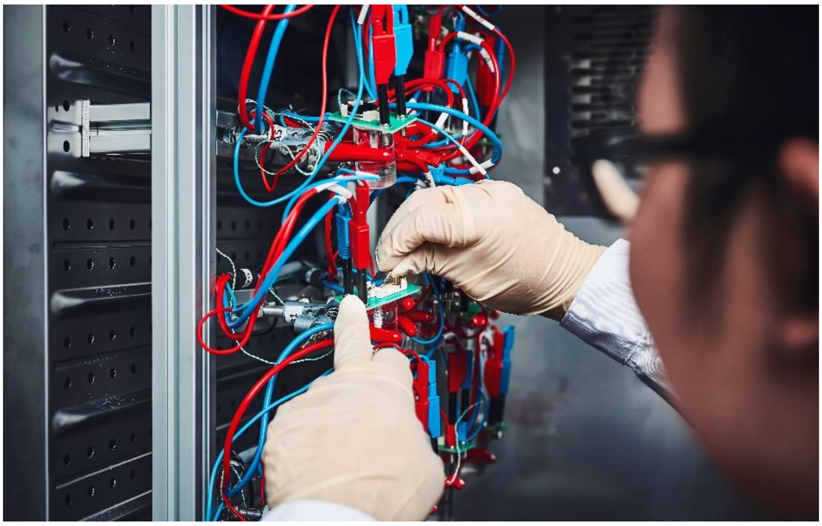
Up to 30 Percent more Capacity for Lithium-ion Batteries

Success of Materials Research at KIT – Major Finding on the Way towards the High-energy Battery



In a world first a team of researchers at KIT explains degradation mechanisms in the cathode material for future high-energy lithium-ion batteries. (Photo: Amadeus Bramsiepe, KIT)

Researchers of Karlsruhe Institute of Technology (KIT) and cooperating institutions studied structural changes during the synthesis of cathode materials for future high-energy lithium-ion batteries and obtained new major findings about degradation mechanisms. These findings might contribute to the development of batteries of far higher capacity, which would then increase the range of electric vehicles. The results are reported in *Nature Communications* (DOI 10.1038/s41467-019-13240-z).

So far, breakthrough of electric mobility has been impeded by insufficient vehicle ranges, among others. Lithium-ion batteries of increased charge capacity might help. "We are in the process of developing such high-energy systems," says Professor Helmut Ehrenberg, Head of the Institute for Applied Materials – Energy Storage Systems (IAM-ESS). "Based on fundamental understanding of electrochemical processes in batteries and by the innovative use of new materials, storage capacity of lithium-ion batteries may be increased by up to 30%

KIT Energy Center: Having future in mind

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Additional materials:
Animation of a single particle of the high-energy cathode material, based on a synchrotron measurement: https://bit.ly/2rUh6Hc

Publication in *Nature Communications:* https://www.nature.com/articles/s41467-019-13240-z#citeas in our opinion." At KIT, this research is conducted at the Center for Electrochemical Energy Storage Ulm & Karlsruhe (CELEST), the biggest German research platform for electrochemical energy storage. Ehrenberg is Deputy Spokesperson of CELEST.

High-energy lithium-ion technology differs from the conventional technology by a specific cathode material. Instead of layered oxides with varying ratios of nickel, manganese, and cobalt that have been used so far, manganese-rich materials with lithium excess are applied, which considerably enhance the energy storage capacity per volume/mass of cathode material. However, use of these materials has been associated with a problem so far. During the insertion and extraction of lithium ions, i.e. basic functioning of a battery, the high-energy cathode material degrades. After a certain time, the layered oxide transforms into a crystal structure with highly unfavorable electrochemical properties. As an undesired consequence, the average charge and discharge voltage decreases from the very beginning of the process, which has prevented the development of suitable high-energy lithium-ion batteries so far.

The team of KIT researchers (from left to right): Michael Knapp, Sylvio Indris, Weibo Hua, Björn Schwarz. (Photo: Amadeus Bramsiepe, KIT)

New Findings about Degradation

The exact degradation mechanism was far from being understood completely. A team of researchers of KIT and cooperating institutions has now described the basic mechanism in *Nature Communications*: "Based on detailed studies of the high-energy cathode material, we found that degradation does not take place directly, but indirectly via the formation of a so far hardly noticed lithium-containing rock-salt structure," says Weibo Hua (IAM-ESS), one of the main authors of the study. "In addition, oxygen plays an important role in the reactions." Apart from these results, the study also reveals that new findings about the behavior of a battery technology do not necessarily have to result directly from the degradation process. Weibo and the other scientists involved made their discovery in studies carried out while synthesizing the cathode material.

These findings of KIT mark an important milestone on the way towards high-energy lithium-ion batteries for electric cars. They enable tests of new approaches to minimizing degradation in layered oxides and starting the development proper of this new battery type.

Original Publication:

Weibo Hua, Suning Wang, Michael Knapp, Steven J. Leake, Anatoliy Senyshyn, Carsten Richter, Murat Yavuz, Joachim R. Binder, Clare P. Grey, Helmut Ehrenberg, Sylvio Indris, and Björn Schwarz: Structural insights into the formation and voltage degradation of high-energy lithium- and manganese-rich layered oxides. Nature Communications, 2019. DOI 10.1038/s41467-019-13240-z

https://www.nature.com/articles/s41467-019-13240-z#citeas

About the CELEST Research Platform with the POLiS Cluster of Excellence

The CELEST (Center for Electrochemical Energy Storage Ulm & Karlsruhe) research platform for strategic collaboration was established in 2018 by KIT, Ulm University, and the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW). It is one of the biggest battery research activities in international comparison. 45 working groups from 29 institutes of KIT, Ulm University, and ZSW contribute their complementary expertise to CELEST – from fundamental research to close-to-practice development to technology transfer. CELEST focuses on three research fields: Lithium-ion technology, energy storage beyond lithium, and alternative technologies for electrochemical energy storage and conversion.

The POLiS (Post Lithium Storage) Cluster of Excellence also is embedded in CELEST. Within POLiS, researchers from Karlsruhe and ULM conduct research relating to the future battery. In late 2018, the Cluster was acquired within the highly competitive Excellence Strategy Competition of the federation and the federal states. It has a budget of about EUR 7 million per year and is scheduled for a duration of initially seven years. POLiS partners are KIT and Ulm University, associated partners are ZSW and Gießen University. Half of the about 100 researchers are working in Karlsruhe, half in Ulm.

More about CELEST: https://www.celest.de/

More on the Cluster of Excellence: https://www.postlithiumstorage.org/

More about the KIT Energy Center: http://www.energy.kit.edu

Being "The Research University in the Helmholtz Association," KIT creates and imparts knowledge for the society and the environment. It is the objective to make significant contributions to the global challenges in the fields of energy, mobility and information. For this, about 9,300 employees cooperate in a broad range of disciplines in natural sciences, engineering sciences, economics, and the humanities and social sciences. KIT prepares its 25,100 students for responsible tasks in society, industry, and science by offering research-based study programs. Innovation efforts at KIT build a bridge between important scientific findings and their application for the benefit of society, economic prosperity, and the preservation of our natural basis of life.

This press release is available on the internet at http://www.sek.kit.edu/english/press_office.php.

The photos in the best quality available to us may be downloaded under www.kit.edu or requested by mail to presse@kit.edu or phone +49 721 608-21105. The photo may be used in the context given above exclusively.

This year's **anniversary logo** recalls the milestones reached by KIT and its long tradition in research, teaching, and innovation. On October 1, 2009, KIT was established by the merger of its two predecessor institutions: the Polytechnic School and later University of Karlsruhe was founded in 1825, the Nuclear Reactor Construction and Operation Company and later Karlsruhe Research Center in 1956.