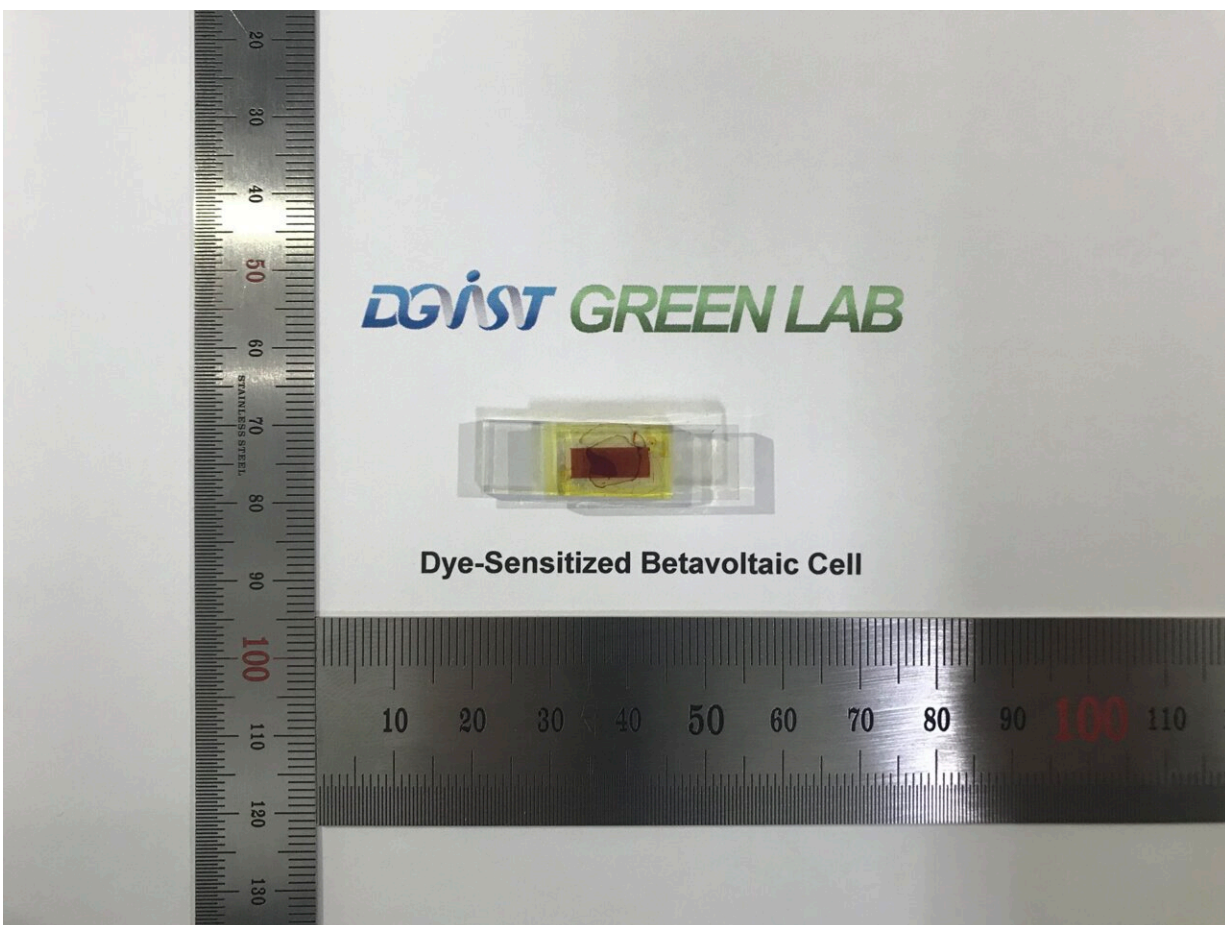


A safe nuclear battery that could last a lifetime

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A small dye-sensitized betavoltaic cell has radiocarbon on both the cathode and anode, which increases its energy-conversion efficiency. Credit: Su-II In

Sometimes cell phones die sooner than expected or electric vehicles don't have enough charge to reach their destination. The rechargeable lithium-ion (Li-ion) batteries in these and other devices typically last hours or days between charging. However, with repeated use, batteries degrade and need to be recharged more frequently.

Now, researchers are considering radiocarbon as a source for safe, small and affordable nuclear batteries that could last decades or longer without charging.

Su-il In, a professor at Daegu Gyeongbuk Institute of Science & Technology, presents his results at the [spring meeting of the American Chemical Society](#) (ACS), held March 23–27.

The frequent charging required for Li-ion batteries isn't just an inconvenience. It limits the utility of technologies that use the batteries for power, such as drones and remote-sensing equipment.

The batteries are also bad for the environment: Mining lithium is energy-intensive and improper disposal of [Li-ion batteries can contaminate ecosystems](#). But with the increasing ubiquity of connected devices, data centers and other computing technologies, the demand for long-lasting batteries is increasing.

And better Li-ion batteries are likely not the answer to this challenge. "The performance of Li-ion batteries is almost saturated," says In, who researches future energy technologies. So, In and his team members are developing nuclear batteries as an alternative to lithium.

Nuclear batteries generate power by harnessing high-energy particles emitted by [radioactive materials](#). Not all radioactive elements emit radiation that's damaging to living organisms, and some radiation can be blocked by certain materials. For example, beta particles (also known as

beta rays) can be shielded with a thin sheet of aluminum, making betavoltaics a potentially safe choice for nuclear batteries.

The researchers produced a prototype betavoltaic battery with carbon-14, an unstable and radioactive form of carbon, called radiocarbon. "I decided to use a radioactive isotope of carbon because it generates only beta rays," says In.

Moreover, a by-product of nuclear power plants, radiocarbon is inexpensive, readily available and easy to recycle. And because radiocarbon degrades very slowly, a radiocarbon-powered battery could theoretically last for millennia.

In a typical betavoltaic battery, electrons strike a semiconductor, which results in the production of electricity. Semiconductors are a critical component in betavoltaic batteries, as they are primarily responsible for energy conversion.

Consequently, scientists are exploring advanced semiconductor materials to achieve a higher energy conversion efficiency—a measure of how effectively a battery can convert electrons into usable electricity.

To significantly improve the energy conversion efficiency of their new design, In and the team used a titanium dioxide-based semiconductor, a material commonly used in [solar cells](#), sensitized with a ruthenium-based dye. They strengthened the bond between the titanium dioxide and the dye with a citric acid treatment.

When beta rays from radiocarbon collide with the treated ruthenium-based dye, a cascade of electron transfer reactions, called an electron avalanche, occurs. Then the avalanche travels through the dye and the titanium dioxide effectively collects the generated electrons.

The new battery also has radiocarbon in the dye-sensitized anode and a cathode. By treating both electrodes with the radioactive isotope, the researchers increased the amount of beta rays generated and reduced distance-related beta-radiation energy loss between the two structures.

During demonstrations of the prototype battery, the researchers found that beta rays released from radiocarbon on both electrodes triggered the ruthenium-based dye on the anode to generate an electron avalanche that was collected by the titanium dioxide layer and passed through an external circuit, resulting in usable electricity.

Compared to a previous design with radiocarbon on only the cathode, the researchers' battery with [radiocarbon](#) in the cathode and anode had a much higher [energy conversion](#) efficiency, going from 0.48% to 2.86%.

These long-lasting nuclear batteries could enable many applications, says In. For example, a pacemaker would last a person's lifetime, eliminating the need for surgical replacements.

However, this betavoltaic design converted only a tiny fraction of radioactive decay into electric energy, leading to lower performance compared to conventional Li-ion batteries. In suggests that further efforts to optimize the shape of the beta-ray emitter and develop more efficient beta-ray absorbers could enhance the battery's performance and increase power generation.

As climate concerns grow, public perception of nuclear energy is changing. But it's still thought of as energy only produced at a large power plant in a remote location.

With these dual-site-source dye-sensitized betavoltaic cell batteries, In says, "We can put safe nuclear energy into devices the size of a finger."

More information: 4200925 - Next generation battery: Highly efficient and stable C14 dye-sensitized betavoltaic cell 8:00 pm - 8:20 pm GMT-4 Wednesday, March 26, 2025. Room: Room 29B (San Diego Convention Center)

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