New insight into battery charging supports development of improved electric vehicles

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A new technique developed by researchers at Technische Universität München, Forschungszentrum Jülich, and RWTH Aachen University, published in Elsevier's *Materials Today*, provides a unique insight into how the charging rate of lithium ion batteries can be a factor limiting their lifetime and safety.

State-of-the-art lithium ion batteries are powering a revolution in clean transport and high-end consumer electronics, but there is still plenty of scope for improving charging time. Currently, reducing charging time by increasing the charging current compromises battery lifetime and safety.

"The rate at which lithium ions can be reversibly intercalated into the graphite anode, just before lithium plating sets in, limits the charging current," explains Johannes Wandt, PhD, of Technische Universität München (TUM).

Lithium ion batteries consist of a positively charged transition metal oxide cathode and a negatively charged graphite anode in a liquid electrolyte. During charging, lithium ions move from the cathode (deintercalate) to the anode (intercalate). However if the charging rate is too high, lithium ions deposit as a metallic layer on the surface of the anode rather than inserting themselves into the graphite. "This undesired lithium plating side reaction causes rapid cell degradation and poses a safety hazard," Dr. Wandt added.

Dr. Wandt and Dr. Hubert A. Gasteiger, Chair of Technical

Electrochemistry at TUM, along with colleagues from Forschungzentrum Jülich and RWTH Aachen University, set out to develop a new tool to detect the actual amount of lithium plating on a graphite anode in real-time. The result is a technique the researchers call operando electron paramagnetic resonance (EPR).

"The easiest way to observe lithium metal plating is by opening a cell at the end of its lifetime and checking visually by eye or microscope," said Dr. Wandt. "There are also nondestructive electrochemical techniques that give information on whether lithium plating has occurred during battery charging."

Neither approach, however, provides much if any information about the onset of lithium metal plating or the amount of lithium metal present during charging. EPR, by contrast, detects the magnetic moment associated with unpaired conduction electrons in metallic lithium with very high sensitivity and time resolution on the order of a few minutes or even seconds.

"In its present form, this technique is mainly limited to laboratory-scale cells, but there are a number of possible applications," explains Dr. Josef Granwehr of Forschungzentrum Jülich and RWTH Aachen University. "So far, the development of advanced fast charging procedures has been based mainly on simulations but an analytical technique to experimentally validate these results has been missing. The technique will also be very interesting for testing battery materials and their influence on lithium metal plating. In particular, electrolyte additives that could suppress or reduce lithium metal plating."

Dr. Wandt highlights that fast charging for electric vehicles could be a key application to benefit from further analysis of the work.

Until now, there has been no analytical technique available that can directly determine the maximum charging rate, which is a function of the state of charge, temperature, electrode geometry, and other factors, before lithium metal plating starts. The new technique could provide a much-needed experimental validation of frequently used computational models, as well as a means of investigating the effect of new battery materials and additives on lithium metal plating.

The researchers are now working with other collaborators to benchmark their experimental results against numerical simulations of the plating process in simple model systems.

"Our goal is to develop a toolset that facilitates a practical understanding of lithium metal plating for different battery designs and cycling protocols," explains Dr. Rüdiger-A. Eichel of Forschungzentrum Jülich and RWTH Aachen University.

More information: Johannes Wandt et al, Quantitative and time-resolved detection of lithium plating on graphite anodes in lithium ion batteries, *Materials Today* (2017). DOI: 10.1016/j.mattod.2017.11.001

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