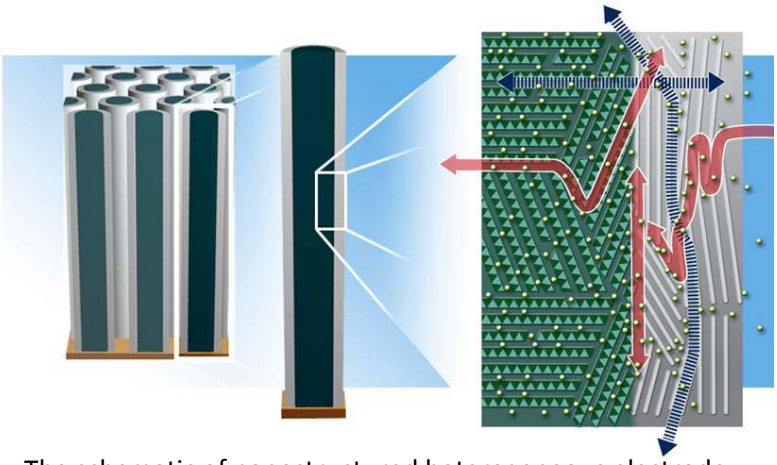
Nanostructures for Electrical Energy Storage (NEES)
EFRC Director: Gary W. Rubloff
Lead Institution: University of Maryland

***Mission Statement*:** *To understand and build nanostructured electrode components as the foundation for new electrical energy storage technologies*

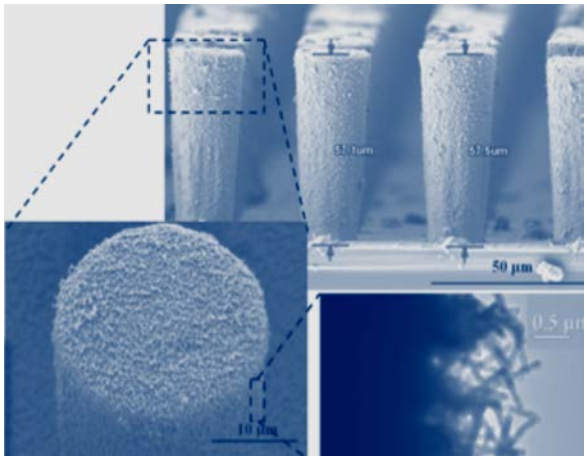
The NEES Energy Frontier Research Center takes on fundamental challenges in lithium-ion battery and supercapacitor energy storage by investigating systems at the length scale of one to hundreds of nanometers. The members of NEES synthesize and study precisely made nanoparticles, nanotubes, nanowires, and nanometer-thick films of different materials (i.e. "nanostructures"). We focus on how the geometry and structure of those materials and configurations of the nanostructures together affects their properties.



The schematic of nanostructured heterogeneous electrode shows the separate ion storage and electron transport layers.

The Center's vision holds that heterogeneous combinations of oxides, silicon, and novel forms of carbon in nanostructures promise to meet the multifunctional requirements of high power, high capacity electrodes. By specifically examining nanostructures that are composed of well-defined and closely controlled materials and geometries, the Center has ideal platforms for investigating how lithium-ion conductivity and capacity, electrical conductivity, and mechanical stability limit the lifetime, energy density, and power of electrochemical energy storage.

NEES has four strategic directions. In the **Cathodic Nanostructures** and **Anodic Nanostructures** strategic directions, researchers explore the underlying processes that control the behavior of carbon nanotubes, graphene, and other carbon materials that are combined with either an oxide material or silicon. The carbon materials in pristine form are both mechanically strong and excellent electronic conductors, while nanoscale oxides and silicon store and release high densities of lithium ions at high rates.



Combining the expertise of electrochemists, materials scientists, electrical engineers, and physicists, the Center's effort analyzes fundamental issues in nanostructure synthesis, charge transport kinetics, and mechanical stability during cycling.

The **Enabling Science & Methods** strategic direction develops model nanostructured systems and creates new instruments and techniques to probe their properties. Researchers create experimental and computational models of surface and interface evolution, critical for teasing out the core factors at play at the junctions of heterogeneous materials.

The researchers also develop new measurement techniques, including microsystems for use in-situ high-resolution transmission electron microscopy (TEM) to evaluate nanoscale processes during electrochemical reactions. They have also developed novel cantilever structures to measure structural changes at the nanoscale. The microsystems for in-situ electrochemical TEM are being developed as a Discovery Platform at the Center for Integrated Nanotechnologies, a user facility that is a joint venture between Sandia National Laboratories and Los Alamos National Laboratory, and thus the platform will be available to the wider scientific community.

The fourth strategic direction on **Nanostructure Forests** is a new area of NEES investigation. Building off the knowledge gained from studying individual nanostructures, researchers investigate ion flow around and to large numbers of nanowire electrodes. The transport of charge through a 'forest' of nanowires presents intriguing challenges for understanding the influence of nanopore geometries and high surface areas on electrolyte flow.

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