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Super-Charging Lithium Batteries

Nanowire electrodes could improve the performance of electric vehicles.

By Peter Fairley

Existing lithium batteries can enable battery-powered electrical vehicles to travel hundreds of miles on a charge, prompting a race among major automakers to demonstrate that the batteries are safe and durable enough for mass marketing. Battery developers, meanwhile, continue to push lithium performance. Last month, Stanford University materials scientists unveiled a nanowire electrode that could more than triple lithium batteries' energy storage capacity and improve their safety.

The development, reported in the scientific journal *Nature Nanotechnology*, stems from the labs of nanowire innovator Yi Cui and battery expert Robert Huggins at Stanford's Materials Science and Engineering Department. The researchers show that nanowires of silicon just a few atoms across can function as high-capacity electrodes, absorbing and releasing about 10 times more lithium ions than the graphite electrodes that are commonly used today.

Charging a lithium battery usually means moving lithium ions from the battery's positive electrode or cathode into its negative electrode or anode. Silicon has the right electrochemical affinity for lithium ions to make it a promising material for anodes. In fact, until now, it has been a bit too promising. Silicon anodes absorb too much lithium. Upon charging, the silicon anodes swell to four times their previous volume, fracturing the material. After just a few charging cycles, the anodes are finished.

Nanowires, in contrast, take the swelling in stride. The Stanford collaborators' silicon nanowires swell when charged from 89 nanometers wide to 141 nanometers wide and simultaneously elongate, thereby releasing the strain. They show no signs of mechanical failure after more than 20 cycles.

Nor, according to Cui, do the silicon nanowires appear as susceptible as graphite to typical failure mechanisms that cause safety problems (including fires that prompted new rules from the U.S. Department of Transportation this week limiting lithium batteries in checked luggage). "Potentially, silicon is going to be much safer than carbon," says Cui, who points out that improved safety could be key to lithium's future acceptance in vehicles. "It only takes an accident or two to destroy a technology." He says that testing over many more cycles is under way to confirm the silicon-nanowire anode's enhanced durability and safety.

The downside is that the nanowire growth process that Cui uses, which feeds gaseous silicon to a liquid gold catalyst to make the solid electrode, is a high-temperature (600 to 900 °C) process that could be costly to scale up. Cui believes that scale-up of the vapor-liquid-solid process is nevertheless feasible, but he acknowledges that he is also "exploring another approach."

Ohio State University chemist Yiying Wu, who also works on nanowire electrodes, calls the Stanford work "definitely very important." But Wu and other materials scientists caution that additional advances will be required before lithium batteries with nanowire electrodes deliver major increases in performance of electric-vehicle batteries. Not least is the need to scale up the process of making nanowires, which have yet to be mass-produced for commercial application.

Another limitation is that while Cui's silicon nanowires make great anodes, lithium-battery technology has greater need for improved cathodes. In a given battery, substituting an anode that stores more lithium ions has no impact without a corresponding cathode that can supply more charge.

Both Cui and Wu (who reported his own lithium anode development last month with a high-capacity cobalt-oxide nanowire) say that their labs are working on novel materials for cathodes. "That's the holy grail for this business," says Wu. "Anyone who can generate much higher cathode capacity will bring a huge breakthrough for the lithium battery."
