Solar battery receives 20% of its energy from the sun

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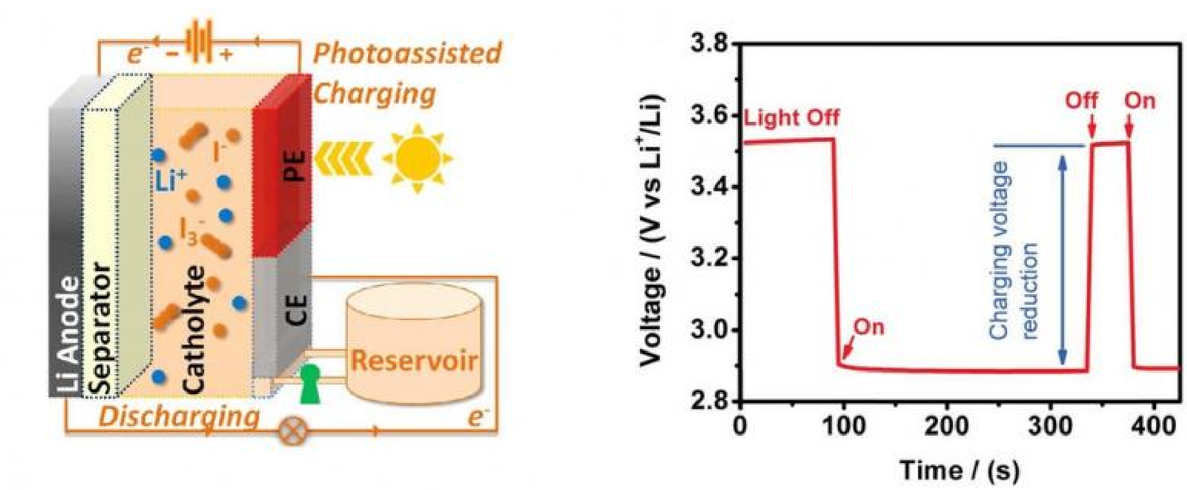

(Left) Illustration of the new Li-I solar flow battery with an aqueous electrolyte, which compared to organic solvents has advantages in terms of performance, cost, and environmental friendliness. (Right) When the solar battery is exposed to light, the voltage that it needs from an external source immediately decreases, as the device is being charged by the solar cell. Credit: Yu, et al. ©2015 American Chemical Society

(Phys.org)—Last October, researchers at Ohio State demonstrated the world's first solar battery—a solar cell and a lithium-oxygen ($Li\text{-}O_2$) battery combined into a single device. The main attraction of the solar battery concept is that, because it can harvest, convert, and store solar energy as chemical energy all in one device, it eliminates losses that occur when transferring electrons between multiple devices. The researchers estimate that this integration can potentially reduce overall costs by about 25%.

Although the solar-charged Li-O_2 battery represented a novel and promising concept, it had a drawback: its electrolyte was made of organic solvents, which are non-aqueous and therefore not compatible with aqueous (water-based) redox flow batteries, limiting the device's performance. Organic solvents also face problems with environmental impact and cost.

Now in a new paper published in the *Journal of the American Chemical Society*, Ohio State Professor Yiying Wu and his research group have improved upon their original design by developing a solar battery that replaces the organic solvents with a more environmentally friendly and cost-effective iodine redox-based aqueous solution. The new version is an aqueous lithium-iodine (Li-I) solar flow battery, which integrates an aqueous Li-I redox flow battery with a dye-sensitized solar cell. This compatibility allows the device to operate at a higher voltage, improving its overall performance and bringing the solar battery a step closer to commercialization.

"I think the greatest significance is the identification and demonstration of aqueous flow batteries as the platform for solar batteries," Wu told *Phys.org*. "Flow batteries are flexible in materials selection. They are modular and scalable, and are being considered for applications in stationary storage, stand-alone power and electric vehicles. Our aqueous flow solar battery is an important step that brings this simultaneous solar energy conversion and storage concept closer to practical applications."

When exposed to sunlight during the charging process, the Li-I solar battery receives about 20% of its charging energy from the sun, meaning it uses 20% less energy from conventional energy sources compared to conventional Li-I batteries. The photoassisted charging process occurs when sunlight illuminates the dye molecules, causing them to become photoexcited and inject their electrons into the photoelectrode—the battery's third electrode, in addition to the conventional cathode and anode. The photoexcited electrons supply a photovoltage to the battery, which reduces the charging voltage (which is supplied by external energy sources) to a value that is even lower than the discharging voltage. As the researchers explain, this feat would be thermodynamically impossible without the solar energy input.

The researchers explain that the key component of the solar battery design is the electrolyte because it bridges the hydrophilic aqueous Li-I battery and the hydrophobic surface of the dye-sensitized solar cell photoelectrode. The electrolyte consists of several ingredients, including lithium iodide salt (LiI), which is essential for the battery's electrochemical reactions, along with various additives that allow the hydrophilic electrolyte to wet the hydrophobic photoelectrode surface. This surface-wetting contact between the two components is essential for efficiently transferring charge from the solar cell to the battery.

Overall, tests showed that the Li-I solar battery has a theoretical capacity (35.7 Ah/L with 2M LiI) close to that of conventional Li-I batteries, and it can be photocharged to about 91% of its theoretical capacity. It also appears to have good cyclability, retaining its full capacity for at least 25 cycles. Unfortunately, it currently takes about 16.8 hours to photocharge the device with a 0.1-mL electrolyte to its full capacity, and this long charge time is one of the biggest areas in need of improvement. The researchers plan to address this problem by improving the efficiency of the aqueous-compatible photoelectrode, among other strategies.

In the future, the scientists also plan to extend some of the concepts in this solar battery design to other combinations of battery chemistry and solar cell photoelectrochemistry. One possibility is developing solar batteries that use sodium instead of lithium as the anode, since sodium has been gaining appeal due to its wide abundance and inexpensive fabrication costs.

"Improving the solar battery's photocharging rate and achieving full photocharging are among our goals," Wu said. "We hope this technology will ultimately be commercialized for applications in grid-scale stationary solar energy conversion and storage."

More information: Mingzhe Yu, et al. "Aqueous Lithium–Iodine Solar Flow Battery for the Simultaneous Conversion and Storage of Solar Energy." *Journal of the American Chemical Society*. DOI: 10.1021/jacs.5b03626