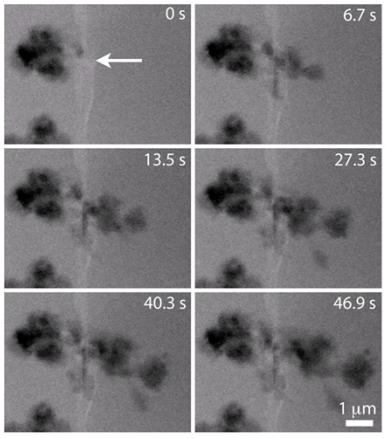
Watching what happens in an operating battery, at the nanoscale



Time-lapse electron microscopy images showing the nucleation and growth of lithium dendrites during battery operation.

Work was performed as User Project at the Center for Nanophase Materials Sciences.

Scientific Achievement

A new microscopy technique (*in situ* electrochemical scanning transmission electron microscopy, or *in situ* ec-S/TEM) allows scientists to observe how the components of a Li-ion battery change while the battery is used.

Significance and Impact

The performance of a Li-ion battery is intrinsically linked to how internal components change during cycling. Being able to observe these changes will lead to ways to control them.

Research Details

- The formation of a solid electrolyte interphase (SEI), the changes in its density, and the nucleation and growth of Li features (dendrites) were observed with *in situ* ec-S/TEM.
- Simultaneous electrochemical measurements were performed on the sample being imaged.

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Narrative Highlight Text:
Lithium dendrite formation is a major safety concern existing in Li-ion and Li-metal batteries. *In situ* ec-S/TEM (a liquid cell electron microscopy based characterization method) is used to perform linear sweep voltammetry to induce solid electrolyte interphase (SEI) formation and stimulate lithium electrodeposition from a standard, aprotic organic Li-ion battery electrolyte. We directly observe the formation of the SEI and preferential nucleation and growth of Li metal dendrites (on the surface and edge of a thin, electron transparent, glassy carbon working electrode) simultaneously with performing quantitative electrochemical measurements and acquiring bright field (BF) and annular dark field (ADF) STEM images. From BF STEM and the chemically sensitive ADF STEM, we quantify the expected contrast mechanisms of light elements (such as Li) within the liquid cell (filled with 1.2M $LiPF_6$ EC:DMC). This work demonstrate that the *in situ* ec-S/TEM approach is capable of quantifying chemical and electrochemical reactions, *in operando,* and at the nanoscale. This approach is widely applicable to study the fundamental mechanisms involved in the functionality of electrochemical energy storage and storage systems such as batteries, fuel cells, and supercapacitors.

Image: Annular dark field STEM during electrodeposition from a 1.2M $LiPF_6$ EC:DMC electrolyte.

Reference:
"Nanoscale Imaging of Fundamental Li Battery Chemistry: Solid-Electrolyte Interphase Formation and Preferential Growth of Lithium Metal Nanoclusters,"
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