National Aeronautics and Space Administration

Atomic Layer Deposition Coatings for Solid-State Lithium Metal Batteries

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Project Objective:

Develop robust coatings for lithium metal towards an all solid state battery

- Fabricate and characterize fluoride coated Li-metal
- Electrochemically analyze coated Li-metal
- Develop new procedure to coat solid Li-ion conductor on Li-metal
- Develop two iterations of solid state cells

Benefits to NASA and JPL (or significance of results):

- Solid state Li-metal rechargeable batteries enable:
  - Size and mass-critical applications (cubesats, landers, aerial vehicles)
  - High radiation tolerance (i.e. Europa)
  - High temperature tolerance (Venus and Mercury)
  - Long duration (1,000s of cycles)
- Smaller, more robust spacecraft power systems potentially integrated with other electronics
- Li-ion state of the art ~250 Wh/kg, 600 Wh/L at the cell level
- Solid state Li-metal cells are predicted to achieve ~400 Wh/kg & 800 Wh/L

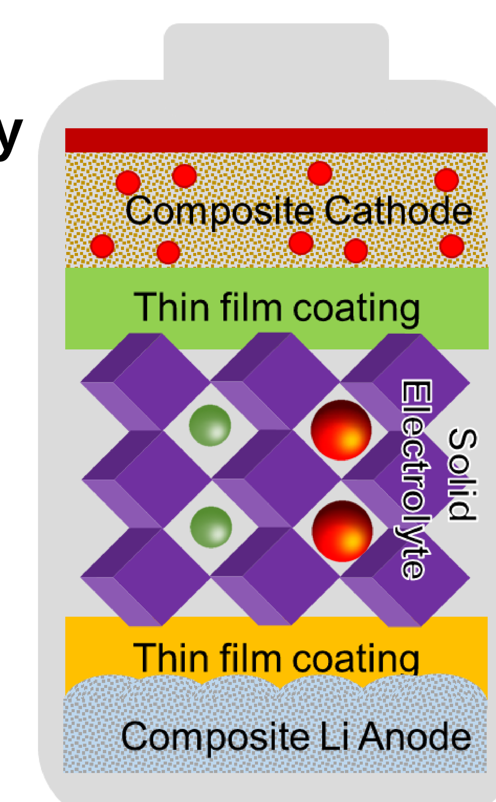
FY19 Results:

- **Demonstrated AlF_3-coating improves lithium stability**
- Successfully deposited thin films on lithium metal
  - AlF_3
  - Al_2O_3
  - $Al_2O_3 + AlF_3$
  - LiF
  - Li_3AlF_6
- Optimized ALD technique for AlF_3 coatings with respect to:
  - Number of cycles
  - Temperature of deposition
  - Different aluminum and fluorine precursors
- Developed electrochemical impedance spectroscopy (EIS) method to rapidly test coated samples
- Analyzed coatings using grazing incidence XRD (SEM and XPS underway)
- Fabricated shadow masks to directly measure conductivity of solid state lithium ion conductors

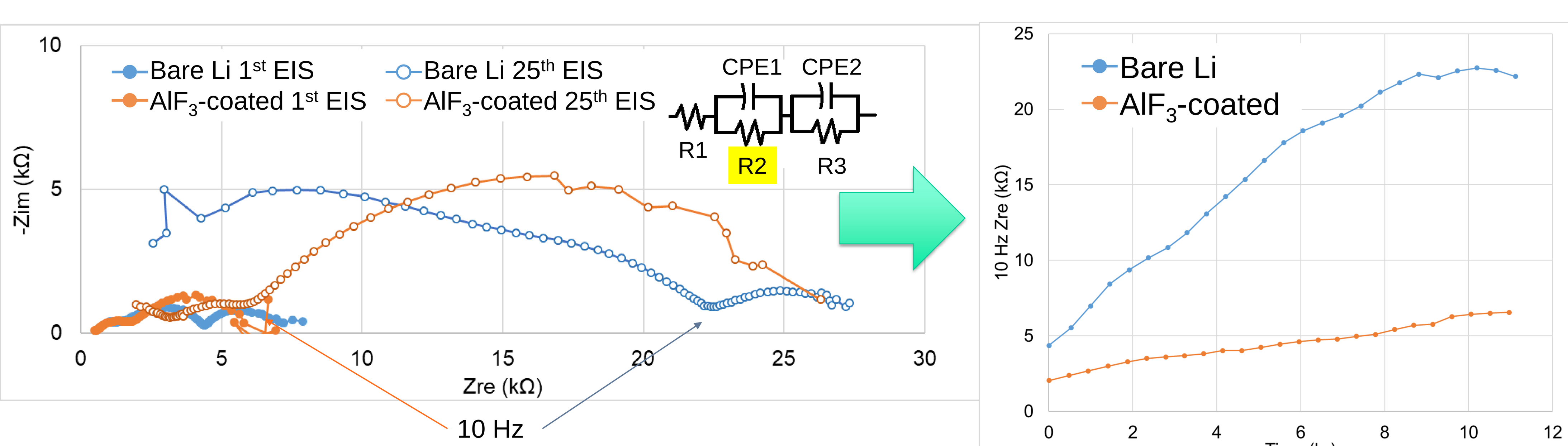
Solid State Li-metal rechargeable battery

Thin film coatings enable lithium metal and solid electrolytes

Extremely thin solid electrolytes enabled via ALD techniques

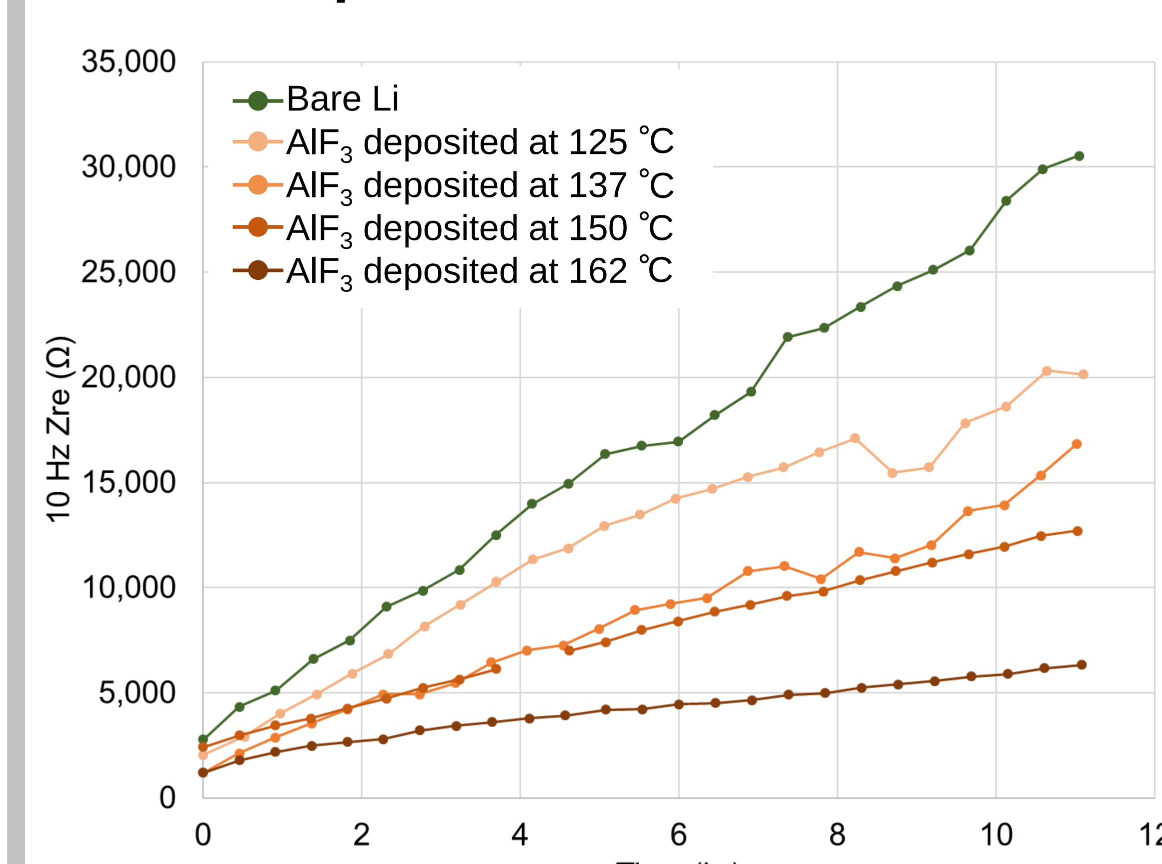


Electrochemical Impedance Spectroscopy Results:



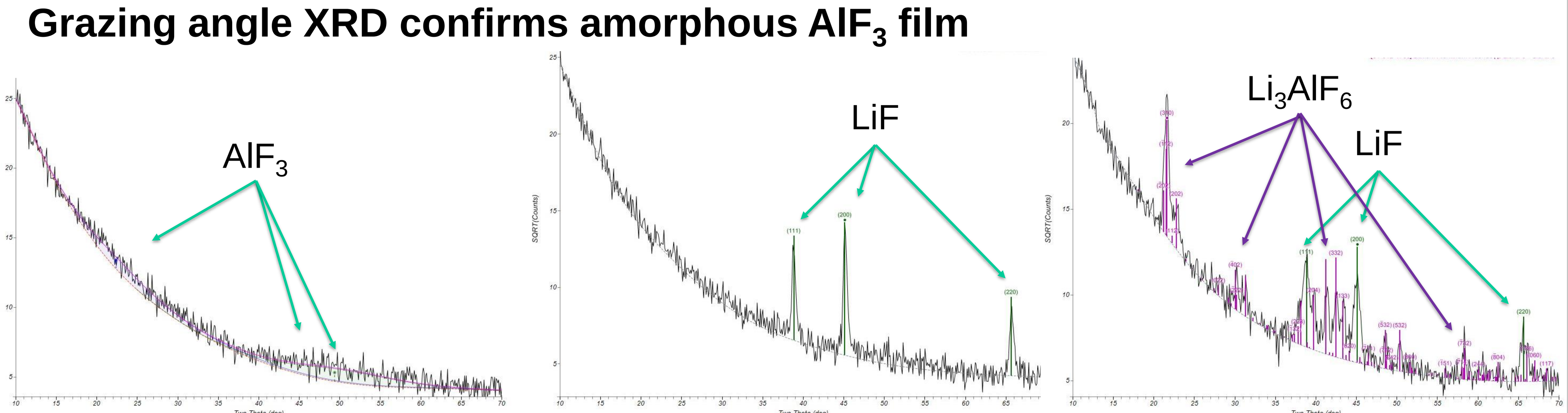
- Directly probe film on electrode surface
- Reduced film growth with AlF_3-coated lithium metal in reactive (1.0 M $LiPF_6$ in acetonitrile) electrolyte
- Rapidly screen samples to inform future experiments

ALD temperature most critical factor



- Higher temperatures not accessible because lithium melts at 180 ° C
- Film thickness and precursor identity not as important to film quality as deposition temperature

Grazing angle XRD confirms amorphous AlF_3 film



Publications:

"Atomic Layer Deposition of Aluminum Fluoride for Lithium Metal Anodes" manuscript in preparation

NTR 50951: aluminum fluoride coating for lithium metal

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