You start to ask how much more energy you can pack in for a given [battery] size or weight," Cui said at a Stanford energy seminar this year. "If we put in a lot more, would we be able to generate a new revolution in the technology, mainly in transportation?" Cui saw portable electronics as another area ripe for change: With better batteries, devices could offer more features, last longer and possibly take on different shapes, as people seek wearable devices with high computing power.

This is ambitious, but Cui, 38, is an astonishingly prolific researcher. (His group has produced at least 40 papers annually since 2011.) Since coming to Stanford in 2005, Cui has worked on a variety of projects, including solar cells and the use of nanoscale paper and textiles as a basis for making everything from ultracapacitors to water filtration technologies. But his battery work has made the biggest splash, starting in 2007 when he produced a widely cited paper on the use of silicon nanowires to increase batteries' energy storage capacity. Months later, he got a $10 million grant from Saudi Arabia's King Abdullah University of Science and Technology, a sum that "made everything fly much faster."

Last year, a Sunnyvale company Cui founded, Amprius, began shipping batteries in China that are used in the ThL cell phone sold there. "It has 20 percent more energy [for the same volume] than the best iPhone batteries on the market—the iPhone 5s," Cui says, as he holds one of the batteries in his palm. Plucked out of the back of a demonstration phone, the battery is about the size of a credit card, but thicker. Already several hundred thousand batteries have been sold, and the phones retail for about $300 each, according to Cui. "This is our generation one," he says of the battery. So far, it is his only product in commercial use.

Cui grew up in Guangxi province in southern China, where his mother taught Chinese at an elementary school and his father was a high school chemistry teacher. Around second or third grade, after school let out, he sometimes wandered into his father's classroom. Occasionally he got to see a chemistry experiment where "all these beautiful colors change," he recalls, a touch wistfully, from his office in the McCullough Building. That, he adds, is how he fell in love with the subject.

Cui studied chemistry at the University of Science and Technology of China (the country's equivalent of Caltech), and after graduating in 1998 he headed to Harvard for more. This was just after the dawn of nanotechnology, the idea that extremely tiny, atomic-level materials have shapes, colors, movements and behaviors that differ from those of larger materials. One example that fascinated Cui early on was gold. "You look at gold—it's gold in color," he explains. "When you make it into small-size particles, you can disperse them into solution. . . . It's a red color!" Nanomaterials, Cui reasoned, could become to our age what stone and ceramics were to other eras: breakthrough materials that could spur innovation.

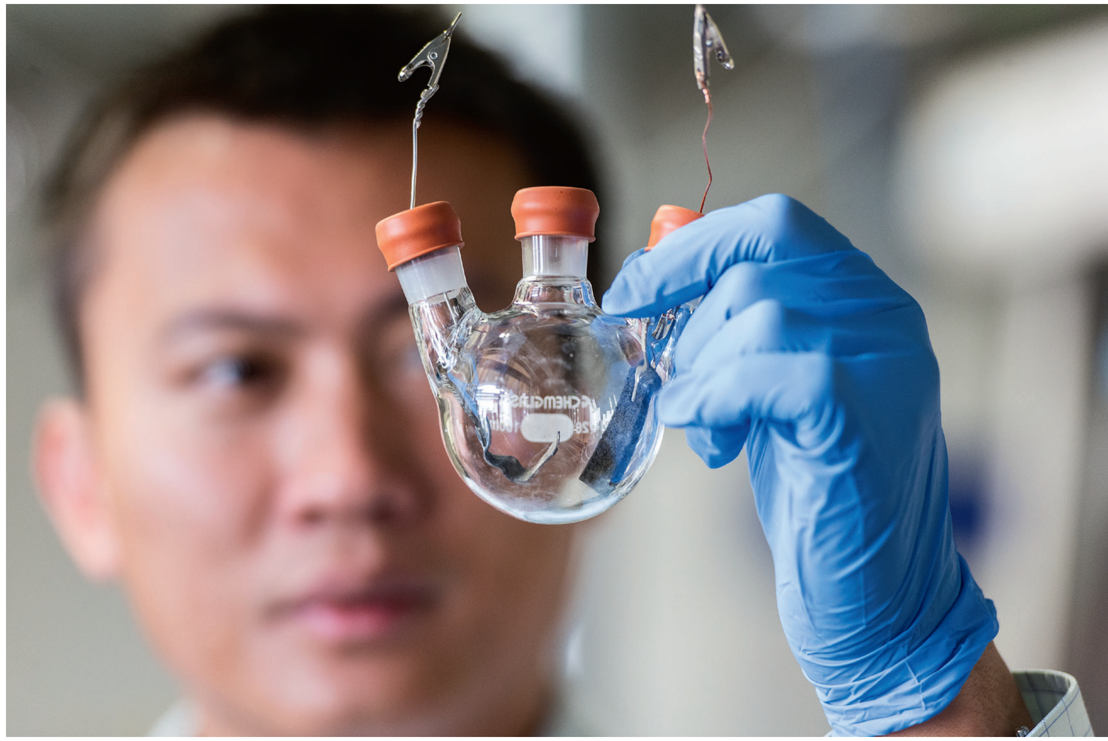
During his Harvard PhD work and a subsequent postdoc at Berkeley, Cui studied under some of the greats: Charles Lieber, a Harvard chemistry professor who shaped the field of nanowires, a type of tiny building block; and Paul Alivisatos, a Lawrence Berkeley National Laboratory expert in nanocrystals, which are a different structure that can come in spherical or cubic shapes. Both men were among the first generation of scientists to study nanomaterials, after powerful machines commercialized in the late 1980s made it possible to move atoms around. This era, the late 1990s and early 2000s, had "a lot of new science coming out," Cui remembers. "Every couple of weeks, you see something jumping out [and think], 'This is amazing.'"

When Cui arrived at Stanford in 2005, he was determined to solve real-world problems using nanoscience. Years of hard work had taken their toll—after completing his PhD, he had gone through a brief burnout period—but at Stanford, he re-energized himself by approaching his research in a different way. Previously, he had explored the properties of nanomaterials and then figured out how those properties could be useful, a type of thinking he calls "left-to-right." But he was eager to change things around, first deciding what real-world issues needed to be addressed and then figuring out how nanomaterials could solve them.

The top three problems, he concluded, were energy, the environment and human health. Energy in particular was a growing concern in 2005, when oil and gas prices were starting to soar, making solar power and other forms of renewable energy more desirable. The Achilles' heel of renewables—the inability to provide backup power in the absence of sun or wind—was obvious. More people were also turning to hybrid-electric cars to avoid expensive gasoline, and demand for portable electronics was growing insatiably.

After poring over papers and books, Cui decided to tackle improving batteries. He says he didn't know much about them at the time.

SMALL WONDERS: Cui experiments with nanoscale materials to improve batteries.



MATT BEARDSLEY

At its simplest, a battery involves the transfer of electrons between an anode, which wants to lose them, and a cathode, which likes to gain them. A substance called an electrolyte, situated between the anode and the cathode, conducts positive ions, which are atoms (or molecules) that have lost electrons. The ions move to the anode when the battery is charging, and to the cathode when discharging. From the anode, the electrons are forced into a wire or equivalent structure, and the subsequent electricity can be used to power a lightbulb or turn on a cell phone. The battery thus converts chemical energy to electric energy, and is a means of storing energy. Sometimes, Cui makes batteries at home with his older son, using an apple or other piece of fruit as the electrolyte. (The fruit's acid allows it to conduct ions easily.) The best batteries, he says, optimize a number of factors: safety, cost, temperature, energy, power (how quickly they charge and discharge), life cycle (number of charges) and longevity (how many years they last).

For more than a century, innovation was relatively stagnant as the lead-acid battery, invented around 1859 by a French scientist, dominated the field. Lead-acid batteries existed in the earliest automobiles, which were powered by electricity during the late 19th century, and they are still used to start engines in modern cars, though the heavy-duty work of propelling the vehicle now falls to energy-dense gasoline. Nickel-cadmium batteries, invented in the late 19th century, powered some of the first laptops.

But in the late 1980s and early 1990s, commercial electronics began to proliferate, driving the need for lighter, more energy-dense batteries than the existing chemistries provided. Lithium-ion batteries, now found in portable electronics and electric cars like the Tesla, began creeping onto the market around 1991. So did others, such as nickel metal hydride batteries, the type found in the Toyota Prius hybrid. Lithium is a good material for batteries because it is a lightweight solid (it is the third-lightest element in the periodic table), abundant in salty lakes and the ocean, and eager to lose its electrons to become an ion. Compared with lead-acid batteries, a lithium-ion battery can store five times as much energy per unit weight, says Cui.

Amid the flurry of work done in the past 10 or 20 years, commercial lithium-ion batteries have improved to the point where they have reached the limits of fundamental chemistry. Lithium is still desirable, but using graphite as an anode and cobalt-oxide as a cathode, as most commercial batteries do, will no longer deliver the steady energy gains of the past decade.

"To have a jump, you really need new materials," says Cui. For some battery structures, he noted at the energy seminar this year, there is now "a whole zoo of battery chemistry you can explore."

In the lab at Moore, Cui began trying to incorporate silicon into an anode. Found in sand, silicon is theoretically ubiquitous, but extracting nanoscale particles of it is expensive. Cui is looking at rice husks, which have compounds that become silicon oxide distributed throughout their biological cells,