Building a Better Battery

New technologies for sustainable transportation and energy storage

A broken battery isn’t only frustrating for mobile phone, tablet and laptop users; energy storage also increasingly impacts transportation. Improved energy storage devices mean increased driving ranges for electric vehicles, which can ultimately reduce carbon dioxide emissions from the transportation sector by lessening its reliance on fossil fuels. Energy storage for sustainable transportation is top of mind for Assistant Professor Don Siegel, who joined the ME faculty in 2009 after working for six years as a research scientist for Ford Motor Company. Today, as head of the U-M Energy Storage and Materials Simulation Lab, Siegel is focusing on overcoming the myriad barriers to high-density energy storage using the tools of computational materials science and high-performance computing.

LOOKING TOWARD NEW AND SAFER BATTERY CHEMISTRIES

Through a number of collaborative initiatives, Siegel is looking at both the fundamental science and translational opportunities for new battery technologies. These include his participation in two centers funded by the U.S. Department of Energy: the U.S.-China Clean Energy Research Center-Clean Vehicle Consortium (CERC-CV) and the Joint Center for Energy Storage Research (JCESR), a public-private energy innovation hub. Both centers are tasked with investigating critical technical questions on the way to developing new energy storage technologies.

“The projects in Siegel’s lab also are supported by the National Science Foundation—he is a recent CAREER Award winner; was selected for a 2011 TV-special as one of industry leaders (Ford, Ford and Denso Corporation). “With these research partners, we look at everything from new battery chemistries to improving ‘here and now’ lithium-ion technologies,” he explained.

As an example of the latter approach, Siegel’s lab is exploring the chemical reactions underlying safety issues in Li-ion batteries. Specifically, he is investigating electrolyte decomposition at the liquid/solid interface between the electrolyte and cathode, a complex interface that has yet to be fully understood (see figure 1).

Where it leaves, however, is that electrolyte decomposition at this interface can lead to the accumulation of gases that, when vented to the atmosphere, release highly flammable vapor. Understanding the reaction pathways that precede these safety events will help Siegel and colleagues develop strategies to mitigate them.

IDENTIFYING MATERIALS FOR THE STORAGE AND CAPTURE OF GASES

While batteries store energy in the form of electrons, the intercalation of materials also can store energy in the form of gases. Hydrogen, for example, is used in fuel cell vehicles. Methane (the primary component of natural gas, which, due to the emergence of hydraulic fracturing, has gained prominence as a low-cost domestic fuel) and methane are attracting attention as alternative fuels. Hydrogen is being explored for use in fuel cell vehicles. Methane is the primary component of natural gas, which, due to the emergence of hydraulic fracturing, has gained prominence as a low-cost domestic fuel. However, just as in batteries, achieving high energy densities with methane are attracting attention as alternative fuels. Hydrogen is being explored for use in fuel cell vehicles. Methane is the primary component of natural gas, which, due to the emergence of hydraulic fracturing, has gained prominence as a low-cost domestic fuel. However, just as in batteries, achieving high energy densities with methane as an alternative fuel is a challenge. Both can gases at standard conditions, and gases typically have very low densities. This results in the same type of “rare earth” (typical for battery-like) electrolyte decomposition at this interface can lead to the accumulation of gases that, when vented to the atmosphere, release highly flammable vapor. Understanding the reaction pathways that precede these safety events will help Siegel and colleagues develop strategies to mitigate them.

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CONNECTING RESEARCH TO SOCIETAL IMPACT

Outreach is a large part of Siegel’s efforts. To illustrate the linkages between energy policy and the science of energy storage, Siegel developed a series of YouTube videos called “Batteries of the Future.” The videos, developed as part of the Microsoft program titled “Batteries of the Future,” have been viewed more than 150,000 times and are reaching a broader audience than his academic colleagues could achieve (see figure 3).

“I believe the videos are helpful because I realize they connect the research students are doing in the lab with their hopes for commercialization,” Siegel said. “I also encourage students to consider the bigger picture. Why is this work important, and how does one translate from the intended application to the properties that the active material must exhibit?” Siegel said.

For summer 2015, Siegel plans to further extend his outreach activities by developing a week-long module on energy storage for the U-M Women in Science & Engineering Girls in Science & Engineering (WISE-GISE) Summer Camp. He’s also adding a segment on Battery Safety to a short course he developed for practicing engineers at the College of Engineering’s Integrated Systems + Design Certificate in Emerging Automotive Technologies.

A highly sought-after speaker for lay and engineering audiences alike, Siegel was named one of four 2014 National Academy of Engineering Gabeleh Lecicore. He spoke on “Energy Storage for Sustainable Transportation” during the NAE National Meeting in February to an audience comprising both NAE members and high school students.

more on the web
View Siegel’s “Batteries of the Future” video series at: goo.gl/kxHJXv

Enabling Next Generations of Energy Storage Devices

Computational materials science is a key example of how advances in physics and chemistry can lead to new battery technologies. These include his participation in two centers funded by the U.S. Department of Energy: the U.S.-China Clean Energy Research Center-Clean Vehicle Consortium (CERC-CV) and the Joint Center for Energy Storage Research (JCESR), a public-private energy innovation hub. Both centers are tasked with investigating critical technical questions on the way to developing new energy storage technologies.

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