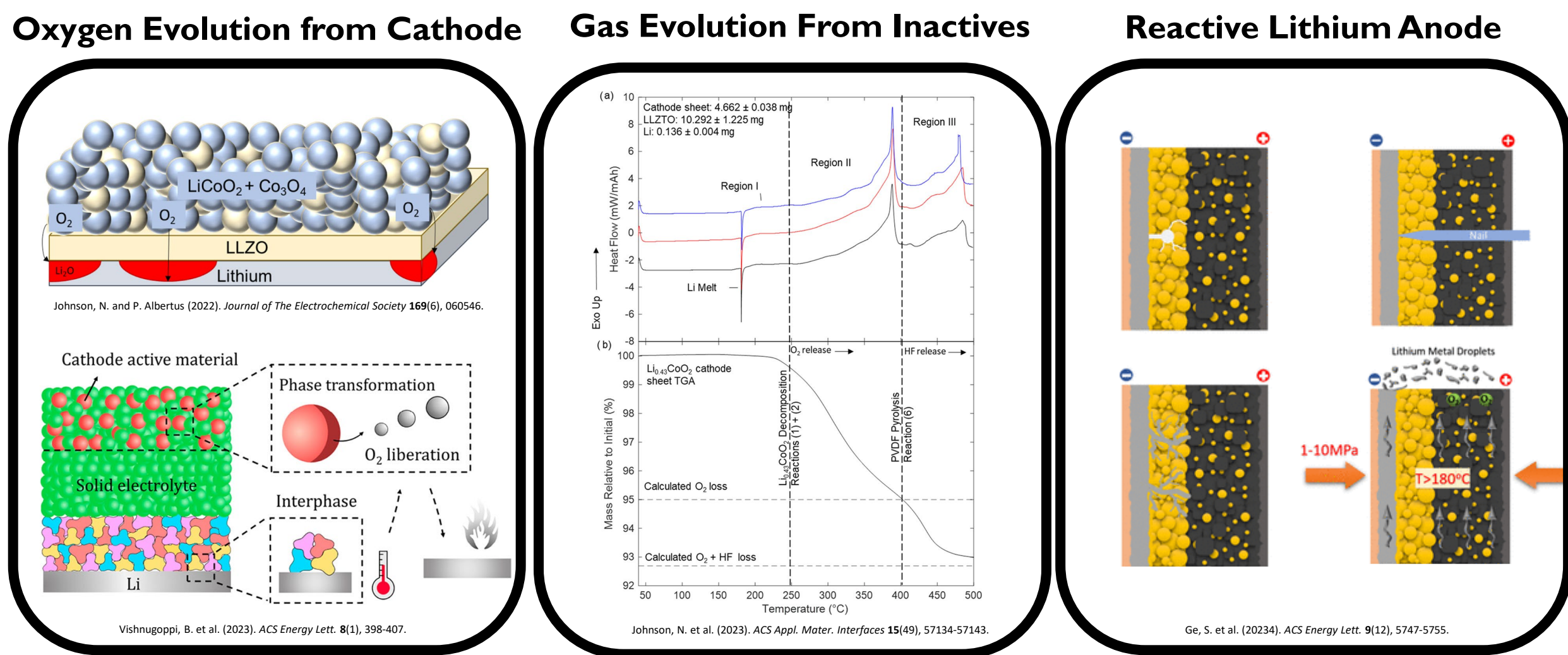




# ARE SOLID-STATE BATTERIES NON-FLAMMABLE? IDENTIFYING LITHIUM THERMITE REACTIONS

Drs. Nathan Brenner Johnson, Alex Bates, and Loraine Torres-Castro

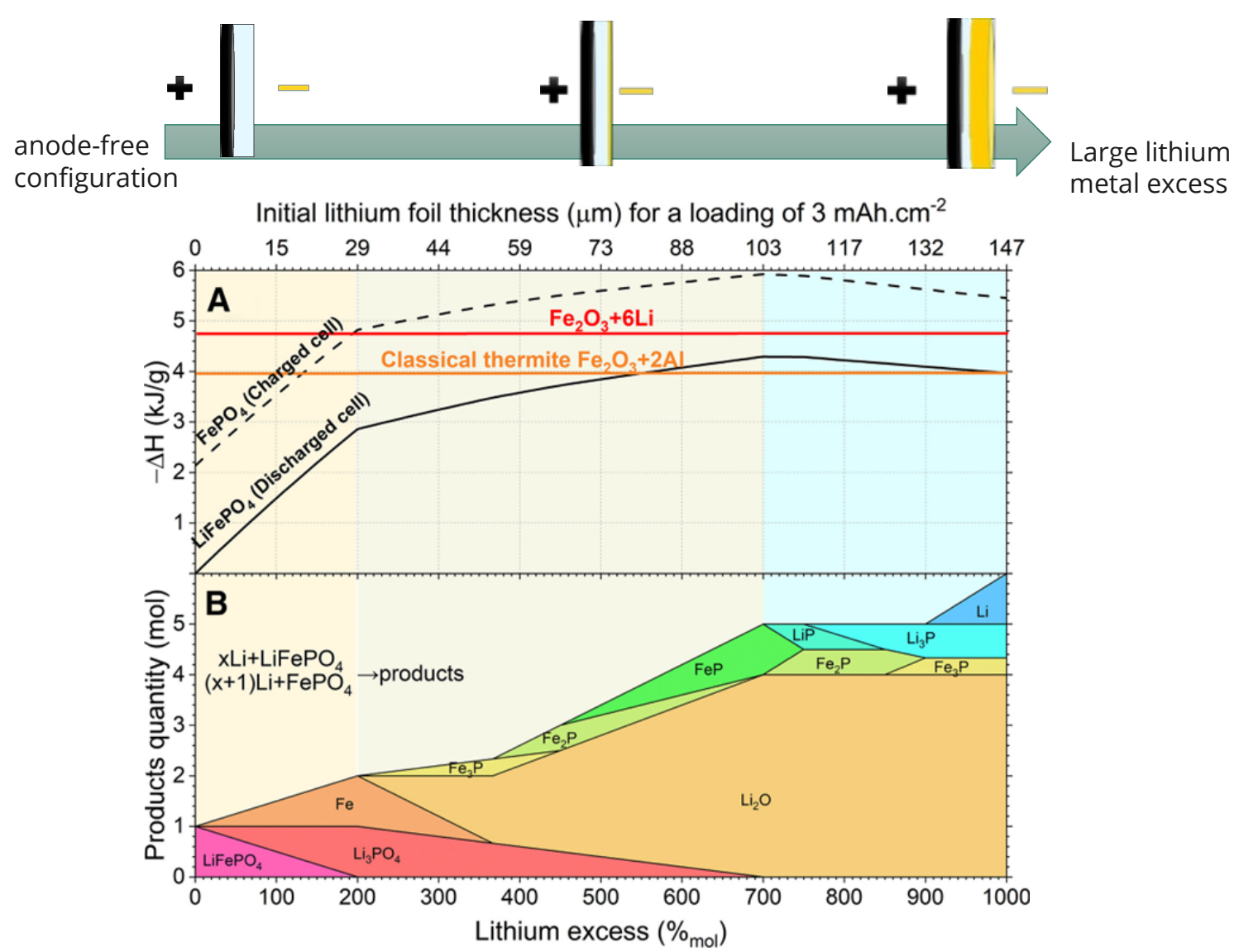
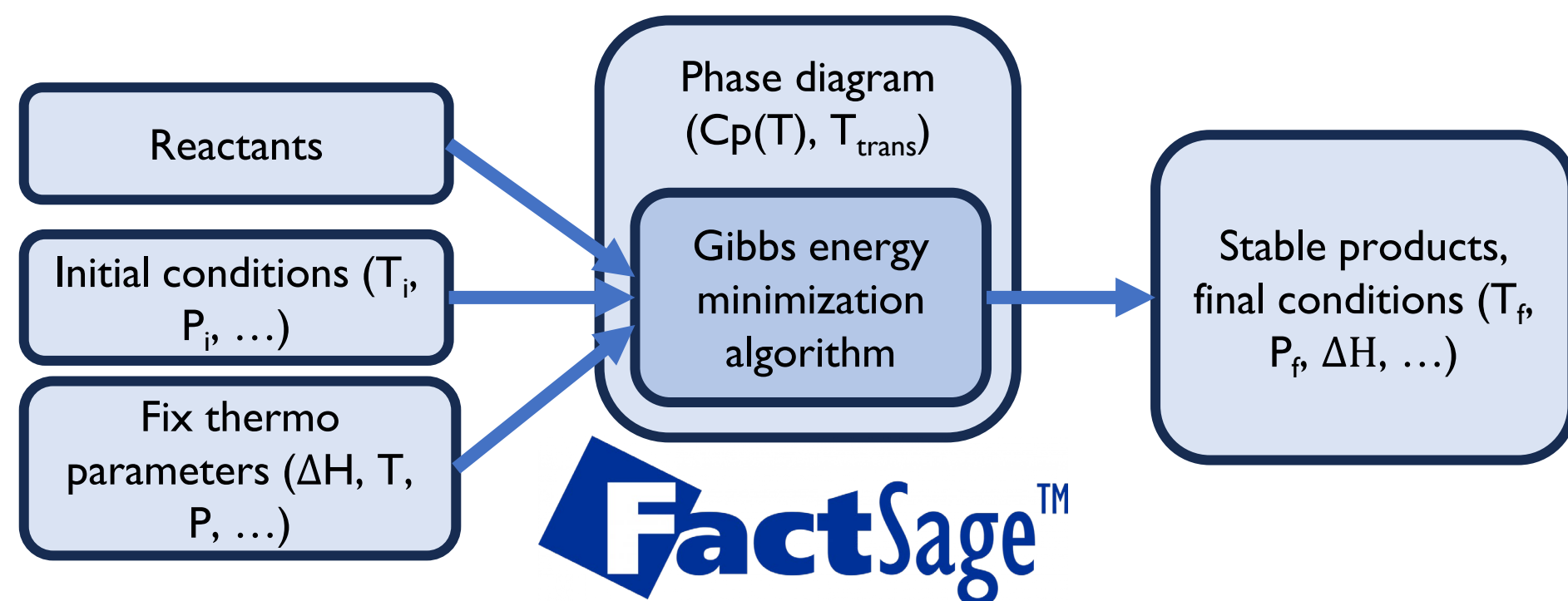
## Motivation



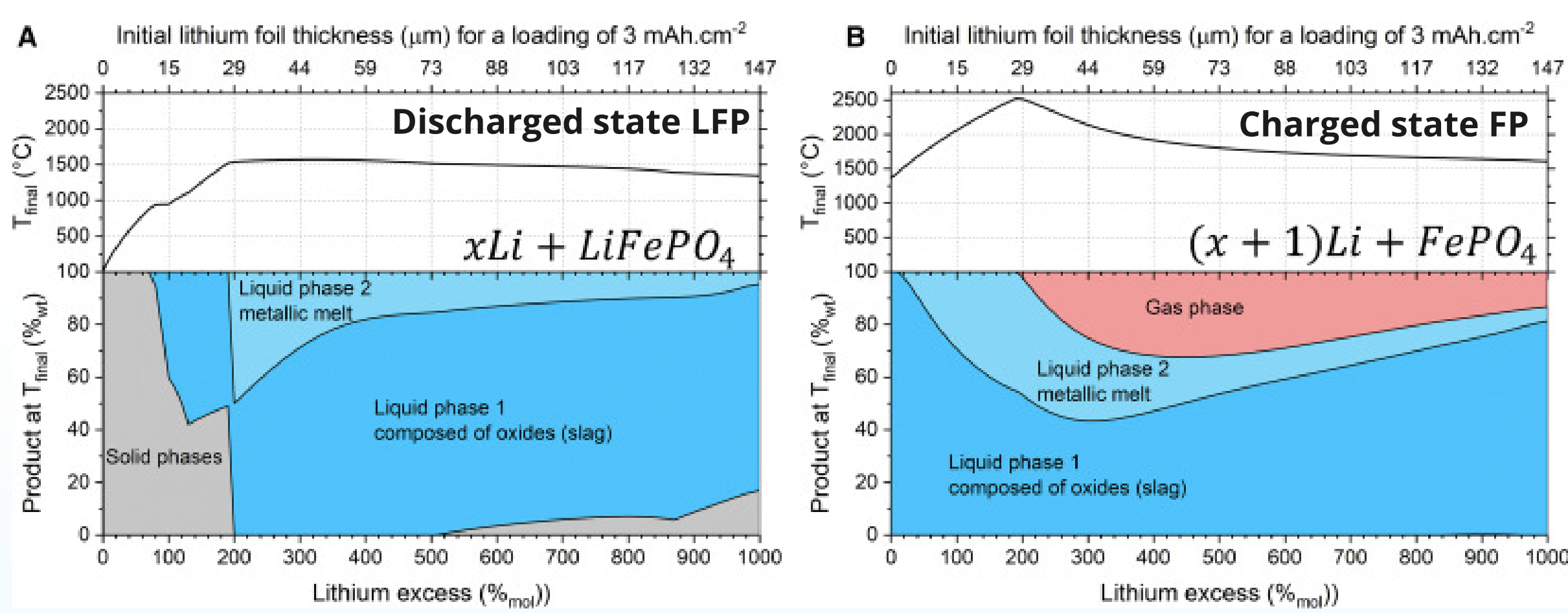
- Previously unconsidered safety hazards of solid state batteries (SSBs) are emerging.
- Current literature considers reactions of the anode with gasses and the electrolyte.
- Cathode-anode contact is the most common form of short-circuit. (e.g. dendrites, separator failure, etc.)

**Key Question:** What safety risks occur when lithium contacts the cathode?

## Thermodynamic Modeling

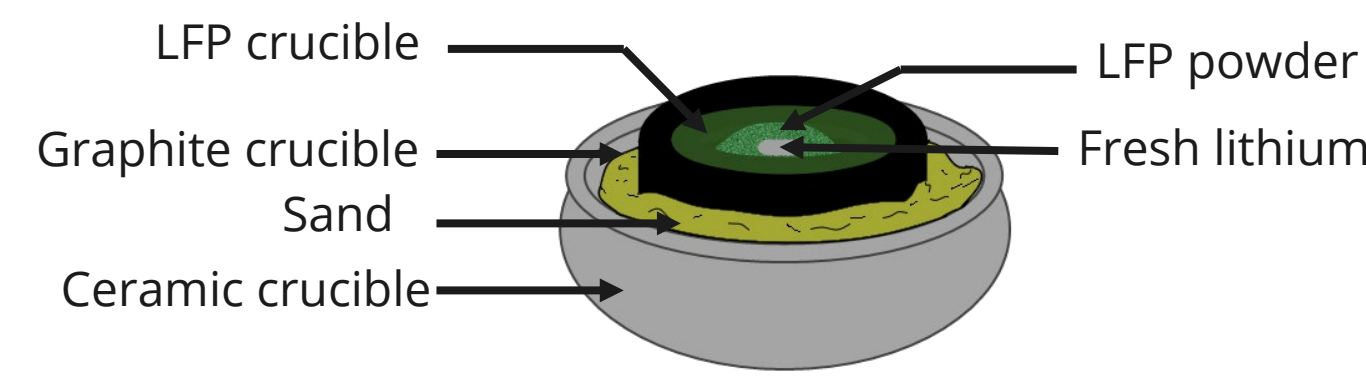


- Thermite reaction is spontaneous at room temperature
- Can react in the charged or discharged state
- Introduction of external oxygen can further increase heat flow >700% excess lithium
- Gibbs energy minimization determines phase diagram

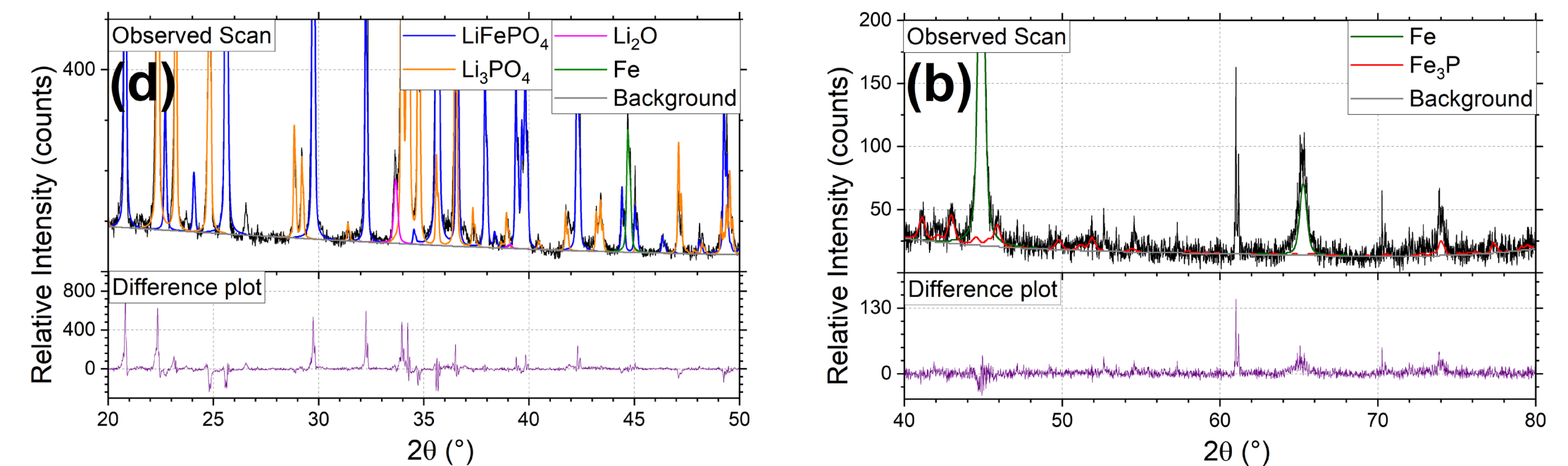
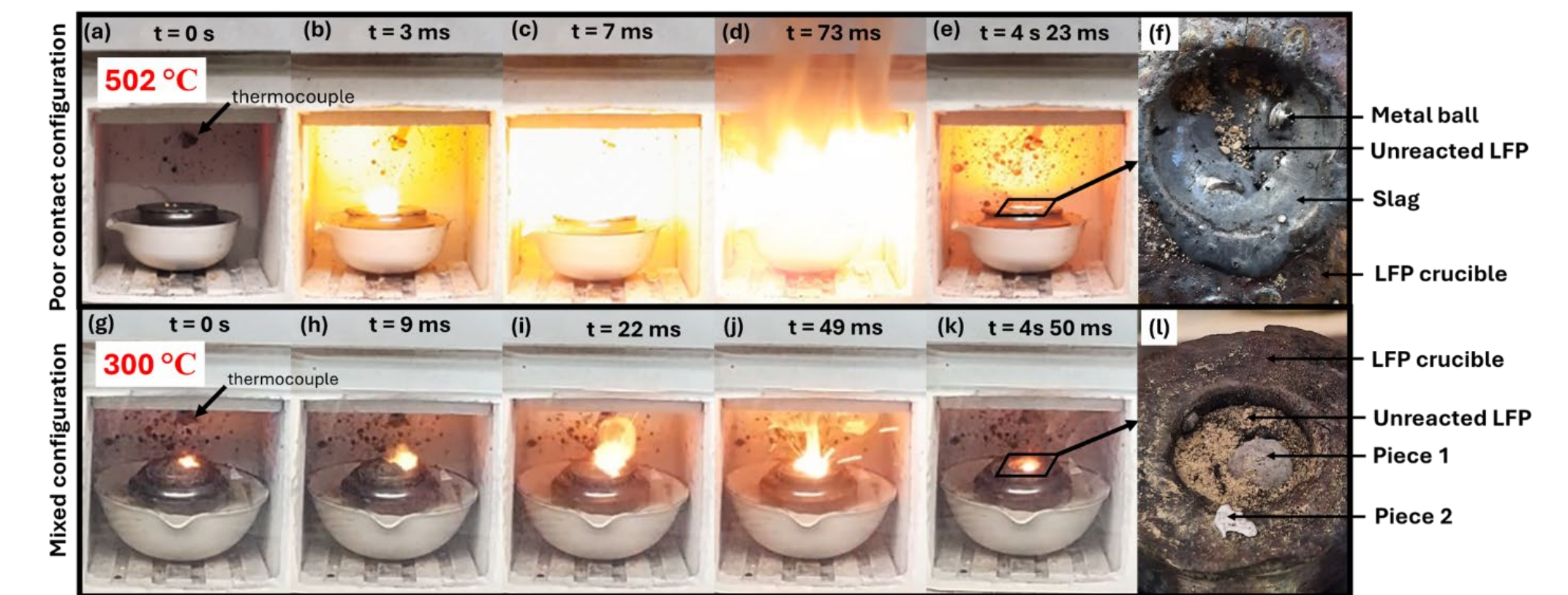


- Discharged and charged state both surpass boiling point of lithium ( $1342^{\circ}\text{C}$ ) at 200% excess lithium
- Decrease in temperature >200% excess is from endothermic phase transitions
- Assumes a closed system with no external oxygen

## Oven Test

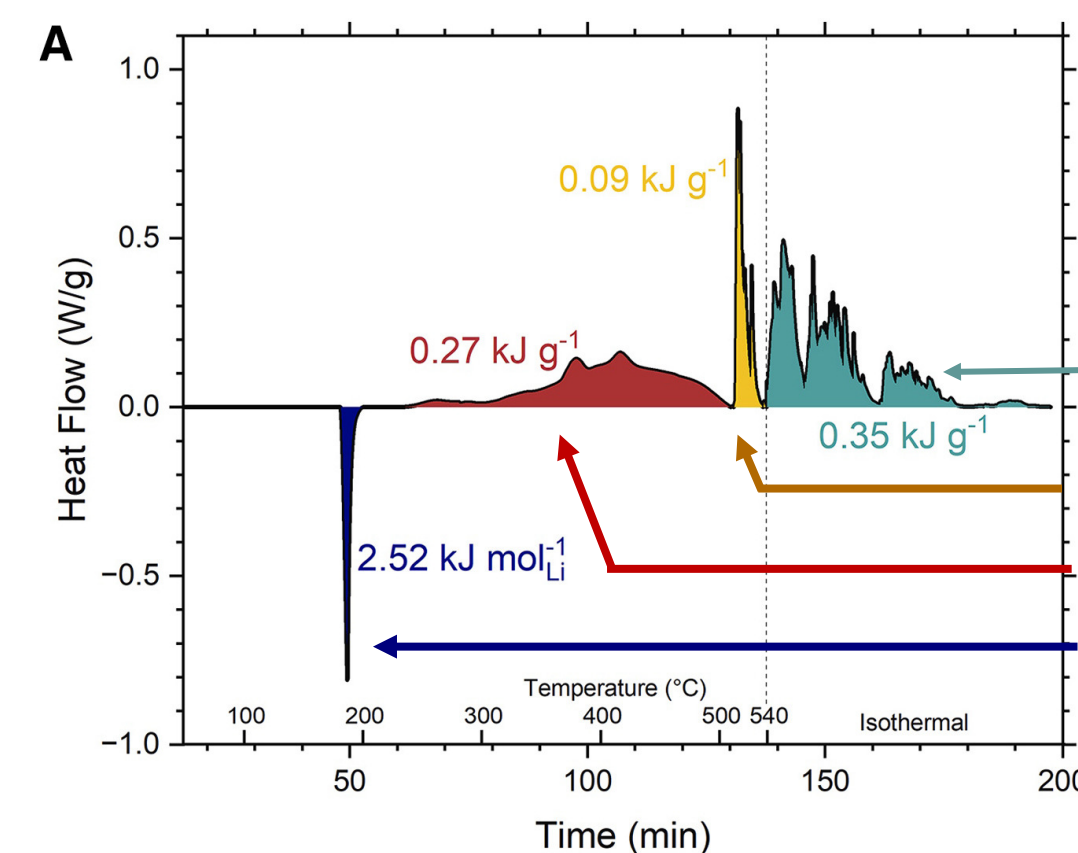


- Dry LFP powder and lithium put in an oven
- $\text{O}_2 < 0.2\text{ppm}$ , no solvents present in glovebox
- Two test: poor surface contact, and hand-mixed Li/LFP



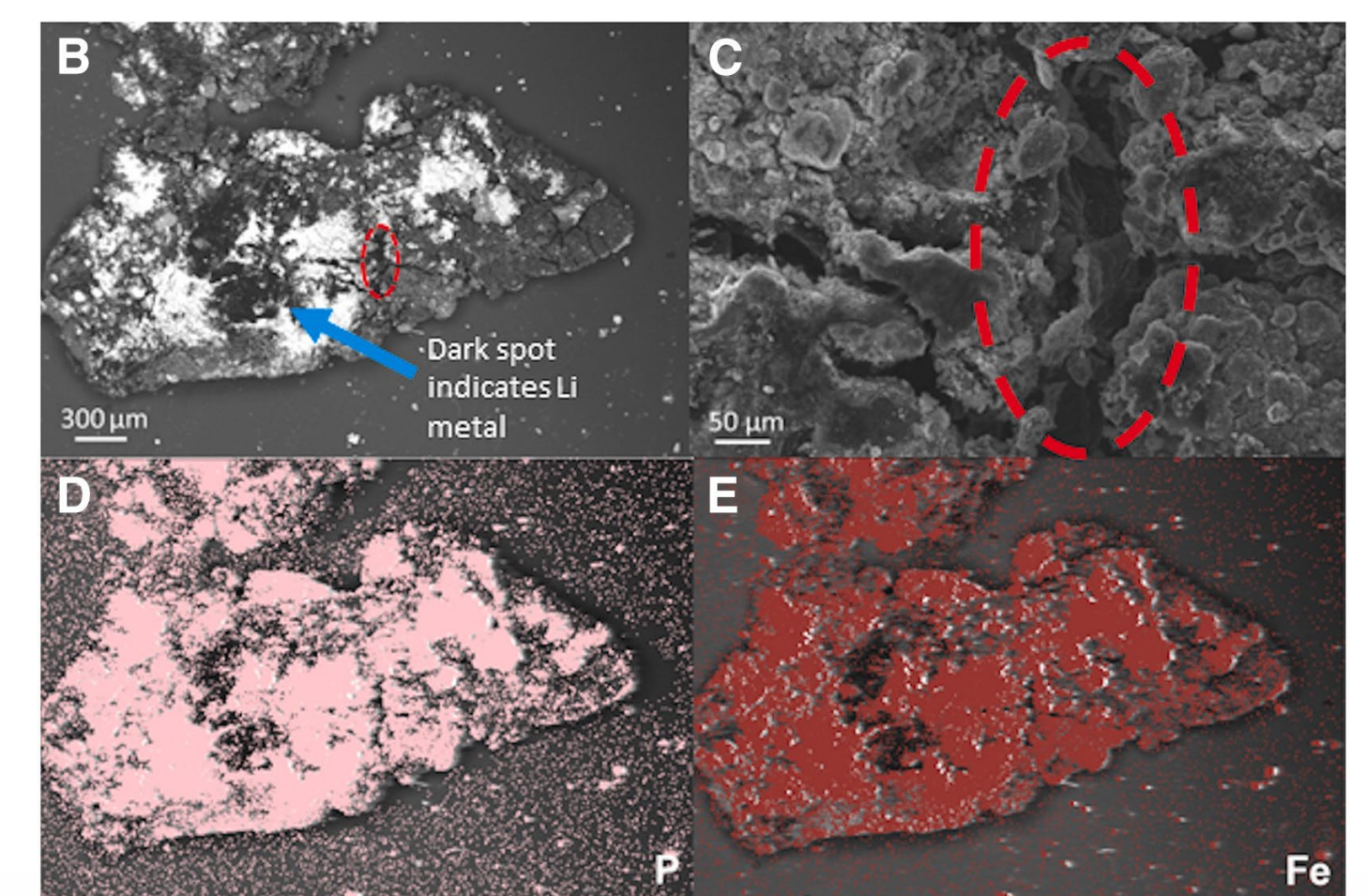
XRD confirms the presence of calculated thermite products

## Materials Scale Analysis

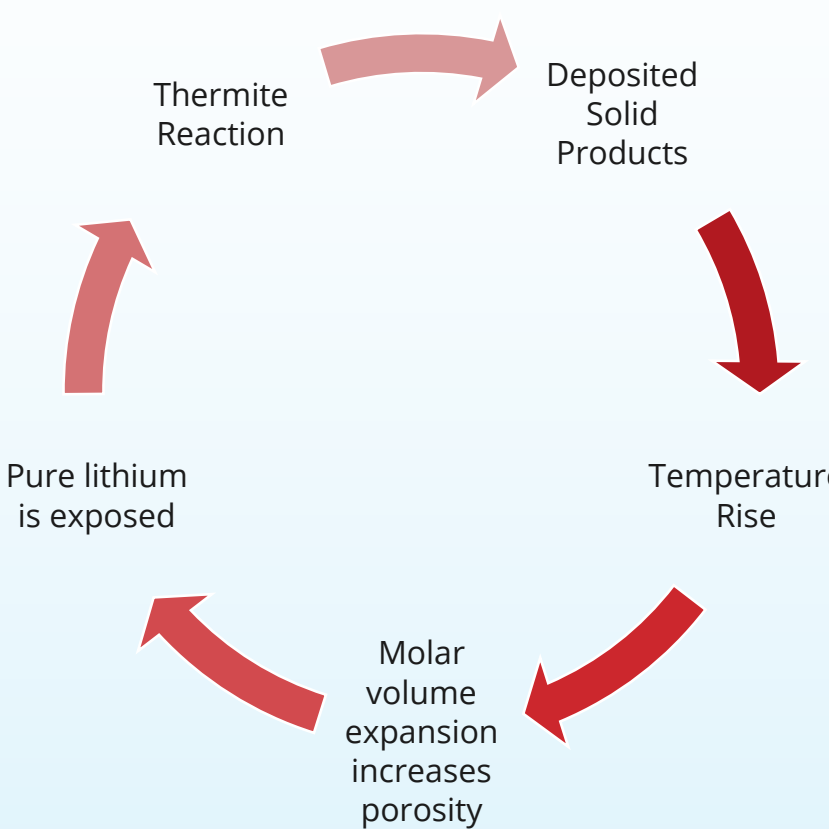


- DSC testing corroborates oven test
- Thermite burns for >1hr
- Kinetically fast and transport limited

- Fe-, P-, and O-rich crust present post-test
- Fresh lithium underneath
- Heat dissipation results in incomplete reaction
- Highly localized and inhomogeneous reaction



## Key Takeaways



- Lithium thermite reactions can ignite flames without flammable solvents
- Maximum adiabatic temperature reaches  $2500^{\circ}\text{C}$
- Transport limitations create large heterogeneity
- Heat dissipation can slow reaction, but adds risk of long burn times and reignition

