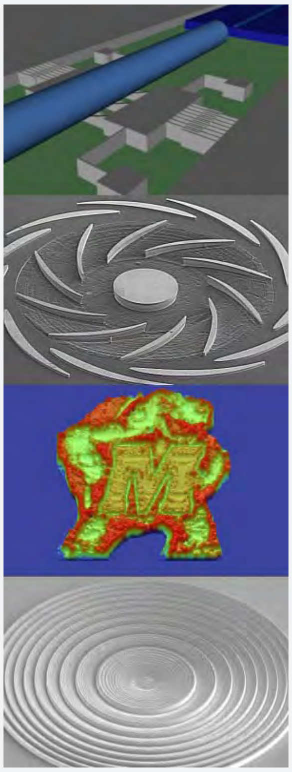
# Innovating Energy Storage at the Nanoscale



Growing demands for energy, particularly renewable energy, require not only new sources but new methods of storage. Such methods are emerging in the burgeoning field of nanotechnology as scientists refine their techniques for structuring matter at the molecular and atomic scale. The Maryland Nanocenter directed by Dr. Gary Rubloff combines research in engineering, chemistry, and physics to develop revolutionary new concepts for energy storage. Working with materials at an extraordinarily minuscule scale—1000 times smaller than a human hair--they are creating new types of batteries that not only hold energy effectively but are fast-charging and fast-discharging, small and lightweight.

The Nanocenter researchers are looking at whether the strengths of batteries and capacitors can be combined at the nano scale. At the standard scale, batteries hold great amounts of energy but can’t utilize it quickly, whereas capacitors discharge energy quickly but can’t hold as much of it. This situation is analogous to the choice between a car with a huge gas tank and low acceleration and a car that accelerates quickly but has a small tank. Nanotechnology brings the possibility of improving both ends of the energy spectrum. Customized nanostructures created by University of Maryland researchers incorporate the strengths of both batteries and capacitors simultaneously. Collectively their work is bringing solar- and wind-based energy, for instance, closer to a practical reality. They envision a day when drivers can spend the same amount of time recharging their electric cars that they now spend pumping gas.

Through a revolutionary process of creating new nanostructures one atomic layer at a time, Gary Rubloff is able to increase the surface density, and thus the energy density, of designer nano configurations.

Sang Bok Lee examines how nanotech advances open up potential new forms of synergy between batteries and capacitors.

Through his leading-edge work in carbon nanotubes and graphene nanostructures, Michael Fuhrer explores new limits in the energy-related applications of lithium.

John Cumings’s research in materials science focuses on enhancing the density and conductivity of lithium.

Reza Ghodssi tests newly created nanostructures for their energy storage capacities. His work in micro-electro-mechanical systems has shown how batteries can be both more energy-efficient and lighter in weight.
**http://www.nanocenter.umd.edu/**

## Layering at the Atomic Level

Materials scientist Gary Rubloff builds new nanostructures by adding trimethyl aluminum and water in alternating doses. Because this layer deposition process is self-limiting, the materials can be controlled in such a way that only one atomic layer is added at a time; this single layer can be spread over any configuration. This unprecedented degree of surface density permits a much higher degree of energy density and leads the way toward forms of energy storage both more compact and more powerful than previous forms.
**Gary Rubloff** **rubloff@umd.edu** **http://www.rubloffgroup.umd.edu/**

## Finding the Synergy Between Batteries and Capacitors

If the strengths of batteries and capacitors could be combined to achieve both high energy and high power, it would be possible to cover the power/energy spectrum more effectively for specific applications such as medical devices, sensor-actuators and renewable energy storages, and remove the main obstacles preventing the widespread use of electric cars: limited acceleration and slow recharging. Materials chemist Sang Bok Lee finds that at the nanoscale, some materials work synergistically, supporting each other's strengths and cancelling out each other's weaknesses. Lee produces energy storage devices by introducing battery materials and highly conductive materials such as conductive polymers and carbons to highly controlled cylindrical nanopores in anodized aluminum oxide (AAO) film, resulting in massive arrays of multi-component nanostructures. The prototype devices he creates verify their increased power and energy through the cooperation of multi-components at the nanoscale to increase conductivity and charge-holding capacity.

**Sang Bok Lee** slee@umd.edu

## Breaking the Lithium Speed Barrier

Why recharge a car overnight if it can be done in 10 minutes? To make such a speedy recharge possible, lithium would need to travel through other materials much faster than it presently does. Enter physicist Michael Fuhrer and his pioneering work in carbon nanotubes and graphene nanostructures. His research aims to create structures that are strong, lightweight, high in electrical conductivity, and resistant to chemical damage. Gauging these properties is no simple task, because materials behave differently at the nanoscale than they do at other scales. The graphene sheets Fuhrer creates provide a needed step in the development of nano-structured electrodes of higher conductivity—to increase the rate at which energy can be discharged from a battery.

**Michael Fuhrer** mfuhrer@umd.edu http://www.physics.umd.edu/mfuhrer

## Strength in Nano-combination

On the road to achieving batteries that are lightweight and fast both to charge and discharge energy, one immediate challenge is to learn what new problems and potential solutions will show up at the nanoscale. Lithium, for instance, turns out to improve when used in combination with other materials. John Cumings's research focuses on the untapped possibilities of lithium—an optimal material because of its placement at the light end of the Periodic Chart, just down from hydrogen and helium, which are presently infeasible as conductors. Where his colleague focuses on lithium's speed barrier, Cumings works to break past its density barrier. Drawing on his background in electron microscopy, Cumings examines whether silicon can be restructured at the nanoscale so as to withstand the addition of lithium. Ordinarily silicon cracks and disintegrates during this process, so Cumings wraps silicon nanowires in carbon nanotubes to increase their strength-to-weight ratio, making them lightweight and extremely tensile.

**John Cumings** cumings@umd.edu http://terpconnect.umd.edu/~cumings/

## Innovating Ball Bearing Technology at the Nanoscale

In the University of Maryland's state-of-the-art fabrication laboratory, or "Fab Lab," Reza Ghodssi uses highly specialized equipment to determine whether newly created nanostructures meet the objectives required for optimal energy storage. In collaboration with military researchers he developed micro-generators that improve on present technology in terms of both efficiency and reliability. Drawing on methods used in the semiconductor industry for making microchips, Ghodssi's team used micro-ball bearing technology to manufacture an extraordinary new micro-system integrating pumps, motors, and turbines. Incorporated into a micro-scale liquid-fuel power generation system, this new technology will significantly reduce the battery load of the digital devices soldiers pack into remote locations. The system holds promise not only for the military but for medical and computer fields, as well as for applications not yet imagined.

**Reza Ghodssi** ghodssi@umd.edu http://www.ece.umd.edu/~ghodssi/