IMPROVING BATTERY PERFORMANCE FOR ELECTRIC VEHICLES

The impending production of many new electric vehicles means that recharging batteries will become a more common—and for many drivers, a daily—activity. Consequently, advances in battery technology that could enable faster charging and enhanced mileage between charges would be very important. That's why the U.S. Department of Energy's Office of Science funded an Energy Frontier Research Center (EFRC)—the NorthEast Center for Chemical Energy Storage.

The Center focused its research on understanding how chemical reactions involving battery cathodes occur, so that the battery's performance could be improved. In today's lithium ion batteries, for example, a lithium ion interacting with an active site in the cathode transfers a single electron. But what if the cathode was made of a material that could accept the transfer of two electrons—in effect, interacting with two

About the image: Dr. Carrie Siu, a postdoctoral researcher at Binghamton University in New York, prepares to test a sample of a novel cathode material she synthesized that holds promise of markedly improving battery performance. *(Marc Francis Hidalgo)* lithium ions—at each active site? Could that also double the rate at which the battery can be recharged and substantially improve the amount of energy stored? The scientists knew that the element vanadium had that kind of electronic character, and they set out to find a structure for the cathode and test whether such a battery would be stable.

The multi-disciplinary team included theoretical chemists, experts skilled in synthesizing new materials, and others skilled at analyzing them. The theorists suggested a particular vanadium phosphate compound to explore; the synthesizers made trial materials; and the analysts studied their properties with a variety of methods, including X-ray analysis at Argonne and Brookhaven National Laboratories. After multiple cycles of research, the team understood why existing battery materials don't achieve their theoretical capacity. Dr. Carrie Siu of Binghamton University then used that understanding to create a synthesis method that optimized the properties of the vanadium material. The result was a nano-sized material that could interact with nearly twice as many lithium ions, pound for pound, as the cathodes in current batteries.

In tests of its electrochemical behavior, this type of cathode proved able to charge and discharge two lithium ions per site, potentially halving re-charging time and doubling the energy storage capacity of a battery. Moreover, the material appeared to be stable after many charge and discharge cycles, suggesting that battery lifetimes might also be improved. Tests showed that such cathodes work best at low voltage, but this should not be a limitation for vehicle batteries.

The Center Director, M. Stanley Whittingham—who was awarded the 2019 Nobel Prize in chemistry for his earlier development of the first lithium ion battery—believes that the new cathode should be easy to manufacture because of broad industry experience with similar materials. The university has patented the new cathode material, and the research team is talking to potential commercial partners.

More broadly, EFRC-supported research has yielded at least two additional approaches to improved batteries—wrapping anode and cathode materials in a nanoscale layer of carbon, and making them from a newly discovered MXene material. With so many novel approaches, it seems clear that the next generation of vehicle batteries is likely to have significantly better performance—enabling faster recharging, greater driving range, and likely improved battery lifetime. This in turn will help enable a transition to electric vehicles.

Top: Dr. Siu conducts electrochemical tests on potential battery materials.
Bottom: The lefthand stack of battery cells made of a novel cathode material has the same energy storage capacity as the righthand stack of cells used in the current generation of batteries.
(Marc Francis Hidalgo)

NorthEast Center for Chemical Energy Storage (NECCES)
Winner — Scientific Ideas Award
www.science.osti.gov/bes/efrc/Centers/NECCES