Organization at the

Chemist Sarah Tolbert explores how size and structure can be used to create change in the properties of materials.

For Sarah Tolbert, her research is all about organization—at the nanoscale.

Tolbert—a professor of chemistry and member of the California NanoSystems Institute—explores the fundamental questions affecting complex materials so small that they are measured at lengths less than one-thousandth the thickness of a human hair. Tolbert's work, while wide-ranging, is based on one of the basic principals of nanoscience: that larger materials, when made very small, can have very different properties.

Tolbert studies optical, magnetic, electrical, and structural behaviors, focusing on the link between those physical properties and the nanoscale structure of the materials. In this way, she works to understand how size and structure can be used to control and change the properties of materials.

"My group often starts with materials in solution," Tolbert said, "with the goal of making the materials organize in ways that give them new properties that we can exploit."

In one example of Tolbert's recent work, her group focuses on exploring issues that could create batteries that have the twin advantages of fast charging, combined with high capacity for storage.

"A major problem with current capacitors (devices that hold an electrical charge) and batteries is that they are either slow to charge, or they don't store enough charge," said Tolbert. "The ideal is to create a system that can be charged quickly, and also stores a lot of charge."

Tolbert and Bruce Dunn, professor of material sciences and engineering, are working on this principle in their work on new types of "supercapacitors"—a storage device halfway between a battery and a capacitor—using her assembly methods at the nanoscale.

"A way to create a battery that can charge and discharge very quickly is to design it so it stores the charge on its surface—but that requires a lot of surface," said Tolbert. "That's where porous materials come in, because they can be created in ways that produce a tremendous amount of surface area."

Tolbert and Dunn are taking nanocrystals that can store a charge, and assembling them onto porous materials, thus creating a matrix of storage sites surrounded by the battery's electrolyte solution.

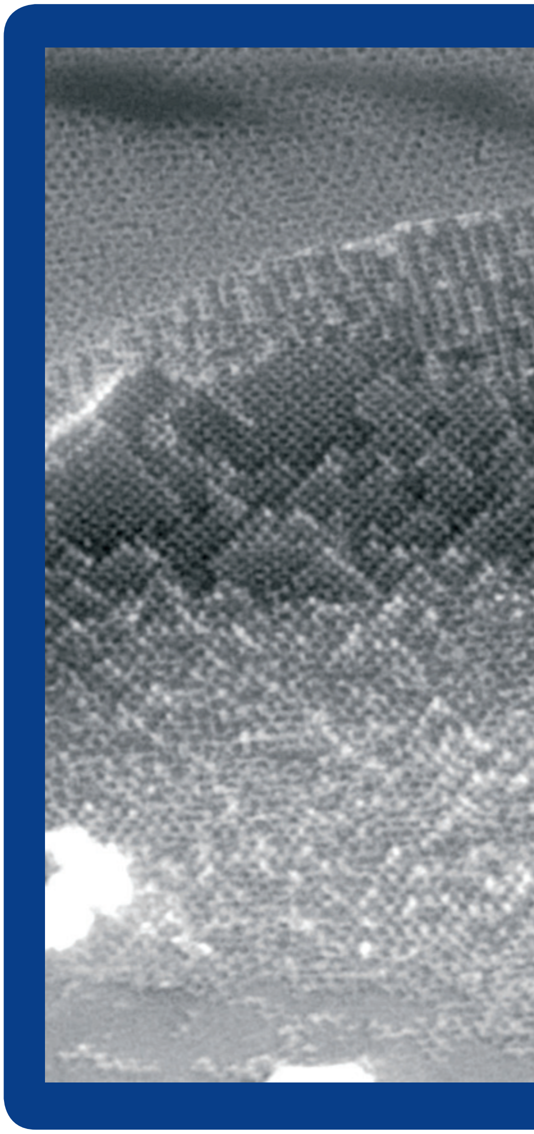
"You could see this nanoscale architecture as being a bit like a 'city for electrons,'" said Tolbert. "All the surface sites on the nanocrystals are like the houses on a map, and the larger pores in the material are like freeways that the electrolyte can wash through."

In another research direction for Tolbert that also has exciting potential for commercial application, she and colleagues use porous materials similar to those used for her work on batteries to organize conducting plastics, forcing them to give off polarized light and to conduct electricity more efficiently. The research could lead to a brighter polarized light source for LEDs in consumer electronics devices, and possibly to more efficient solar cells as well.

In this work, the Tolbert group takes plastics that consist of long chains of atoms that work as semiconductors called "semiconducting polymers"—and stretches them out by putting them in nano-size holes in a glass matrix.

"If you have polymer chains that can wiggle like spaghetti, it's hard to make them all point in the same direction," Tolbert said. "What we do here is to again make tiny, nanometer-sized holes in a piece of glass or a related material like titania and force the polymer chains into the holes. The holes are so small that the spaghetti chains have no space to coil up. They have to lie straight, and all the chains end up pointing in the same direction."

Because the chains point in the same direction, they absorb polarized light and give off polarized light. This leads to a number of exciting results:



Nanoscale

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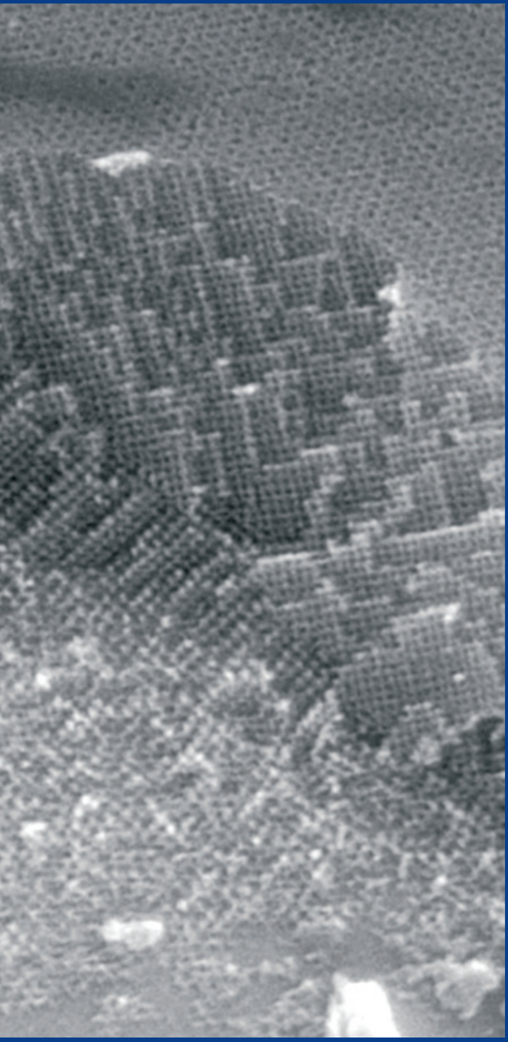
for example, the lined-up polymer chains show advantages for laser technology because all the chains can participate in the lasing process, and they can make the light polarized without the need for any external optical elements.

In addition to being both strong absorbers of light and efficient emitters of light, semiconducting polymers can conduct electricity. They only conduct along the polymer chains, however, so again, lining them up inside of pores can produce improved properties—this time better conductivity. The Tolbert group is working on using these aligned semiconducting polymers in both plastic solar cells and in field-effect transistors (also known as FETs) which form the basis for low cost plastic circuits.

The Tolbert group works with the groups of Benjamin Schwartz and Yves Rubin in the Department of Chemistry and Biochemistry on plastic solar cells and with Canon, Inc. on plastic FETs.



"There is huge interest in exploiting plastic electronics for a range of applications," Tolbert said, "because they are inexpensive to produce and to process. In many cases, however, these plastics simply are not good enough conductors. It is exciting that straightening the chains out by putting them into nanopores may be a way to significantly improve this conductivity."

Tolbert believes that extending her research and teaching beyond the lab is also a priority. She works with the California NanoSystems Institute (CNSI) to introduce high school teachers to new developments in nanoscience that are already reshaping our world. Tolbert directs the High School Nanoscience Program, which trains teachers to incorporate nanoscience into their standard core curriculum. The program is a joint effort of the CNSI, a National Science Foundation-funded IGERT training grant, and the UCLA Graduate School of Education.

"We created this program with the goal of using nanoscience to show high school students just how exciting science can be," said Tolbert. "We develop experiments and material for the high school teachers, and then show them how to do the experiments with their classes."

Since 2003, post-doctoral scholars and graduate students have trained hundreds of teachers from across Southern California—instructors who have then spread the nanoscience message to thousands of high school students.

"This is an exciting program for all involved," said Tolbert. "Our post-doctoral scholars and graduate students get valuable experience learning how to present science, and the high school teachers receive classroom materials and training on some of the latest developments in nanotechnology. Everyone gets excited about working on projects that involve real cutting edge science."

Left: an image taken with a scanning electron microscope of a titania that contains ordered nanosized pores. The sample was produced by the group headed by Professor Sarah Tolbert (below).