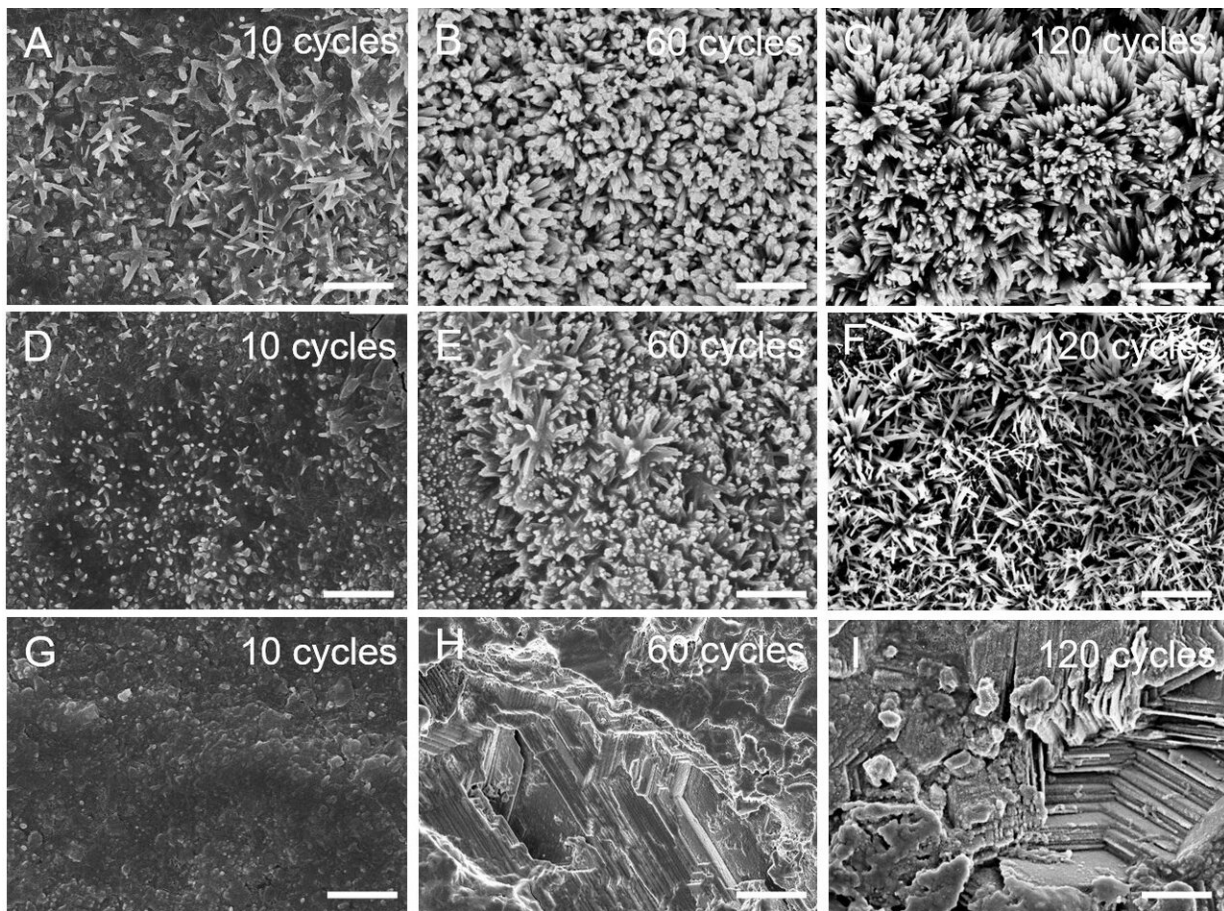


Biomorphic batteries could provide 72x more energy for robots

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Scanning electron microscopy images of the surface of zinc electrode after going through a certain number of cycles. Credit: Wang et al., *Sci. Robot.* 5, eaba1912 (2020)

Like biological fat reserves store energy in animals, a new rechargeable zinc battery integrates into the structure of a robot to provide much more energy, a team led by the University of Michigan has shown.

This approach to increasing capacity will be particularly important as robots shrink to the microscale and below—scales at which current stand-alone batteries are too big and inefficient.

"Robot designs are restricted by the need for batteries that often occupy 20% or more of the available space inside a [robot](#), or account for a similar proportion of the robot's weight," said Nicholas Kotov, the Joseph B. and Florence V. Cejka Professor of Engineering, who led the research.

Applications for mobile robots are exploding, from delivery drones and bike-lane take-out bots to robotic nurses and warehouse robots. On the micro side, researchers are exploring swarm robots that can self-assemble into larger devices. Multifunctional structural batteries can potentially free up space and reduce weight, but until now they could only supplement the main [battery](#).

"No other structural battery reported is comparable, in terms of [energy](#) density, to today's state-of-the-art advanced lithium batteries. We improved our prior version of structural zinc batteries on 10 different measures, some of which are 100 times better, to make it happen," Kotov said.

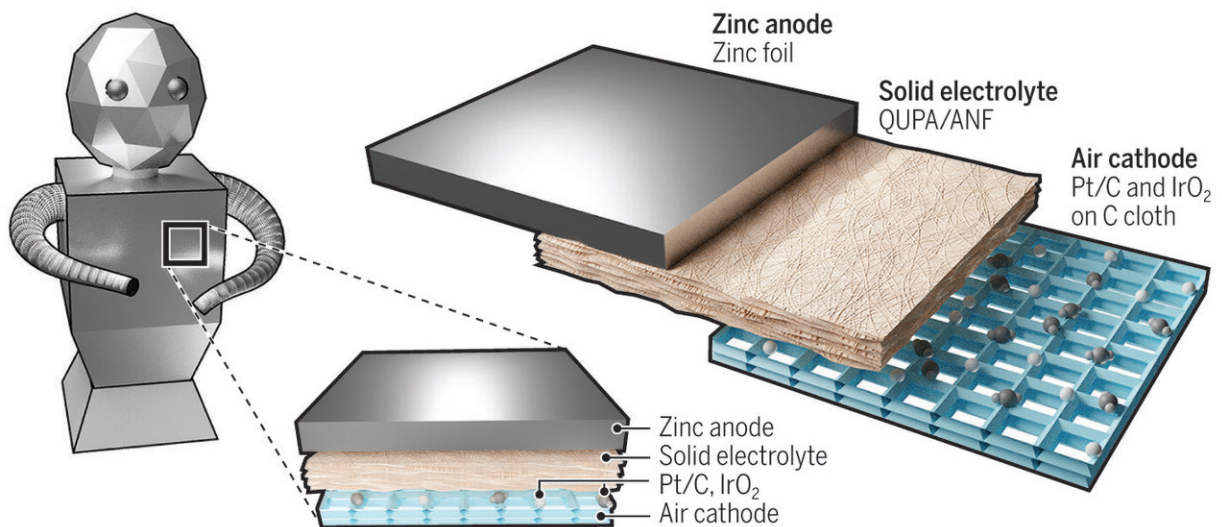
The combination of energy density and inexpensive materials means that the battery may already double the range of delivery robots, he said.

"This is not the limit, however. We estimate that robots could have 72 times more power capacity if their exteriors were replaced with zinc batteries, compared to having a single lithium ion battery," said

Mingqiang Wang, first author and recently a visiting researcher to Kotov's lab.

The new battery works by passing hydroxide ions between a zinc electrode and the air side through an electrolyte membrane. That membrane is partly a network of aramid nanofibers—the carbon-based fibers found in Kevlar vests—and a new water-based [polymer gel](#). The gel helps shuttle the [hydroxide ions](#) between the electrodes.

Made with cheap, abundant and largely nontoxic materials, the battery is more environmentally friendly than those currently in use. The gel and aramid nanofibers will not catch fire if the battery is damaged, unlike the flammable electrolyte in lithium ion batteries. The aramid nanofibers could be upcycled from retired body armor.



Schematic of a structural Zn-air battery and an example of how it could be used to provide structure to a robot. Credit: Alice Kitterman / Science Robotics

To demonstrate their batteries, the researchers experimented with regular-sized and miniaturized toy robots in the shape of a worm and a scorpion. The team replaced their original batteries with zinc-air cells. They wired the cells into the motors and wrapped them around the outsides of the creepy crawlers.

"Batteries that can do double duty—to store charge and protect the robot's 'organs'—replicate the multifunctionality of fat tissues serving to store energy in living creatures," said Ahmet Emre, a doctoral student in biomedical engineering in Kotov's lab.

The downside of zinc batteries is that they maintain high capacity for about 100 cycles, rather than the 500 or more that we expect from the lithium ion batteries in our smartphones. This is because the zinc metal forms spikes that eventually pierce the membrane between the electrodes. The strong aramid nanofiber network between the electrodes is the key to the relatively long cycle life for a zinc battery. And the inexpensive and recyclable materials make the batteries easy to replace.

Beyond the advantages of the battery's chemistry, Kotov says that the design could enable a shift from a single battery to distributed [energy storage](#), using graph theory approach developed at U-M.

"We don't have a single sac of fat, which would be bulky and require a lot of costly energy transfer," Kotov said. "Distributed energy storage, which is the biological way, is the way to go for highly efficient biomorphic devices."

A paper on this research is to be published in *Science Robotics*, titled, "Biomorphic structural batteries for robotics."

More information: M. Wang et al., "Biomorphic structural batteries for robotics," *Science Robotics* (2020). robotics.sciencemag.org/lookup...

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Provided by University of Michigan

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