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3. NATIONAL LABS:

Reversing a trend toward 'nano,' DOE asks researchers to think 'meso'

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To scientists who study the building blocks of the universe, the search for new technology has usually meant working on an ever-shrinking scale.

The unaided human eye gave way centuries ago to the magnifying lens and then to the basic microscopes that now can be found in any science classroom. In the middle of the 20th century, the creation of the first electron microscopes made visible a world that had always been too small to see. And then, along came new machines that could make images of molecules and their bonds, helping to birth today's hot field of nanotechnology.

Another shakeup is now on the agenda at the Department of Energy. But this time, it's about going larger, not smaller.

DOE has asked its scientists to start doing research in the realm of the "meso," a Greek prefix that means "middle" and signifies a size closer to a living cell than the atomic level.

On the behest of William Brinkman, the acting undersecretary for science, researchers from the national laboratory system are holding town halls around the country with the goal of making the so-called mesoscale as hot among scientists as nanoscale research had become when the federal government created the National Nanotechnology Initiative (NNI) a decade ago.

George Crabtree, a physicist at Argonne National Laboratory in Illinois who is leading the push along with John Sarrao of Los Alamos National Laboratory, was skeptical at first. During a recent meeting of a DOE advisory panel on basic energy sciences, Crabtree said his initial response to Brinkman's letter was: "What are you talking about? Didn't we do that 30 years ago?"

But he has since become convinced that the field holds promise for a wide range of clean energy technologies, such as carbon capture, solar panels and batteries.

Money for Meso

When the Obama administration came out with its fiscal 2013 budget proposal this February, the request for the Department of Energy's science office was a coming-out party of sorts for the new field of mesoscale research.

Materials Physics Research

Fiscal 2012 budget: $123.7 million

Fiscal 2013 proposal: $148.7 million

Most of the $25 million increase would go toward a new $15 million program on "mesoscale phenomena to advance new materials and functionalities for energy."

Materials Discovery and Design

Fiscal 2012 budget: $76.6 million

Fiscal 2013 proposal: $84.6 million

Most of the $8 million increase would go toward a new $6 million program on "mesoscale phenomena to extend the lifetime and self-repair of materials," as well as "novel materials for carbon capture and storage."

"The whole trend for really, the last 50 years, has been to go to smaller and smaller scales and to understand things in what's called a 'reductionist' way," Crabtree said in an interview. "A big thing is made up of small things, and a small thing is made up of even smaller things. The way to understand the big thing we can hold in our hands has been to understand the smaller things that make it up.

"This turns that around," he added.

Mesoscale research has become a hot field within the past year, but it is difficult to explain. Crabtree said he defines it as the quest for mankind to imitate the complex functions that have come to exist in biology by the fortunate accidents of evolution -- think photosynthesis, which lets plants turn plentiful carbon dioxide, water and sunlight into useful sugars.

During photosynthesis, sunlight damages the reaction center that splits molecules of water, so plants have learned to replace them every half-hour or so. Compare that to a battery or a solar panel, where a whole device can break if one component fails.

In the eyes of people like Energy Secretary Steven Chu, who has tried to shift the agency's research toward cleaner forms of energy that release less of the emissions that cause climate change, that makes this area of research a crucial one.

The administration asked for $42 million for the new mesoscale program in fiscal 2013. It is a tiny request compared to the $1.8 billion that the White House wants for the nanotechnology initiative, but mesoscale is getting plenty of attention from top DOE officials.

The prefix "meso-" appears 11 times in the request for Brinkman's office. In last year's request, it showed up once.

Building a better battery

Humans and plants are able to heal small wounds, but few man-made materials are able to fix themselves.

That's a particular problem for batteries. They could help the United States run its fleet of cars and trucks on electricity instead of carbon-emitting fossil fuels, but they are still expensive to manufacture, and they need to be replaced when they lose their charge.

Venkat Srinivasan, the head of a battery research group at Lawrence Berkeley National Laboratory, is working on a lightweight new design for a lithium-ion battery, similar to the ones used in electric cars and computers.

The battery holds more energy per pound, but Srinivasan's team has found that as ions shuttle back and forth between its two electrodes, the lithium starts to form lumpy buildups. The more times the battery is recharged, the larger and more plentiful these lithium nodules become, and slowly, the battery can't hold as much charge as it once did.

Nanotechnology has helped scientists make better batteries by tinkering with the atomic structure of their components. They can now build graphite into sheets of carbon a single atom thick, but they are still having a hard time making lithium exactly go where they need it to go, Srinivasan said at his office in Berkeley, Calif.

"In a battery, if you want to get thousands of cycles, you have to do the same thing again and again and again in a controlled fashion," he said. "That's what we've been struggling with."

When the lithium moves from one end of the battery to the other, it can cause tiny cracks to form in the graphite electrodes.

These cracks grow over time and make the electrodes less capable of taking up lithium -- a process that researchers at General Motors Co., the makers of the Chevy Volt electric car, painstakingly caught on video in an effort to design a better battery.

These cracks cannot be stopped or fixed without understanding why lithium moves the way it does. And that process takes place at the mesoscale, a size that is smaller than a battery's electrode but larger than a molecule.

With more research, scientists could come up with a way to heal the defects or at least slow them down, Crabtree said.

Finding the right image

To get scientists to focus on mesoscale research, DOE will need to sell them on its promise, members of an agency advisory panel told the leaders of the campaign during a recent gathering in Bethesda, Md., around the corner from the headquarters of the Nuclear Regulatory Commission.

When the ball started rolling on nanotechnology, the members of the Basic Energy Sciences Advisory Committee said, DOE tried to get people excited by telling them to imagine storing all the information in the Library of Congress in a space the size of a sugar cube. Mesoscale research might need an image of its own.

One scientist suggested that people could rally around the idea of materials that can build themselves into special forms or regenerate themselves when broken -- think, perhaps, of the shape-shifting Terminator robot played by Arnold Schwarzenegger in the Hollywood science-fiction film of the same name.

It may seem like science fiction, but that's true of many areas of mesoscale research, said John Hemminger, a chemistry professor at the University of California, Irvine, and the chairman of the Basic Energy Sciences Advisory Committee. (He co-hosted one of the town hall meetings that were held at Brinkman's request, during an American Chemical Society meeting this February in San Diego.)

Some of the new technology is based on a concept called meso-photonics, in which a material is custom built to interact with light in ways that go against the usual laws of physics. The materials can have characteristics that do not exist in nature; for instance, they can be made unseeable, as if shrouded by an invisibility cloak like the ones in Star Trek, Hemminger said.

One device that uses the technology, called a meso-photonic solar-pumped laser, runs a laser beam using sunlight rather than electricity. DOE says that refining the technology could lead to breakthroughs in solar power and lighting, or in photocatalysis, a process in which a laser turns water into hydrogen for fuel.

Shape-shifting and invisible materials are far from becoming commonplace, but Brinkman told the House Appropriations Committee's energy and water panel last month that some of the other applications could more quickly prove useful.

"We can make all kinds of new things that reach up into the mesoscale," he said. "These kinds of materials where you use the nanoscale-sized things and put them together in complex ways will make for, for instance, a very high-strength steel or composite materials that are much, much stronger than what we have today."

'Frontier of complexity'

The advocates of mesoscale research are still searching for an identity for the new field, but there's a conundrum: If it's not based on a never-before-seen part of the universe, will people get as excited about it?

Some of the researchers from DOE's own national laboratories lightheartedly questioned the mesoscale concept at the recent meeting in Maryland. In between sessions, one scientist made a tongue-in-cheek comment to another about being asked to work at a scale that his grandfather could have seen with an ordinary microscope.

And as DOE officials have made their case on Capitol Hill, even the science experts there haven't been exactly sure what to make of the idea.

Rep. John Olver, a senior Democrat from Massachusetts who taught chemistry at the University of Massachusetts before going into politics, brought up the $42 million request during the House Appropriations hearing. He asked Brinkman to explain the plan to work at a larger scale than the realm of nanotechnology.

"What is this? Are we going in the other direction?" Olver asked.

Cutting-edge microscopes made nanotechnology possible -- and exciting, Hemminger recalls. The term "nanotechnology" was coined in the 1970s, but it only entered into wide use the following decade, once the invention of the scanning tunneling microscope allowed scientists to make images all the way down to the atomic level.

Still, beyond the "collective social phenomenon" that got the brand-new discipline off the ground, there was a real usefulness that grew it to its current prominence, he said.

Only once every 20 years or so will a field so influential come around. Mesoscale is completely different from nanotechnology, Hemminger said, because "we're learning the rules of how these systems work, as opposed to breaking things down into smaller components just because we can."

The leaders of the new push said they did not know whether reversing the move to the atomic level will make mesoscale research more of a longshot. It has inspired plenty of jokes from colleagues, Crabtree said, "and we love them." But he added that he is confident scientists will see the value in studying the phenomena that occur at a larger scale.

"It's strange to think of a frontier in a space that you've already been to," he said. "Is it really a frontier? Well, it's a frontier of complexity."