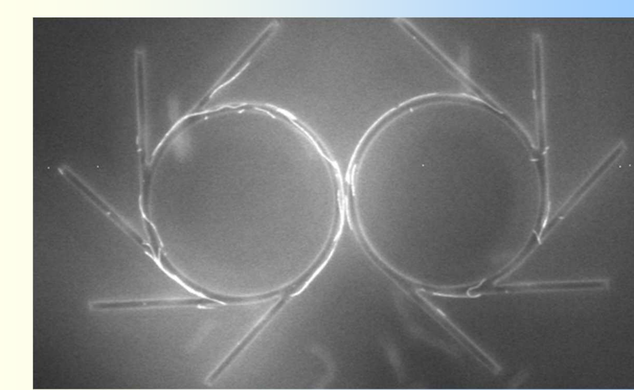


Directed Transport in μFluidic Systems

Kinesin-based transport of molecular shuttles may be confined in microfluidic systems using a combination of chemical and physical barriers. Directed transport can be achieved using mechanical rectifiers (e.g., arrows) as well as electrical and magnetic fields.



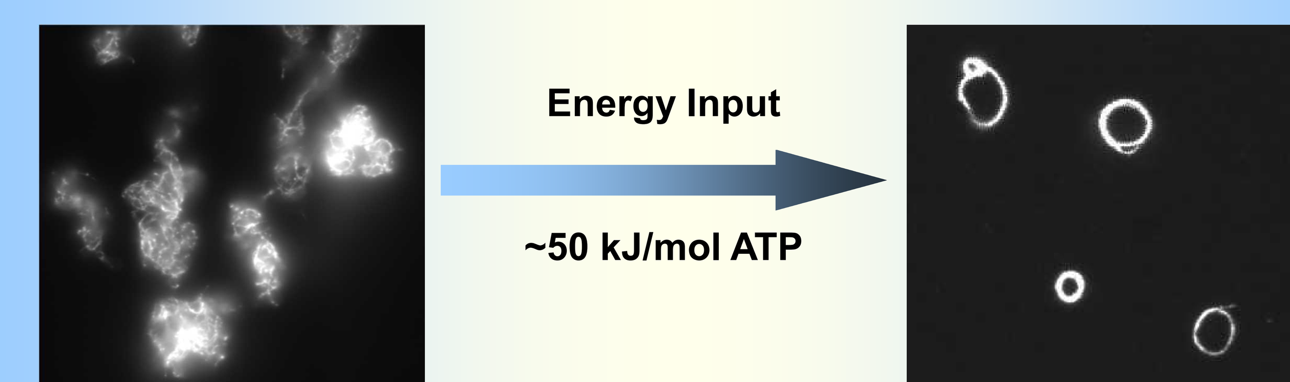
Mechanical rectifiers direct shuttle transport



Unidirectional transport using ratchet patterns

Energy-driven Assembly of Nanocomposites

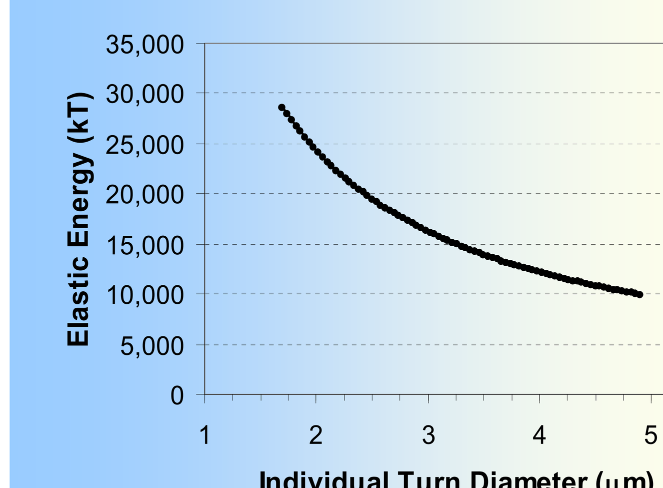
Energy converted by kinesin motor proteins via ATP hydrolysis may be used to assemble ordered structures consisting of protein filaments (i.e., microtubules) and semiconductor nanoparticles. These structures are highly non-equilibrium, and capable of storing large amounts of elastic energy (>10^6 kT).

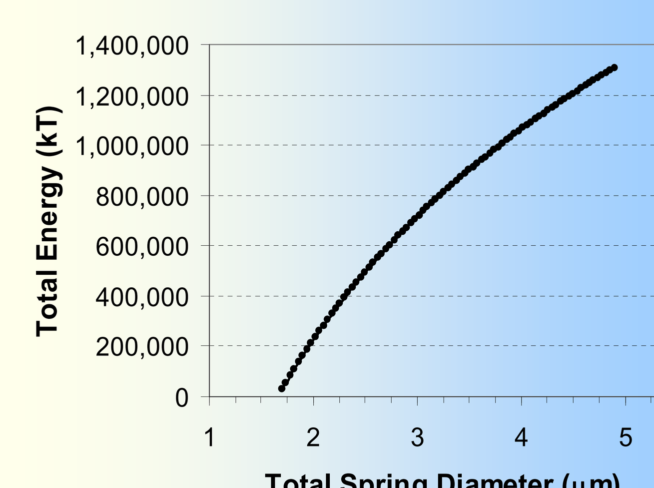


U (*elastic energy*) = $\frac{2\pi\kappa}{D}$

$\kappa_{MT} = 3.2 \times 10^{-23}$ N m^2

The energy stored in these composite "nano-springs" is dependent on the (1) individual radius of each turn, and (2) the total diameter of the spring.





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