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Disordered crystals are promising for future battery technology

December 19 2018

Tiny, disordered particles of magnesium chromium oxide may hold the key to new magnesium battery energy storage technology. Credit: UCL

Tiny, disordered particles of magnesium chromium oxide may hold the key to new magnesium battery energy storage technology, which could possess increased capacity compared to conventional lithium-ion batteries, find UCL and University of Illinois at Chicago researchers.

The study, published today in *Nanoscale*, reports a new, scalable method for making a material that can reversibly store magnesium ions at high-voltage, the defining feature of a cathode.

While it is at an early stage, the researchers say it is a significant development in moving towards magnesium-based batteries. To date, very few inorganic materials have shown reversible magnesium removal and insertion, which is key for the magnesium battery to function.

"Lithium-ion technology is reaching the boundary of its capability, so it's important to look for other chemistries that will allow us to build batteries with a bigger storage capacity and a slimmer design," said co-lead author, Dr. Ian Johnson (UCL Chemistry).

"Magnesium battery technology has been championed as a possible solution to provide longer-lasting phone and electric car batteries, but getting a practical material to use as a cathode has been a challenge."

One factor limiting lithium-ion batteries is the anode. Low-capacity carbon anodes have to be used in lithium-ion batteries for safety reasons, as the use of pure lithium metal anodes can cause dangerous short circuits and fires.

In contrast, magnesium metal anodes are much safer, so partnering magnesium metal with a functioning cathode material would make a battery smaller and store more energy.

Previous research using computational models predicted that magnesium chromium oxide ($MgCr_2O_4$) could be a promising candidate for Mg battery cathodes.

Inspired by this work, UCL researchers produced a ~5 nm, disordered magnesium chromium oxide material in a very rapid and relatively low temperature reaction.

Collaborators at the University of Illinois at Chicago then compared its magnesium activity with a conventional, ordered magnesium chromium oxide material ~7 nm wide.

They used a range of different techniques including X-ray diffraction, X-ray absorption spectroscopy and cutting-edge electrochemical methods to see the structural and chemical changes when the two materials were tested for magnesium activity in a cell.

The two types of crystals behaved very differently, with the disordered particles displaying reversible magnesium extraction and insertion, compared to the absence of such activity in larger, ordered crystals.

"This suggests the future of batteries might lie in disordered and unconventional structures, which is an exciting prospect and one we've not explored before as usually disorder gives rise to issues in battery materials. It highlights the importance of seeing if other structurally defective materials might give further opportunities for reversible battery chemistry" explained Professor Jawwad Darr (UCL Chemistry).

"We see increasing the surface area and including disorder in the crystal structure offers novel avenues for important chemistry to take place compared to ordered crystals.

Conventionally, order is desired to provide clear diffusion pathways, allowing cells to be charged and discharged easily—but what we've seen suggests that a disordered structure introduces new, accessible diffusion pathways that need to be further investigated," said Professor Jordi Cabana (University of Illinois at Chicago).

These results are the product of an exciting new collaboration between UK and US researchers. UCL and the University of Illinois at Chicago intend to expand their studies to other disordered, high surface area materials, to enable further gains in magnesium storage capability and develop a practical magnesium battery.

More information: Linhua Hu et al, Tailoring the Electrochemical Activity of Magnesium Chromium Oxide Towards Mg Batteries Through Control of Size and Crystal Structure, *Nanoscale* (2018). DOI: 10.1039/C8NR08347A

Provided by University College London