Prof. Matthew McDowell's Research Group

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Goals and Motivation

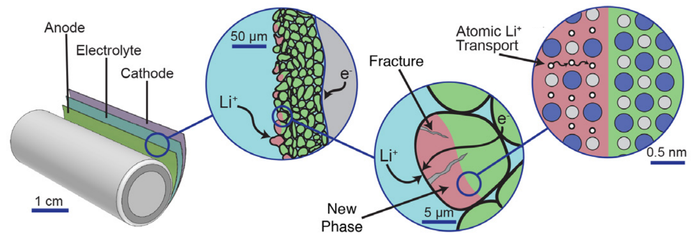
Dynamic materials processes are at the heart of many energy and electronics technologies.

Batteries for portable/grid energy storage

Electric flight

Electric vehicles

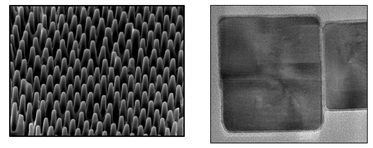
It is critical to understand materials dynamics for better devices.

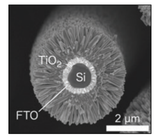


Materials transformations across length scales

Research Theme: **Use real-time experiments to understand how materials behave in energy and electronic devices for improved performance.**

Materials Synthesis





In Situ Characterization

Synchrotron

TEM

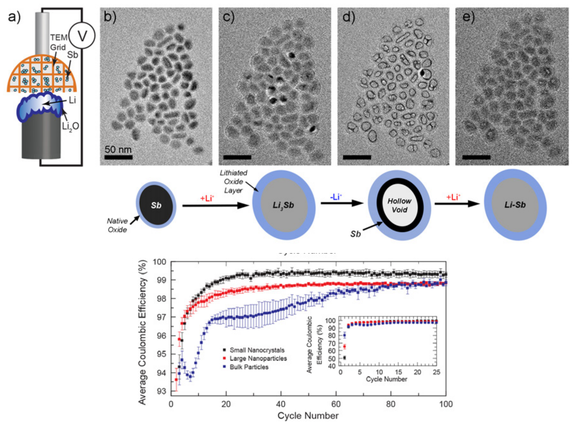
X-rays

Devices

1: Investigating Transformations in Battery Materials

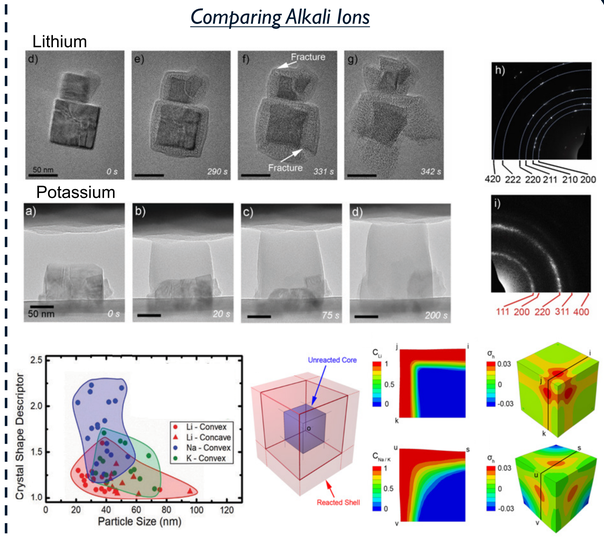
Goal: Develop and use *in situ* techniques to probe reaction mechanisms *in real time* in lithium-, sodium-, and potassium-ion batteries from the nanoscale to the mesoscale.

In *situ* transmission electron microscopy (TEM)



M. Boebinger *et al., Nature Nanotechnology,* (2020) 15, 475-481.

Comparing Alkali Ions

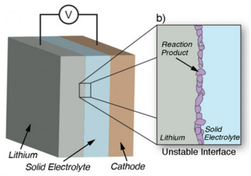


M. Boebinger *et al., Joule,* (2018) 2(9), 1783-1799.
G. Nava *et al. Nano Lett.* (2019) 19, 10, 7236-7245.
M. Boebinger *et al., J. Mater. Chem. A,* (2019) 5 (23) , 11701-11709

2: Stabilizing Interfaces in Solid-State Batteries

Goal: Enable solid-state alkali metal batteries by controlling and understanding transformations/degradation at interfaces.

Solid-state batteries could have very high energy density, but reactions and degradation at interfaces (between electrodes and solid-state electrolyte) decrease performance.

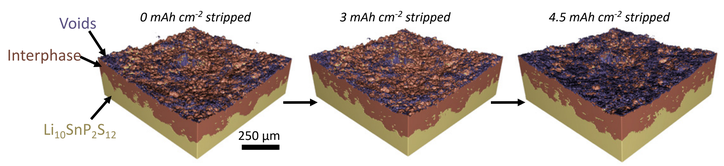


Objectives:

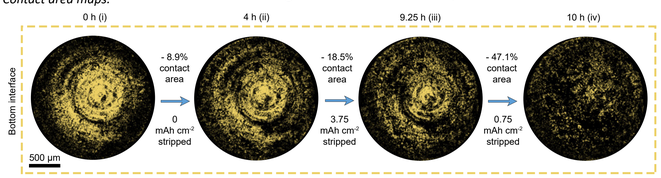
1. Understand and control interphase formation at solid-state battery interfaces
2. Understand chemo-mechanical evolution of solid-state batteries

J. Lewis *et al. Trends in Chem.,* 2019, 1, 9, 845-857.
J. Lewis, *et al. ACS Energy Lett.,* 2019, 4, 2, 591-599.

X-ray tomography for understanding batteries



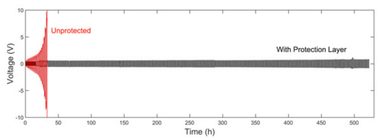
Void growth at the lithium interface



J. Lewis *et al. Nature Materials, 2020,* In Press

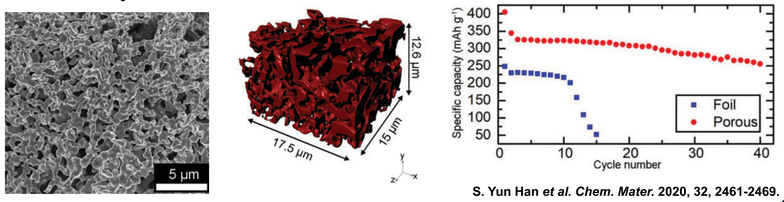
J. Tippens *et al. ACS Energy Lett.,* 2019, 4, 1475-1483

Engineering interfaces for solid-state batteries



F. Cortes, *et al. J. Electrochem. Soc.* 2019, 167, 5, 050502.

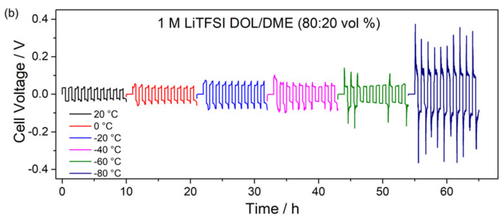
Structured Alloy Anodes

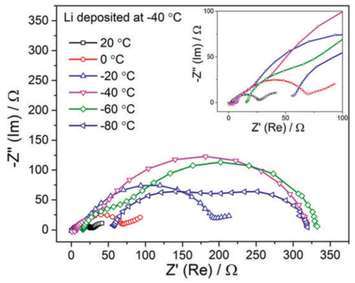


S. Yun Han *et al. Chem. Mater.* 2020, 32, 2461-2469.

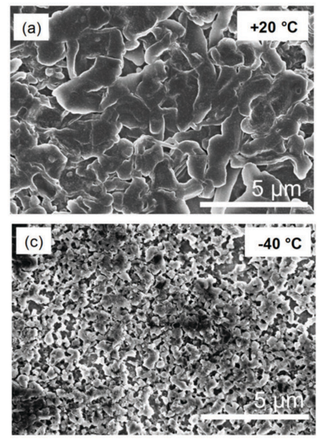
3: Low-Temperature Batteries

Enabling low-temperature operation of lithium metal electrodes by tailoring electrolytes and controlling electrodeposition





Lithium morphology and cycling efficiency strongly correlated to temperature

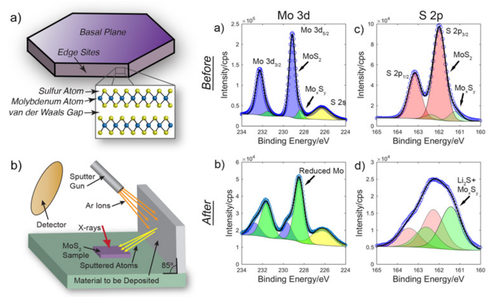


A. Thenuwara *et al. Nano Lett.,* 2019, 19, 12, 8664-8672.
A. Thenuwara *et al. ACS Energy Lett.* 2020, 5, 2411-2420

4: Transformations in Layered Electronic and Catalytic Materials

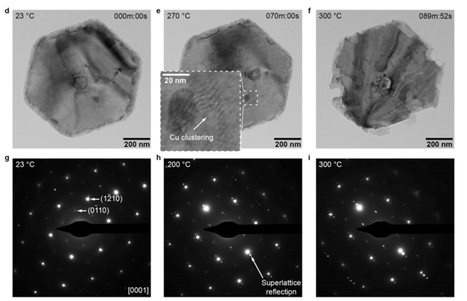
Goal: Controlled synthesis and characterization of metal-TMDC interfaces for superior electronic and catalytic properties.

In situ XPS to investigate transformations at MoS_2 interfaces



N. Kondekar, et al. *ACS Appl. Mater. Interfaces*, (2017) 9, (37), 32394-32404.
N. Kondekar *et al. ACS Nano*, 2019, 13, 6, 7117-7126.

Nanoscale transformations in layered materials



P. Shetty *et al., Matter* (2020), 3, 4, 1246-1262.

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