Lithium battery life expectancy

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The culprit behind the degradation of lithium-ion batteries over time is not lithium, but hydrogen emerging from the electrolyte, a new study finds. This discovery could improve the performance and life expectancy of a range of rechargeable batteries.

Lithium-ion batteries power everything from smart phones and laptops to electric cars and large-scale energy storage facilities. Batteries lose capacity over time even when they are not in use, and older cellphones run out of power more quickly. This common phenomenon, however, is not completely understood.

Now, an international team of researchers, led by the University of Colorado-Boulder, SLAC National Accelerator Laboratory, and Stanford University has revealed an underlying mechanism behind such battery degradation. Their discovery could help scientists develop better batteries, which would allow electric vehicles to run farther and last longer, while also advancing energy storage technologies that would accelerate the transition to clean energy.

The findings were published Sept. 12 in the journal Science.

"We are helping to advance lithium-ion batteries by figuring out the molecular level processes involved in their degradation," said Michael Toney, a senior author of the study and a professor of chemical and biological engineering at the University of Colorado.

"Having a better battery is very important in shifting our energy infrastructure away from fossil fuels to more renewable energy sources," said Toney, who was a senior staff scientist at SLAC when most of this study"s experiments were done.

Transportation is the single largest source of greenhouse gases generated in the U.S, accounting for 28% of the country"s emissions in 2021. In an effort to reduce emissions, many automakers have committed to moving away from developing gasoline cars to produce more EVs instead. But EV manufacturers face a host of challenges, including limited driving range, higher production costs and shorter battery lifespan than conventional vehicles. In the U.S. market, a typical all-electric car can run about 250 miles in a single charge, about 60% that of a gasoline car. The new study has the potential to address all these issues, Toney said.

Rechargeable batteries lose stored energy when they"re not being used because an idle battery undergoes internal chemical reactions that slowly drain its energy. This "self-discharge" process can eventually consume active ingredients in the cathode, where the electron-spent lithium ions collect while the device is in use. This shortens a battery"s life expectancy.

For decades, researchers have assumed that self-discharge inlithium-ion batteriesis caused by the movement of

lithium ions, but the new research finds compelling evidence that hydrogen, not lithium, is the true culprit. Using facilities from U.S. Department of Energy"sArgonne National LaboratoryandPacific Northwest National Laboratory, this team discovered that hydrogen atoms from the battery"s electrolyte would move to cathode and the protons will take some of the spots that lithium ions normally bind to.The cathode is also the conduit for electrons while charging the battery, but not so much if many hydrogen atoms - the tiniest of all atoms - are occupying lithium-ion parking spots.

"Numerous electrolyte degradation pathways have been predicted by various theoretical modeling," said Kang Xu, a senior author of this study and the chief scientist at SES AI, a producer of lithium metal batteries. "Our study provides one of the first direct and solid experimental evidence on the hydrogen transfer that led to the electrolyte degradation."

The scientists discovered that the more lithium is pulled out of the cathode during charging, the more hydrogen atoms accumulate on the surface.

"Also, removing lithium from the charged cathode generates a lot of openings on the surface that allow hydrogen atoms to go deeper inside," said Gang Wan, lead author of the study and a research scientist in Stanford"s School of Engineering. "This process induces self-discharge and causes mechanical stress that can cause cracks in the cathode and accelerate degradation."