Calcium batteries: New electrolytes, enhanced properties

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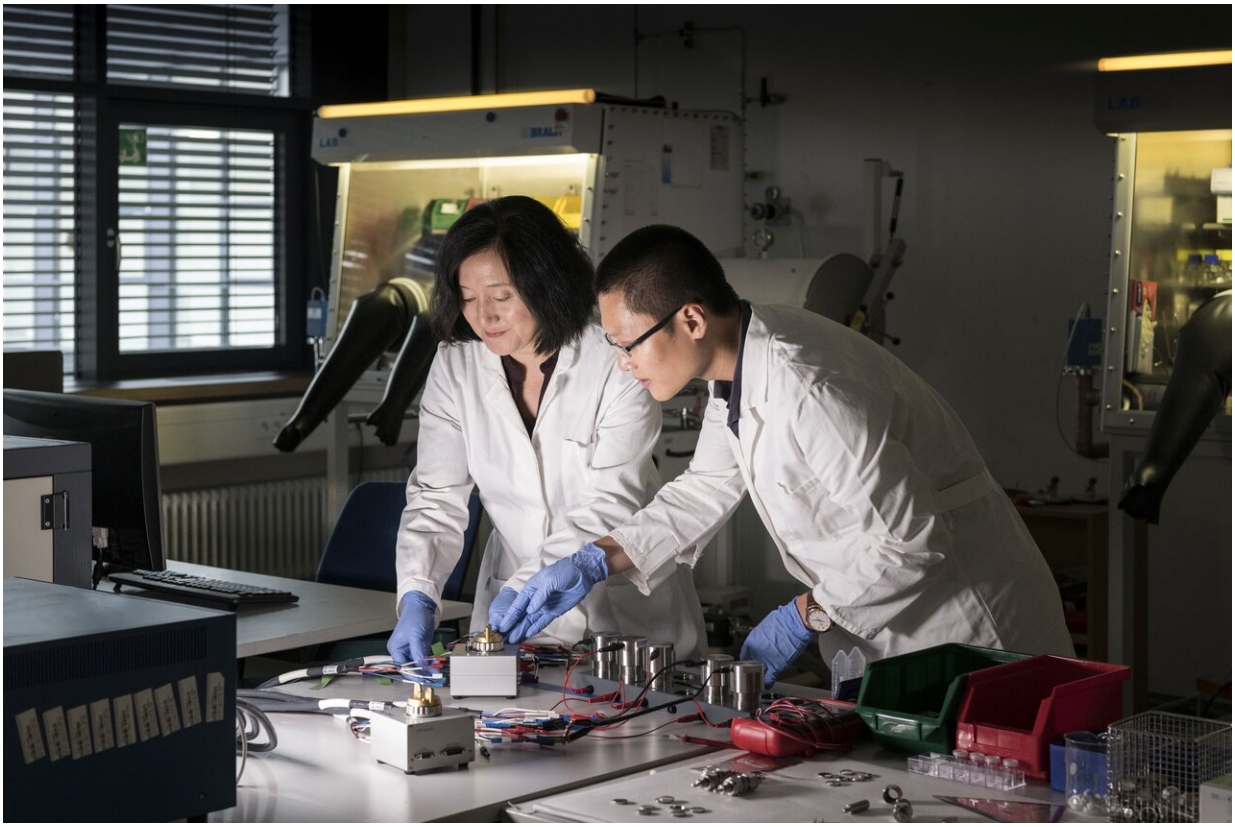

Zhirong Zhao-Karger (left) and Zhenyou Li (right) from the POLiS (Post Lithium Storage) Cluster of Excellence succeeded in producing promising electrolytes for calcium batteries. Credit: Markus Breig/KIT

Calcium-based batteries promise to reach a high energy density at low

manufacturing costs. This lab-scale technology has the potential for replacing lithium-ion technology in future energy storage systems. Using the electrolytes available, however, it has been impossible so far to charge calcium batteries at room temperature. In the *Energy & Environmental Science* journal, researchers of Karlsruhe Institute of Technology (KIT) now present a promising electrolyte class, with which this will be possible.

Efficient, large, and low-cost energy storage systems will facilitate nationwide transition to zero-emission mobility and power supply. Today's predominant lithium-ion technology, however, cannot fulfill this task on a global scale, says Professor Maximilian Fichtner of KIT, Director of the research platform CELEST (Center for Electrochemical Energy Storage Ulm & Karlsruhe). Here, calcium batteries and other storage technologies are studied. "In the medium term, lithium-ion batteries will reach their limits in terms of performance and some of the resources used for their manufacture. This will prevent their future use wherever that would be reasonable for the energy transition. Availability of resources needed for manufacture, such as cobalt, nickel, and lithium, is limited." At the Helmholtz Institute Ulm (HIU) established by KIT in cooperation with Ulm University, Fichtner and his team focus on alternative battery technologies instead. These technologies are based on more abundant resources. Calcium is a promising candidate, because it can release and accept two electrons per atom contrary to lithium and because it supplies a voltage similar to that of lithium: "Calcium is the fifth most abundant element in the Earth's crust. It is distributed homogeneously on Earth and it is safe, non-toxic, and inexpensive."

Search for a Suitable Electrolyte

Still, there has been a big obstacle in calcium battery development so far: In contrast to the established lithium-ion technology or more recent sodium or magnesium technologies, practicable electrolytes to produce

rechargeable calcium batteries have been lacking so far. "For a few years now, experimental electrolytes and, hence, prototypes of the calcium battery have been available," say Dr. Zhenyou Li, first author of the study, and Dr. Zhirong Zhao-Karger, who heads the project. Both are working in the POLiS (Post Lithium Storage) Cluster of Excellence of KIT that is embedded in CELEST. "But these electrolytes enable charging at temperatures beyond 75 degrees Celsius only and additionally they are susceptible to undesired side reactions."

The researchers have now succeeded in synthesizing a class of new electrolytes based on special organic calcium salts. These electrolytes enable charging at room temperature. Using the new electrolyte calcium tetrakis[hexafluoroisopropyloxy]borate, the researchers demonstrated feasibility of calcium batteries of high energy density, storage capacity, and quick-charging capability. Their results are reported in the journal *Energy & Environmental Science*.

Calcium Batteries as Sustainable Energy Storage Systems

The new class of electrolytes is an important basis for transferring calcium batteries from the laboratory to application. In electric vehicles, mobile electronic devices, and stationary storage systems, they might replace the presently predominating lithium-ion battery one day. But this may take a while: "The new electrolytes are a first important step," Fichtner emphasizes. "There still is a far way to go to the mature calcium battery."

More information: Zhenyou Li et al. Towards stable and efficient electrolytes for room-temperature rechargeable calcium batteries, *Energy & Environmental Science* (2019). DOI: 10.1039/c9ee01699f