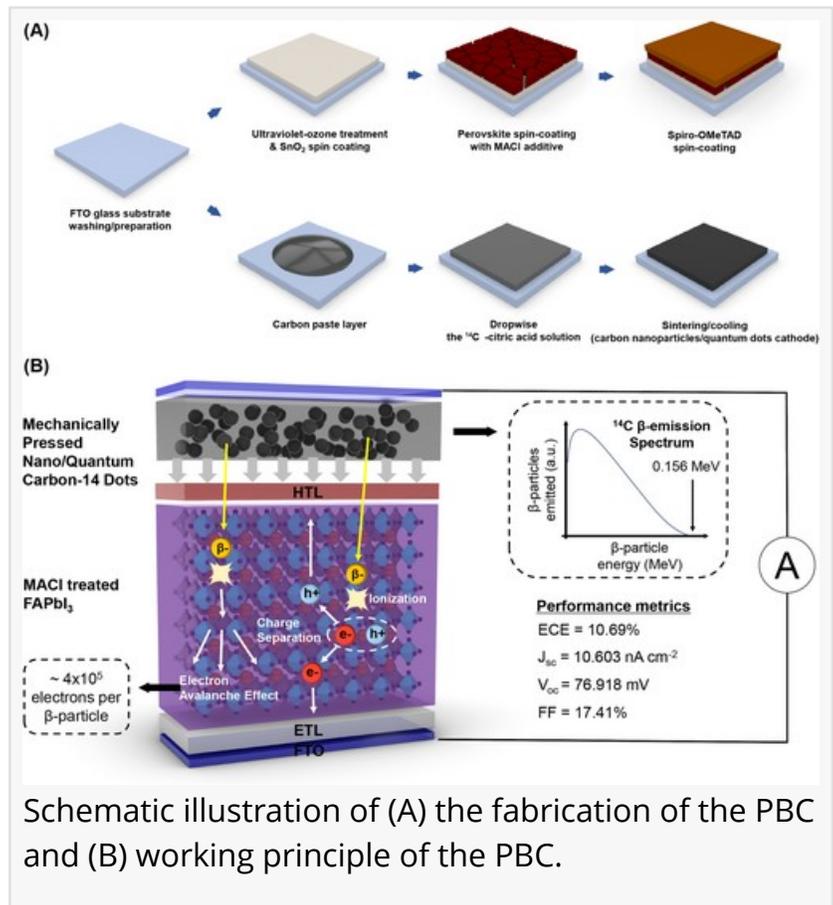


# Perovskite nuclear battery sets efficiency record

GA, UNITED STATES, March 25, 2026 /EINPresswire.com/ -- A new generation of nuclear microbatteries may soon power electronics that must operate for years without maintenance. Researchers have developed a perovskite-based [betavoltaic](#) device that directly converts beta radiation into electricity with a record energy conversion efficiency of 10.79%. By integrating carbon-14 nanoparticles with a formamidinium lead iodide (FAPbI<sub>3</sub>) perovskite absorber, the system dramatically improves charge generation and transport within the device. Each incoming  $\beta$ -particle triggers an electron avalanche that multiplies the number of charge carriers, significantly enhancing electrical output. The work demonstrates how advanced perovskite engineering can overcome long-standing efficiency barriers in nuclear batteries and provides a promising pathway toward durable, self-powered microelectronics for extreme environments and autonomous technologies.



Schematic illustration of (A) the fabrication of the PBC and (B) working principle of the PBC.

The rapid growth of autonomous electronics, implantable medical devices, and edge artificial intelligence systems has increased the demand for compact and long-lasting power sources. Conventional lithium-ion batteries face inherent limitations, including short lifespans, safety risks, and reduced performance in harsh environments. Betavoltaic nuclear batteries offer a compelling alternative because they generate electricity from the energy released during radioactive decay and can operate for years with minimal maintenance. However, practical deployment has been limited by extremely low energy conversion efficiencies, typically below 4%, largely due to inefficient radiation absorption and poor charge transport in conventional

semiconductor materials. Due to these challenges, deeper research is needed to develop more efficient materials and device architectures for next-generation betavoltaic energy systems.

A study published (DOI: 10.1002/cey2.70149) in 2025 in the journal *Carbon Energy* by researchers from the Korea Brain Research Institute, Daegu Gyeongbuk Institute of Science & Technology, and Yonsei University reports a major advance in nuclear microbattery technology. The team designed a perovskite betavoltaic cell integrating formamidinium lead iodide (FAPbI<sub>3</sub>) with carbon-14 nanoparticles, enabling direct conversion of beta radiation into electricity. The device achieved an unprecedented 10.79% energy conversion efficiency, the highest reported for a perovskite-based betavoltaic system, demonstrating the potential of advanced perovskite materials for highly efficient nuclear energy harvesting.

To build the device, the researchers engineered a multilayer structure consisting of a fluorine-doped tin oxide substrate, a SnO<sub>2</sub> electron-transport layer, a FAPbI<sub>3</sub> perovskite absorber, and a carbon electrode embedded with carbon-14 nanoparticles. When carbon-14 undergoes radioactive decay, it emits  $\beta$ -particles that penetrate the perovskite layer. These energetic particles generate electron-hole pairs within the semiconductor, which are then separated by the device's internal electric field to produce electrical current. A key innovation of the study lies in additive and solvent engineering of the perovskite film. By introducing methylammonium chloride (MACl) additives and applying isopropanol-assisted crystallization during fabrication, the researchers produced large-grain perovskite films with significantly reduced defect densities. The improved crystal structure enhanced charge mobility and suppressed recombination losses, enabling more efficient harvesting of radiation energy.

Performance measurements revealed a short-circuit current density of 10.60 nA cm<sup>-2</sup>, an open-circuit voltage of 76.92 mV, and a fill factor of 17.41, resulting in the record 10.79% energy conversion efficiency. Notably, each incoming  $\beta$ -particle generated more than  $4 \times 10^5$  charge carriers through an electron avalanche effect, greatly amplifying the electrical output. The device also demonstrated stable operation for over 15 hours under continuous radiation, confirming the feasibility of perovskite materials as active absorbers in nuclear microgenerators and establishing a new benchmark for betavoltaic energy conversion.

According to the research team, the breakthrough demonstrates how material engineering can transform the performance of nuclear batteries. The researchers explain that optimizing the crystal structure of the perovskite absorber significantly improves radiation interaction and carrier transport, allowing the device to convert a much larger fraction of  $\beta$ -particle energy into electricity. They note that the synergy between additive engineering and solvent-assisted crystallization enabled a highly uniform perovskite film with fewer defects, which was critical to achieving the record efficiency. The team believes these insights will guide the development of more durable and higher-performance betavoltaic power systems.

High-efficiency betavoltaic power sources could transform the design of electronic systems that require extremely long lifetimes or operate in inaccessible environments. Because carbon-14 has

a half-life of more than 5,000 years, devices based on this technology could theoretically power sensors or microelectronics for decades without replacement. Potential applications include implantable medical devices, space exploration instruments, remote environmental sensors, and edge-AI systems that must operate autonomously. The scalable fabrication strategy demonstrated in this study also suggests that perovskite-based nuclear microgenerators could eventually be integrated into compact electronics. With further improvements in stability and radiation tolerance, such systems may become a viable long-term energy solution for next-generation autonomous technologies.

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Lucy Wang

BioDesign Research

[email us here](#)

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