The most complete study of battery failure sees the light

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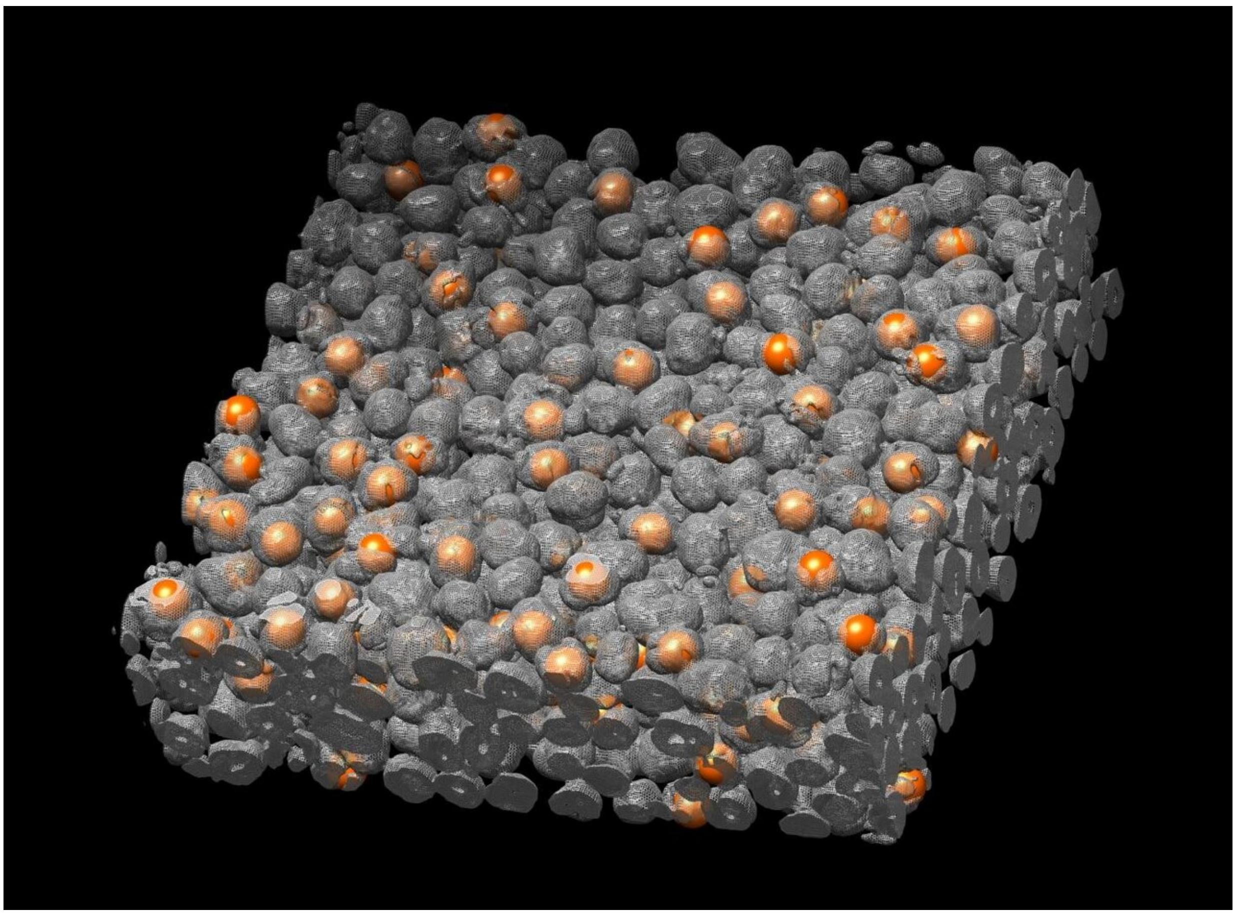


Researchers have created a new technique that scans thousands of particles in the electrode of a battery at once. The goal is to understand how cracks in these particles impact battery performance, so that the industry can build more reliable batteries with higher charging capacity. Credit: Yang Yang/ESRF

An international team of researchers just published in *Advanced Energy Materials* the widest study on what happens during battery failure, focusing on the different parts of a battery at the same time. The role of the ESRF, the European Synchrotron, in France, was crucial for its success.

We have all experienced it: you have charged your mobile phone and after a short period using it, the battery goes down unusually quickly. Consumer electronics seem to lose power at uneven rates and this is due to the heterogeneity in batteries. When the phone is charging, the top layer charges first and the bottom layer charges later. The mobile phone may indicate it's complete when the top surface level is finished charging, but the bottom will be undercharged. If you use the bottom layer as your fingerprint, the top layer will be overcharged and will have safety problems.

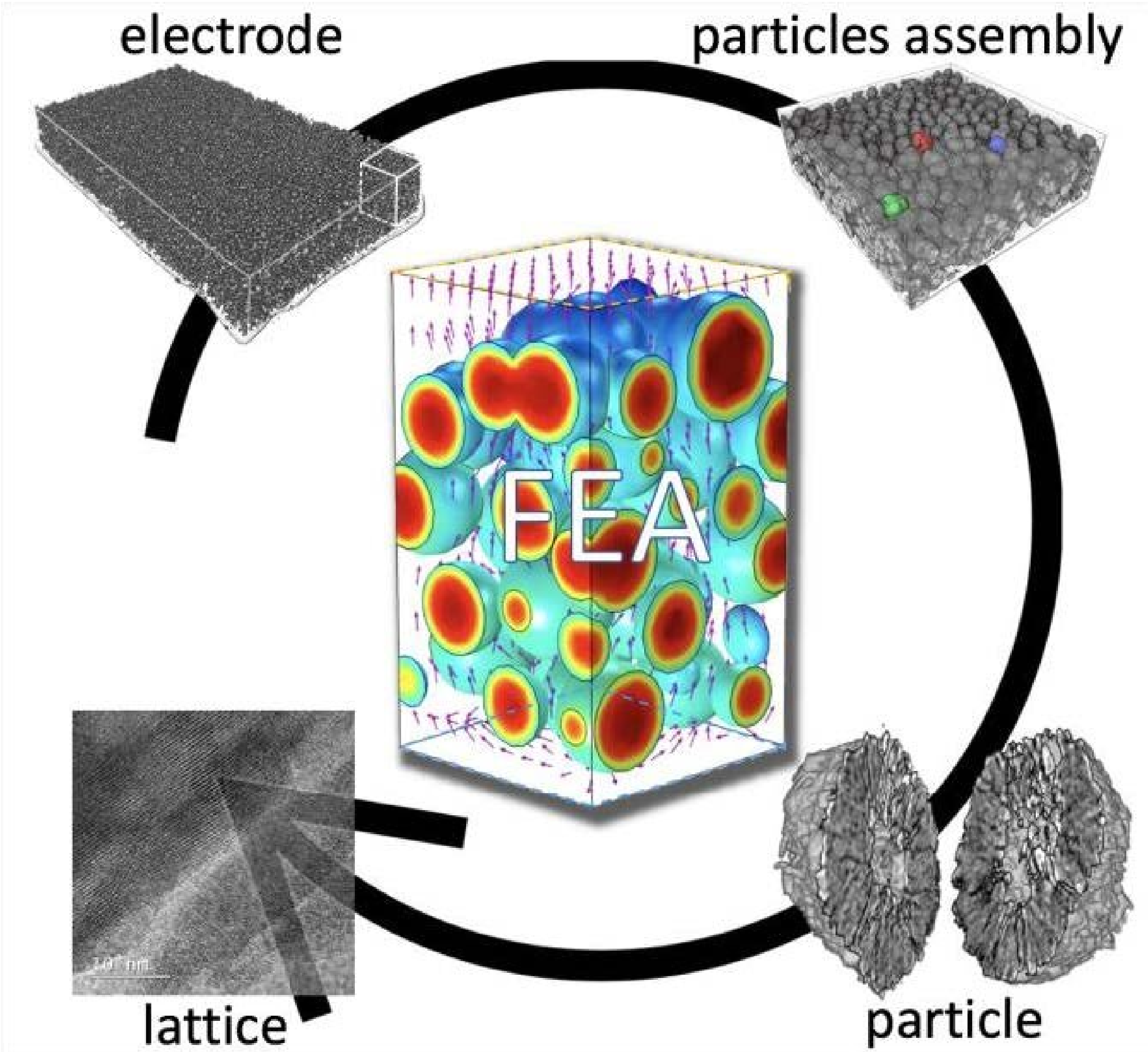
The truth is, batteries are composed of many different parts that behave differently. Solid polymer helps hold particles together, carbon additives provide electrical connection, and then there are the active battery particles storing and releasing the energy.

An international team of scientists from the ESRF, SLAC, Virginia Tech and Purdue University wanted to understand and quantitatively define what leads to the failure of lithium-ion batteries. Until then, studies had either zoomed in on individual areas or particles in the cathode during failure or zoomed out to look at cell level behavior without offering sufficient microscopic details. Now this study provides the first global view with unprecedented amount of microscopic structural details to complement the existing studies in the battery literature.

If you have a perfect electrode, every single particle should behave in the same fashion. However, electrodes are very heterogeneous and contain millions of particles. There's no way to ensure each particle behaves the same way at the same time.

To overcome this challenge, the research team relied heavily on the synchrotron X-ray methods and used two synchrotron facilities to study electrodes in batteries, the ESRF, the European synchrotron in Grenoble, France and Stanford's SLAC National Accelerator Laboratory, in US. "The ESRF allowed us to study larger quantities of battery particles at higher resolution," says Feng Lin, assistant professor at Virginia Tech. Complementary experiments, in particular nano-resolution X-ray spectro-microscopy, took place at SLAC.

"Hard X-ray phase contrast nano-tomography showed us each particle at remarkable resolution across the full electrode thickness. This allowed us to track the level of damage in each of them after using the battery. Around half of the data from the paper came from the ESRF," explains Yang Yang, scientist at ESRF and first author of the paper.



Hard X-ray phase contrast tomography, capable of nano-probing thousands of active particles at once, enables an unprecedented statistical analysis of the chemomechanical transformation of composite electrodes under fast charging conditions. Credit: P. Cloetens.

"Before the experiments we didn't know we could study these many particles at once. Imaging individual active battery particles has been the focus of this field. To make a better battery, you need to maximize the contribution from each individual particle," says Yijin Liu, scientist at SLAC.

The Virginia Tech lab manufactured the materials and batteries, which were then tested for their charging and degradation behaviors at the ESRF and SLAC. Kejie Zhao, assistant professor at Purdue University, led the computational modelling effort in this project.

The findings from this publication offer a diagnostic method for the particles utilization and fading in batteries. "This could improve how industry designs electrodes for fast-charging batteries," concludes Yang.

More information: Yang Yang et al, Quantification of Heterogeneous Degradation in Li-Ion Batteries, *Advanced Energy Materials* (2019). DOI: 10.1002/aenm.201900674

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