Power to the batteries

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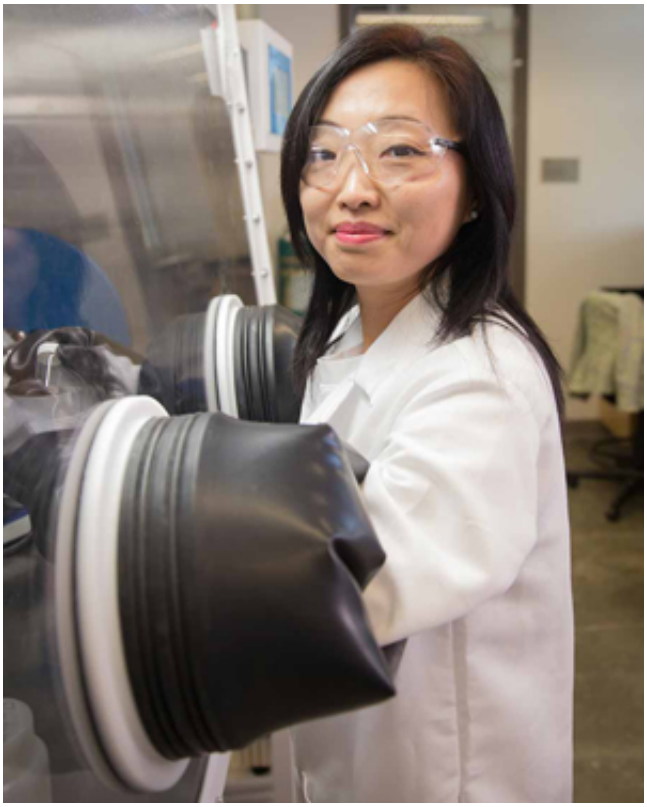

NanoEngineering professor Shirley Meng

Better solar panels and wind turbines are important to helping ensure a low-carbon future. But they are not enough. The energy from these intermittent sources must be stored, managed, converted and accessed when it's needed most. And the cost of the battery systems that do this work needs to drop.

This is where the new Sustainable Power and Energy Center at UC San Diego comes in.

NanoEngineering professor Shirley Meng is the inaugural director of the center. She often uses electric cars to frame her own research on battery materials.

To usher in an age of inexpensive, carbon-neutral electric cars, we need higher performance and less expensive batteries, Meng explains. This includes batteries to power the cars themselves and batteries at charging stations that hold energy captured from the sun and wind.

The behind-the-scenes technical challenges to developing better and cheaper batteries are daunting. But the benefits for humanity from $100 kilowatt-hour batteries (about half of today's prices) would be even greater.

"Our center is quite unique in the sense that it includes engineering, physical sciences and social sciences," said Meng. "We are hoping to engage public policy experts on campus as well, so that together we can work on sustainable power and energy from different angles."

Center faculty are also training and mentoring tomorrow's workforce for green and advanced energy.

Work done by center researchers will inevitably address technical and non-technical challenges inherent in California Governor Jerry Brown's recent call to establish, by 2030, a California greenhouse gas reduction target of 40 percent below 1990 levels.

Center researchers are well-positioned to make important contributions, in part, because they have the expertise and infrastructure access that lets them collaborate on projects that extend from theoretical and

computational materials science all the way to device manufacturing, integration and testing on the campus microgrid.

San Diego itself is another plus. The mild climate offers ideal conditions for maximizing battery life and performance in electric vehicles, microgrids and more. The abundant sunshine and extensive photovoltaic installations are critical for electric-car-charging infrastructure powered by the sun.

More than technology

The center's engineers, materials scientists, physicists, chemists and micro-grid experts work with social scientists to address tough problems that cannot be solved with technology alone.

"We can solve the scientific and engineering challenges, but that's not enough. My colleagues and I reach across UC San Diego and engage with experts on the many non-technical issues that need to be addressed in order to create truly robust and functioning ecosystems for electric vehicles, as well as to enable carbon neutrality for our microgrid in the next decade," said Meng.

This includes working with UC San Diego economists to identify and compare the economic potential of various renewable energy technologies and breakthroughs.

Another issue is "range anxiety," which revolves around fears that electric cars can only go so far between charges.

"Even though surveys show 70 percent of people in the U.S. drive less than 40 miles a day, people get really nervous when electric cars cannot go beyond 100 miles," explained Meng.

Addressing people's fears about range limitations "is really outside the range of what engineers and physical scientists can do. We will need the help from social scientists and other sectors at UC San Diego," said Meng.

Batteries as black box

Unless you are directly involved in the hard work of improving battery performance while reducing costs, here is a detail you probably don't know: in many ways, batteries are still a black box.

Sure, it's well known that rechargeable batteries allow energy to be stored in chemical form—and to be converted between electrical and chemical forms. But how exactly does a specific kind of battery wear out? And why isn't there a battery that lasts forever?

To answers these kinds of questions, you need to know how batteries work at the level of atoms and molecules. You also need to know what is happening exactly where one battery component meets another battery component—at the interfaces.

"We now have the visualization tools to locate where an atom sits at crucial locations within battery materials. We also have high-end computational tools that allow us to put the atom here or there, and then compute how the properties of the material changes," said Meng. "Advanced materials research for energy…that's the approach we're taking. With this hypothesis-based and discovery-driven type of research enabled by nanotechnology and nanoscience, we are able to accelerate the pace of the discovery."

Working at the level of atoms is just the start. UC San Diego is home to one of the world's most advanced microgrids. Having a world-class microgrid in its backyard means center researchers can test their

experimental devices in both laboratory and grid-connected conditions.

"Microgrid energy storage is very complicated," said Meng. "There are more than 20 different uses of energy storage on microgrids, including frequency regulation, load leveling and voltage smoothing. The microgrid at UC San Diego is an extremely valuable resource. It provides researchers from many different disciplines with a real-world testing environment."

Battery research gets the most attention because it's easy to grasp the importance of batteries, but center research involves many other energy technologies including supercapacitors, fuel cells as well as wearable solar, printable batteries and thermoelectrics.

How do batteries fail?

Meng's own research group in the nanoengineering department has uncovered how different lithium-ion electrode materials for batteries degrade and fail – at the levels of single particles and individual atoms. This is the kind of tough-to-generate information that companies need in order to manufacture higher performance and less expensive materials for batteries.

"I develop diagnosis tools to provide industry with critical information about what happens when batteries are in operation. Once you know how the bulk and surface of the battery material changes after certain battery operation processes, you can formulate strategies to protect the surface and/or chemically modify the bulk of the materials to make batteries last longer or operate at higher efficiency," said Meng.

Her work is focused on materials chemistry that is usually five to 10 years in the future, and her past work has already made a difference in the marketplace.

Meng's team is also working on new materials for extremely inexpensive rechargeable alkaline batteries.

In addition, her group is developing new kinds of low-cost batteries made to store and manage large amounts of energy, such as the electricity generated by solar and wind energy projects. One cutting-edge project in this area: large batteries made with sodium ions. Unlike lithium, sodium is abundant in California and can be harvested sustainably. High-capacity, low-cost batteries made with local and abundant raw materials are important for California and the nation.

Agile research centers at the Jacobs School of Engineering

The Sustainable Power and Energy Center is one of a series of new "agile" research centers launched by self-organized teams of faculty at the Jacobs School of Engineering. These bottom-up centers harness the strength of the entire UC San Diego research enterprise. Interdisciplinary groups of researchers organize themselves around emerging topics that are of great interest for faculty, students and industry partners. Under the leadership of dean Albert P. Pisano, the Jacobs School has launched agile centers around the topics of wearable sensors, extreme events research, visual computing and sustainable power and energy. Additional centers are currently under development, including one focused on the systems biology for cell lines that produce many of the proteins that serve as "biopharmaceuticals."

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