Engineers design tiny batteries for powering cell-sized robots

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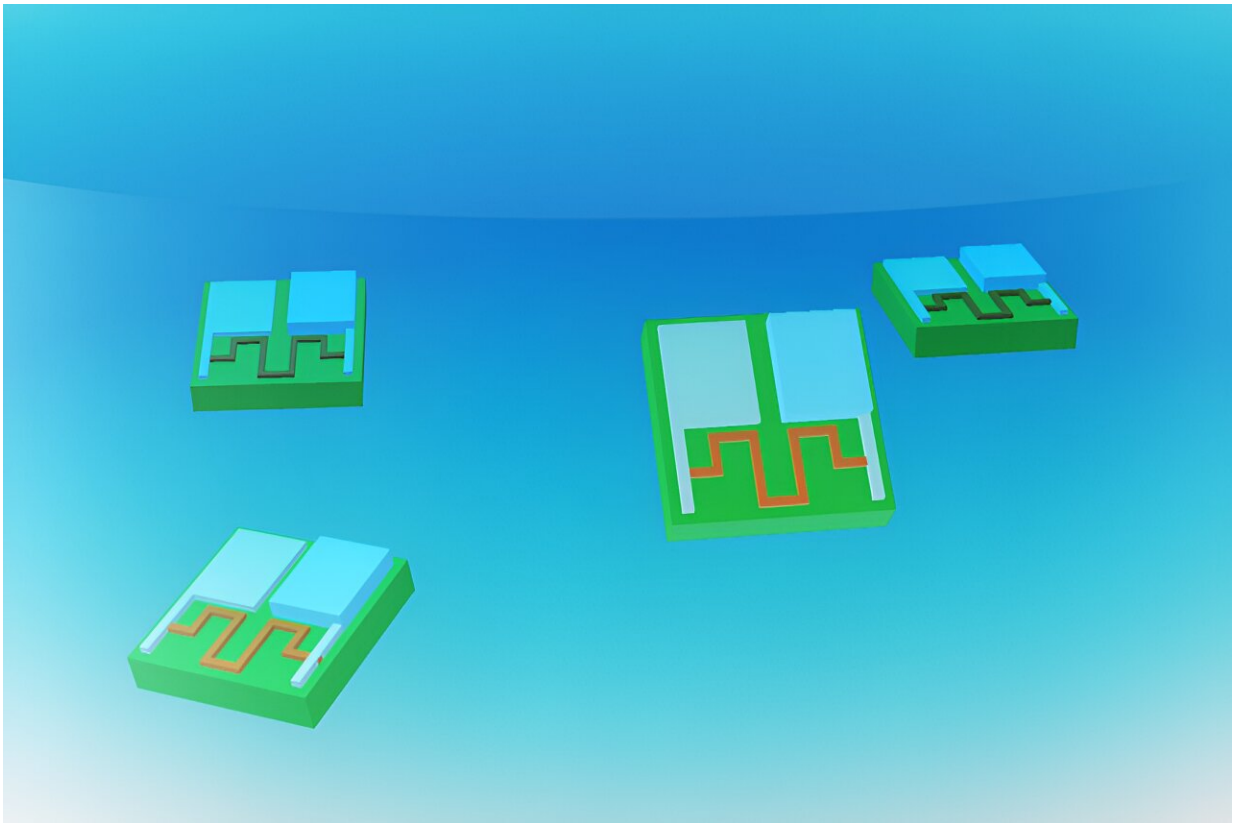

The zinc-air battery is 0.1 millimeters long and 0.02 millimeters thick. Credit: Massachusetts Institute of Technology

A tiny battery designed by MIT engineers could enable the deployment of cell-sized, autonomous robots for drug delivery within in the human

body, as well as other applications such as locating leaks in gas pipelines.

The new battery, which is 0.1 millimeters long and 0.002 millimeters thick—roughly the thickness of a human hair—can capture oxygen from air and use it to oxidize zinc, creating a current of up to 1 volt. That is enough to power a small circuit, sensor, or actuator, the researchers showed.

"We think this is going to be very enabling for robotics," says Michael Strano, the Carbon P. Dubbs Professor of Chemical Engineering at MIT and the senior author of the study. "We're building robotic functions onto the battery and starting to put these components together into devices."

Ge Zhang, Ph.D. and Sungyun Yang, an MIT graduate student, are the lead authors of the paper, which appears in *Science Robotics*.

Powered by batteries

For several years, Strano's lab has been working on tiny robots that can sense and respond to stimuli in their environment. One of the major challenges in developing such tiny robots is making sure that they have enough power.

Other researchers have shown that they can power microscale devices using solar power, but the limitation to that approach is that the robots must have a laser or another light source pointed at them at all times. Such devices are known as "marionettes" because they are controlled by an external power source. Putting a power source such as a battery inside these tiny devices could free them to roam much farther.

"The marionette systems don't really need a battery because they're getting all the energy they need from outside," Strano says. "But if you

want a small robot to be able to get into spaces that you couldn't access otherwise, it needs to have a greater level of autonomy. A battery is essential for something that's not going to be tethered to the outside world."

To create robots that could become more autonomous, Strano's lab decided to use a type of battery known as a zinc-air battery. These batteries, which have a longer lifespan than many other types of batteries due to their high energy density, are often used in hearing aids.

The battery that they designed consists of a zinc electrode connected to a platinum electrode, embedded into a strip of a polymer called SU-8, which is commonly used for microelectronics. When these electrodes interact with oxygen molecules from the air, the zinc becomes oxidized and releases electrons that flow to the platinum electrode, creating a current.

In this study, the researchers showed that this battery could provide enough energy to power an actuator—in this case, a robotic arm that can be raised and lowered. The battery could also power a memristor, an electrical component that can store memories of events by changing its electrical resistance, and a clock circuit, which allows robotic devices to keep track of time.

The battery also provides enough power to run two different types of sensors that change their electrical resistance when they encounter chemicals in the environment. One of the sensors is made from atomically thin molybdenum disulfide and the other from carbon nanotubes.

"We're making the basic building blocks in order to build up functions at the cellular level," Strano says.

Robotic swarms

In this study, the researchers used a wire to connect their battery to an external device, but in future work they plan to build robots in which the battery is incorporated into a device.

"This is going to form the core of a lot of our robotic efforts," Strano says. "You can build a robot around an energy source, sort of like you can build an electric car around the battery."

One of those efforts revolves around designing tiny robots that could be injected into the human body, where they could seek out a target site and then release a drug such as insulin. For use in the human body, the researchers envision that the devices would be made of biocompatible materials that would break apart once they were no longer needed.

The researchers are also working on increasing the voltage of the battery, which may enable additional applications.

More information: Ge Zhang et al, High energy density picoliter-scale zinc-air microbatteries for colloidal robotics, *Science Robotics* (2024). DOI: 10.1126/scirobotics.ade4642