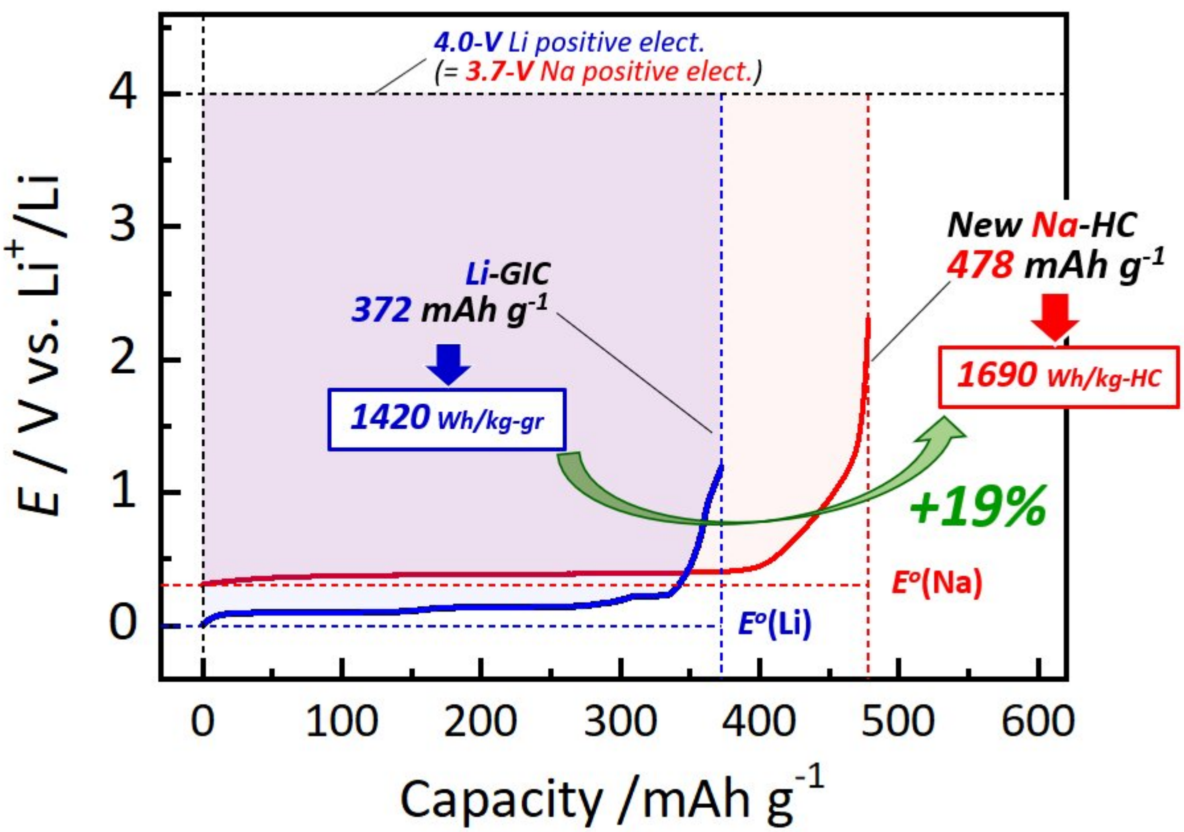
New hard-carbon anode material for sodium-ion batteries will solve the lithium conundrum

December 14 2020



The higher capacity of this new hard carbon electrode material means that a 19% increase in energy density by weight is possible in sodium-ion batteries compared with lithium-ion batteries Credit: Shinichi Komaba from Tokyo University of Science

Cost-effective rechargeable batteries are at the heart of virtually all portable electronic devices, which have become ubiquitous in modern daily life. Moreover, rechargeable batteries are essential components in many environment-friendly technologies, such as electric cars and systems that harvest renewable energy. They are also key enablers of various medical devices and facilitate research in various fields as the energy source of electronic sensors and cameras. So, it shouldn't come as a surprise that there is a lot of effort spent in developing better and cheaper rechargeable batteries.

So far, rechargeable lithium-ion batteries hold the number-one spot thanks to their great performance across the board in terms of capacity, stability, price, and charging time. However, lithium, and other minor and costly metals like cobalt and copper, are not among the most abundant materials on the earth's crust, and their ever-increasing demand will soon lead to supply problems around the world. At the Tokyo University of Science, Japan, Professor Shinichi Komaba and colleagues have been striving to find a solution to this worsening conundrum by developing rechargeable batteries using alternative, more abundant materials.

In a recent study published in *Angewandte Chemie International Edition*, the team found an energy efficient method to produce a novel carbon -based material for sodium-ion batteries. Apart from Prof. Komaba, the team also included Ms. Azusa Kamiyama and Associate Prof. Kei Kubota from Tokyo University of Science, Dr. Yong Youn and Dr. Yoshitaka Tateyama from National Institute for Materials Science, Japan, and Associate Prof. Kazuma Gotoh from Okayama University, Japan. The study focused on the synthesis of hard carbon, a highly porous material that serves as the negative electrode of rechargeable batteries, through the use of magnesium oxide (MgO) as an inorganic template of nano-sized pores inside hard carbon.

The researchers explored a different technique for mixing the ingredients of the MgO template so as to precisely tune the nanostructure of the resulting hard carbon electrode. After multiple experimental and theoretical analyses, they elucidated the optimal fabrication conditions and ingredients to produce hard carbon with a capacity of 478 mAh/g, the highest ever reported in this type of material. Prof. Komaba states, "Until now, the capacity of carbon-based negative electrode materials for sodium-ion batteries was mostly around 300 to 350 mAh/g. Though values near 438 mAh/g have been reported, those materials require heat treatment at extremely high temperatures above 1900°C. In contrast, we employed heat treatment at only 1500°C, a relatively low temperature." Of course, with lower temperature comes lower energy expenditure, which also means lower cost and less environmental impact.

The capacity of this newly developed hard carbon electrode material is certainly remarkable, and greatly surpasses that of graphite (372 mAh/g), which is currently used as the negative electrode material in lithium-ion batteries. Moreover, even though a sodium-ion battery with this hard carbon negative electrode would in theory operate at a 0.3-volt lower voltage difference than a standard lithium-ion battery, the higher capacity of the former would lead to a much greater energy density by weight (1600 Wh/kg versus 1430 Wh/kg), resulting in +19% increase of energy density.

Excited about the results and with his eyes on the future, Prof. Komaba remarks, "Our study proves that it is possible to realize high-energy sodium-ion batteries, overturning the common belief that lithium-ion batteries have a higher energy density. The hard carbon with extremely high capacity that we developed has opened a door towards the design of new sodium-storing materials."

Further studies will be required to verify that the proposed material actually offers superior lifetime, input-output characteristics, and low temperature operation in actual sodium-ion batteries. With any luck, we might be on the verge of witnessing the next generation of rechargeable batteries!

More information: Azusa Kamiyama et al, MgO-Template Synthesis of Extremely High Capacity Hard Carbon for Na-Ion Battery, *Angewandte Chemie International Edition* (2020). DOI: 10.1002/anie.202013951

Provided by Tokyo University of Science