Letter abstract

High-performance lithium battery anodes using silicon nanowires
Candace K. Chan¹, Hailin Peng², Gao Liu³, Kevin McIver², Xiao Feng Zhang³, Robert A. Huggins² & Yi Cui²

There is great interest in developing rechargeable lithium batteries with higher energy capacity and longer cycle life for applications in portable electronic devices, electric vehicles and implantable medical devices¹. Silicon is an attractive anode material for lithium batteries because it has a low discharge potential and the highest known theoretical charge capacity (4,200 mAh g⁻¹; ref. 2). Although this is more than ten times higher than existing graphite anodes and much larger than various nitride and oxide materials³-⁴, silicon anodes have limited applications⁵ because silicon's volume changes by 400% upon insertion and extraction of lithium which results in pulverization and capacity fading⁶. Here, we show that silicon nanowire battery electrodes circumvent these issues as they can accommodate large strain without pulverization, provide good electronic contact and conduction, and display short lithium insertion distances. We achieved the theoretical charge capacity for silicon anodes and maintained a discharge capacity close to 75% of this maximum, with little fading during cycling.

¹. Department of Chemistry, Stanford University, Stanford, California 94305, USA
². Department of Materials Science and Engineering, Stanford University, Stanford, California 94305, USA
³. Environmental Energy Technologies Division, Lawrence Berkeley National Lab, 1 Cyclotron Road, Mail Stop 70R108B, Berkeley, California 94720, USA
⁴. Electron Microscope Division, Hitachi High Technologies America, Inc., 5100 Franklin Drive, Pleasanton, California 94588, USA

Correspondence to: Yi Cui² e-mail: yicui@stanford.edu
A 40-Hour Laptop Battery?

By Robert F. Service

ScienceNOW Daily News
17 December 2007

Although improvements in laptop computers and other electronics continue at a torrid pace, the batteries that power them have made only modest strides in recent years. A new advance in nanotechnology could change all that. Lithium ion batteries made with tiny whiskers of silicon can store as much as 10 times the charge of conventional rechargeable batteries, researchers report. In principle, the new technology could result in laptop batteries that run for days and electric cars that cruise for hundreds of kilometers on a single charge—but it must still clear some key hurdles to make it to market.

The advance centers on increasing the charge that a battery's positively charged electrode, or anode, can hold. When a battery charges, positively charged lithium ions grab an electron provided by an electrical outlet and migrate to the anode. As the battery discharges, the lithium ions give up their extra electrons—to power whatever device the battery is connected to—and migrate through a conductive gel to a cathode, the negatively charged electrode. Today's anodes are made up of sheetlike layers of carbon atoms, and it takes roughly six of these carbons to hold onto each lithium ion. Silicon has the potential to do much better, as each silicon atom can hold four lithiums. But when researchers have constructed anodes made from silicon films or particles, the large number of whizzing lithium atoms pulverizes the silicon and breaks some of its contact with the underlying metal substrate, sapping its strength.

Anodes forged from whiskerlike wires of silicon fare much better, report Yi Cui, a materials scientist at Stanford University in Palo Alto, California, and colleagues. The researchers used a standard technique for growing a forest of silicon nanowires directly bonded to a stainless steel substrate. They then added a common electrolyte and top electrode and cycled their battery through a series of test runs. The silicon nanowires still swelled and contracted but did not break away from the substrate, Cui and his team report online this week in Nature Nanotechnology. The key, Cui says, is that the nanowire shape allows the lattice of silicon atoms to expand and contract radially across the whiskers to relieve any built-up strain, thereby keeping the silicon nanowires firmly attached to the metal contact. As a result, Cui's team found that their anode materials were able to hold up to 10 times the

http://sciencenow.sciencemag.org/cgi/content/full/2007/1217/2?eaf

12/17/2007
"It's a really nice proof of concept," says Gerbrand Ceder, a materials scientist and battery expert at the Massachusetts Institute of Technology in Cambridge. Making lithium ion batteries capable of holding 10 times the charge of conventional versions still requires a cathode that holds 10 times the charge, too, Ceder says. However, he adds, incorporating a silicon nanowire-based anode could allow batterymakers to reduce the weight and volume of the anode and add more cathode material in its place, which could give lithium batteries a power boost. That could make life a little easier for all of us.