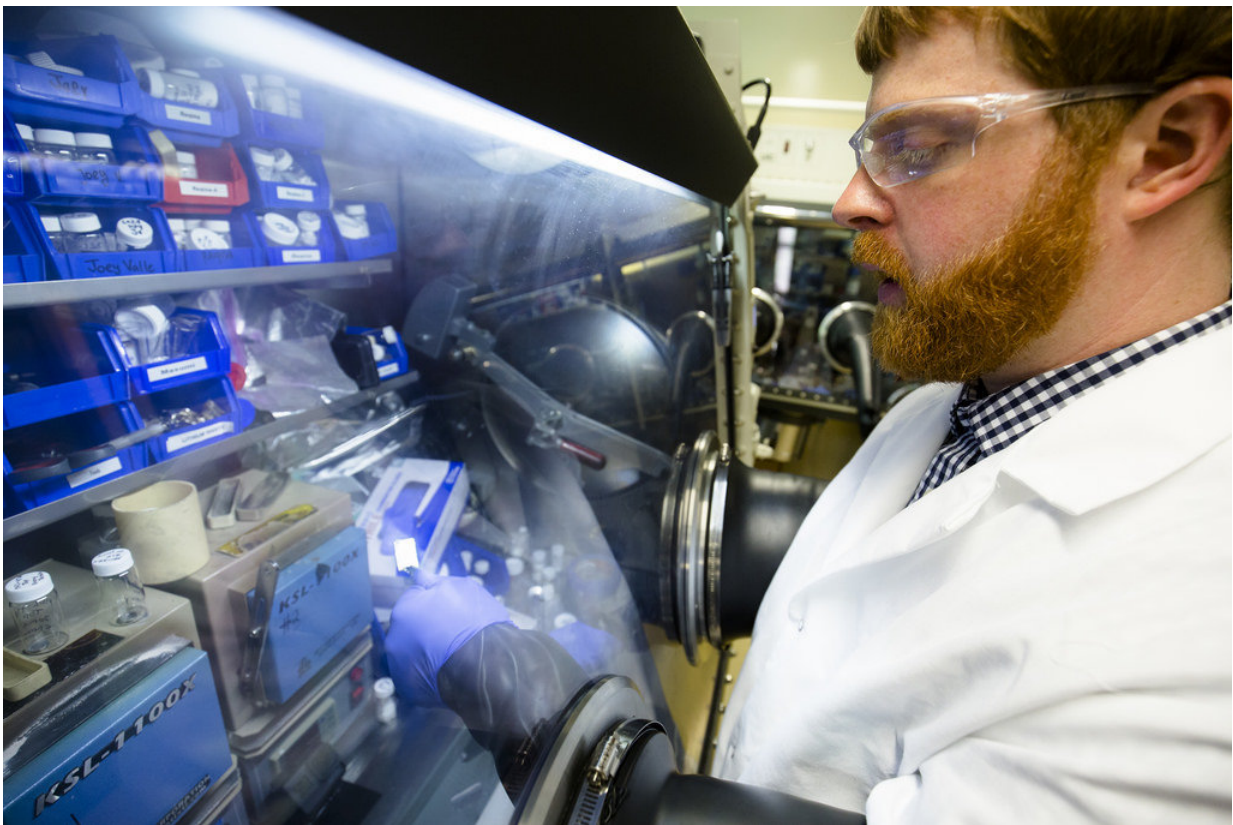


Battery breakthrough: Doubling performance with lithium metal that doesn't catch fire

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Nathan Taylor, a post-doctoral fellow in mechanical engineering, inspects a piece of lithium metal in the Phoenix Memorial Laboratory building at the University of Michigan on Aug. 7, 2018 in Ann Arbor, MI. Taylor works in the lab of Jeff Sakamoto, professor of mechanical engineering. Their team has developed a process for creating lithium metal solid state batteries with LLZO as an electrolyte that could drastically improve upon the performance and capacity of

current lithium-ion battery technologies. Credit: Evan Dougherty/Michigan Engineering Communications & Marketing

A rechargeable battery technology developed at the University of Michigan could double the output of today's lithium ion cells—drastically extending electric vehicle ranges and time between cell phone charges—without taking up any added space.

By using a ceramic, solid-state electrolyte, engineers can harness the power of [lithium metal](#) batteries without the historic issues of poor durability and short-circuiting. The result is a roadmap to what could be the next generation of rechargeable batteries.

"This could be a game-changer—a paradigm shift in how a [battery](#) operates," said Jeff Sakamoto, a U-M associate professor of mechanical engineering who leads the work.

In the 1980s, rechargeable lithium metal batteries that used liquid electrolytes were considered the next big thing, penetrating the market in early portable phones. But their propensity to combust when charged led engineers in different directions. The lithium atoms that shuttle between the electrodes tended to build tree-like filaments called dendrites on the electrode surfaces, eventually shorting the battery and igniting the flammable electrolyte.

The lithium ion battery—a more stable, but less energy-dense technology—was introduced in 1991 and quickly became the new standard. These batteries replaced lithium metal with graphite anodes, which absorb the lithium and prevent dendrites from forming, but also come with performance costs:

Graphite can hold only one lithium ion for every six carbon atoms, giving it a specific capacity of approximately 350 milliampere hours per gram (mAh/g.) The lithium metal in a solid state battery has a specific capacity of 3,800 mAh/g.

Current lithium ion batteries max out with a total energy density around 600 watt-hours per liter (Wh/L) at the cell level. In principal, solid-state batteries can reach 1,200 Wh/L.

To solve lithium metal's combustion problem, U-M engineers created a ceramic layer that stabilizes the surface—keeping dendrites from forming and preventing fires. It allows batteries to harness the benefits of lithium metal—energy density and high-conductivity—without the dangers of fires or degradation over time.

"What we've come up with is a different approach—physically stabilizing the lithium metal surface with a ceramic," Sakamoto said. "It's not combustible. We make it at over 1,800 degrees Fahrenheit in air. And there's no liquid, which is what typically fuels the battery fires you see.

"You get rid of that fuel, you get rid of the combustion."

In earlier solid state electrolyte tests, lithium metal grew through the ceramic electrolyte at low charging rates, causing a short circuit, much like that in liquid cells. U-M researchers solved this problem with chemical and mechanical treatments that provide a pristine surface for lithium to plate evenly, effectively suppressing the formation of dendrites or filaments. Not only does this improve safety, it enables a dramatic improvement in charging rates, Sakamoto said.

"Up until now, the rates at which you could plate lithium would mean you'd have to charge a lithium metal car battery over 20 to 50 hours (for

full power)," Sakamoto said. "With this breakthrough, we demonstrated we can charge the battery in 3 hours or less.

"We're talking a factor of 10 increase in charging speed compared to previous reports for solid state lithium [metal](#) batteries. We're now on par with [lithium](#) ion cells in terms of charging rates, but with additional benefits. "

That charge/recharge process is what inevitably leads to the eventual death of a [lithium ion battery](#). Repeatedly exchanging ions between the cathode and anode produces visible degradation right out of the box.

In testing the ceramic electrolyte, however, no visible degradation is observed after long term cycling, said Nathan Taylor, a U-M post-doctoral fellow in mechanical engineering.

"We did the same test for 22 days," he said. "The battery was just the same at the start as it was at the end. We didn't see any degradation. We aren't aware of any other bulk solid state electrolyte performing this well for this long."

Bulk solid state electrolytes enable cells that are a drop-in replacement for current [lithium ion](#) batteries and could leverage existing battery manufacturing technology. With the material performance verified, the research group has begun producing thin solid [electrolyte](#) layers required to meet solid state capacity targets.

The group's findings are published in the Aug. 31 issue of the *Journal of Power Sources*.

More information: Nathan J. Taylor et al. Demonstration of high current densities and extended cycling in the garnet $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ solid electrolyte, *Journal of Power Sources* (2018). [DOI:](#)

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