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Welcome to the Era of Supercharged Lithium-Silicon Batteries

Batteries with silicon anodes promise to make devices last more than 20 percent longer on a single charge.

By Daniel Oberhaus

Most lithium-ion cells today use graphite anodes.PHOTOGRAPH: GETTY IMAGES

GENE BERDICHEVSKY BELIEVES in batteries. As employee number seven at Tesla, he helmed the team that designed the lithium-ion battery pack for, the Roadster, which convinced the world to take electric vehicles seriously. A decade later, EVs can hold their own against your average gas guzzler, but there's still a large trade-off between the shelf life of their batteries and the amount of energy packed into them. If we want to totally electrify our roads, Berdichevsky realized, it would require a fundamentally different approach.

In 2011, Berdichevsky founded Sila Nanotechnologies to build a better battery. His secret ingredient is nanoengineered particles of silicon, which can supercharge lithium-ion cells when they're used as the battery's negative electrode, or anode. Today, Sila is one of a handful of companies racing to bring lithium-silicon batteries out of the lab and into the real world, where they promise to open new frontiers of form and function in electronic devices ranging from earbuds to cars.

The long-term goal is high-energy EVs, but the first stop will be small devices. By this time next year, Berdichevsky plans to have the first lithium-silicon batteries in consumer electronics, which he says will make them last 20 percent longer per charge. As the lustrous feedstock for the digital hearts of most modern gadgets, silicon and lithium are a dynamic duo on par with Batman and Robin. Crack open your favorite portable device—be it a phone, laptop, or smartwatch—and you'll find a lithium-ion battery eager to provide electrons, plus a silicon-soaked circuit board that routes them where they need to go. But if you combine the metals in a battery, it can create all sorts of problems.

Several lithium-ion cell prototypes containing Sila Nanotechnologies' silicon anode.
COURTESY OF SILANANOTECH

When a lithium-ion battery is charging, lithium ions flow to the anode, which is typically made of a type of carbon called graphite. If you swap graphite for silicon, far more lithium ions can be stored in the anode, which increases the energy capacity of the battery. But packing all these lithium ions into the electrode causes it to swell like a balloon; in some cases, it can grow up to four times larger.

The swollen anode can pulverize the nanoengineered silicon particles and rupture the protective barrier between the anode and the battery's electrolyte, which ferries the lithium ions between the electrodes. Over time, crud builds up at the boundary between the anode and electrolyte. This both blocks the efficient transfer of lithium ions and takes many of the ions out of service. It quickly kills any performance improvements the silicon anode provided.

One way out of this problem is to sprinkle small amounts of silicon oxide—better known as sand—throughout a graphite anode. This is what Tesla currently does with its batteries. Silicon oxide comes pre-puffed, so it reduces the stress on the anode from swelling during charging. But it also limits the amount of lithium that can be stored in the anode. Juicing a battery this way isn't enough to produce double-digit performance gains, but it's better than nothing.

Cary Hayner, cofounder and CTO of NanoGraf, thinks it's possible to get the best of silicon and graphite without the loss of energy capacity from silicon oxide. At NanoGraf, he and his colleagues are boosting the energy of carbon-silicon batteries by embedding silicon particles in graphene, graphite's Nobel Prize-winning cousin. Their design uses a graphene matrix to give silicon room to swell and to protect the anode from damaging reactions with the electrolyte. Hayner says a graphene-silicon anode can increase the amount of energy in a lithium-ion battery by up to 30 percent.

But to push that number into the 40 to 50 percent range, you have to take graphite completely out of the picture. Scientists have known how to make silicon anodes for years, but they have struggled to scale the advanced nanoengineering processes involved in manufacturing them.

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An engineer at Sila Nanotechnologies developing the materials for the company's silicon anode.

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Sila was one of the first companies to figure out how to mass-manufacture silicon nanoparticles. Their solution involves packing silicon nanoparticles into a rigid shell, which protects them from damaging interactions with the battery's electrolyte. The inside of the shell is basically a silicon sponge, and its porosity means it can accommodate swelling when the battery is charging.

This is similar to the approach used by materials manufacturer Advano, which is producing silicon nanoparticles by the ton in its New Orleans factory. To lower the costs of producing nanoparticles, Advano sources its raw material from silicon wafer scrap from companies that make solar panels and other electronics. The Advano factory uses a chemical process to grind the wafers down into highly engineered nanoparticles that can be used for battery anodes.

"The real problem is not 'Can we get a battery that is powerful?' It's 'Can we make that battery cheap enough to build trillions of them?'" says Alexander Girau, Advano's founder and CEO. With this scrap-to-anode pipeline, Girau believes he has a solution.

So far, none of these companies have seen their anode material used in a consumer product, but each is in talks with battery manufacturers to make it happen. Sila expects its anodes to be in unnamed wireless earbuds and smartwatches within a year. Advano, which counts iPod cocreator Tony Fadell among its investors, is also in talks to have its anodes placed in consumer electronics in the near future. It's a long way from EVs, but proving the tech works in gadgets is a small step in that direction.

"The pace of battery development is not as fast as other technology areas, such as computing," says Matthew McDowell, a materials scientist at the Georgia Institute of Technology. The reason, he says, has to do with the complex interplay of the variables involved when swapping out graphite for silicon in battery anodes. It's not just a matter of increasing energy density, but also making sure that this doesn't reduce the battery's thermal stability, charge rate, or life span.

"Engineering new materials at scale that can improve capacity while satisfying all these other metrics is a major challenge," McDowell says. "It's not surprising that commercialization has taken a while."

This is why companies are starting with small consumer electronics for the first wave of silicon-lithium batteries. They are the "low-hanging fruit," says Laurence Hardwick, director of the Stephenson Institute for Renewable Energy. Batteries in gadgets only need to last for a few years. EVs require batteries that last more than a decade and can handle daily recharging, a wide range of temperatures, and other unique stressors. Hardwick says that building a lithium-silicon battery that retains its high energy over longer time spans is a "much greater challenge."

Berdichevsky is well aware of the obstacles to the mass production of an EV-worthy lithium-silicon battery. He doesn't expect to see silicon anodes in commercial EVs until at least the middle of the decade. But once they arrive, he believes, lithium-ion batteries will remake the auto industry—again.