Virtual Research Presentation Conference

Atomic Layer Deposition Coatings for Solid-State Lithium Metal Batteries

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Program: Topical RTD

Assigned Presentation # RPC-235

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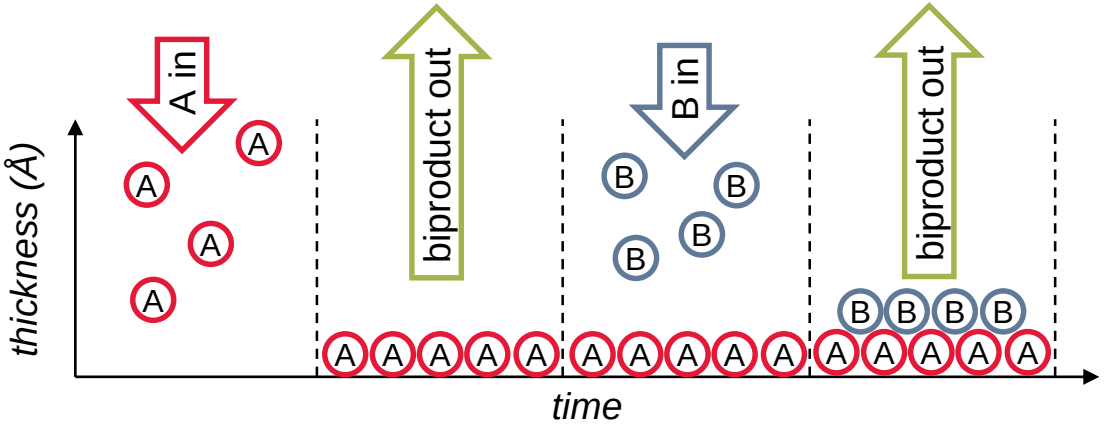
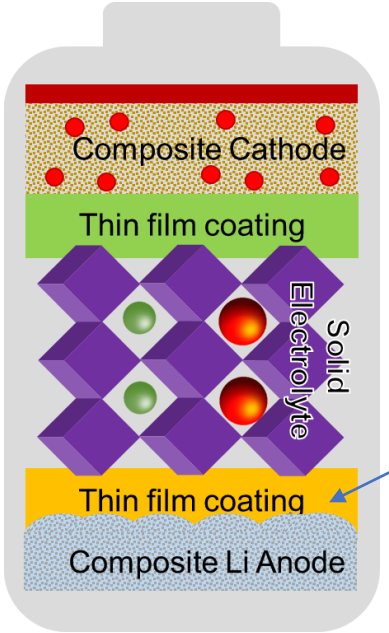
Tutorial Introduction

- Atomic layer deposition (ALD) is a powerful tool for producing atomically precise, nm-thick coatings
- Next generation “beyond Li-ion” batteries will use lithium metal anodes
- No current electrolyte system can support long term rechargeable lithium anodes due to high reactivity and dendrite formation
- We are targeting a thin coating which could interface between the conductive electrolyte and reactive lithium metal anode





Targeting anode film

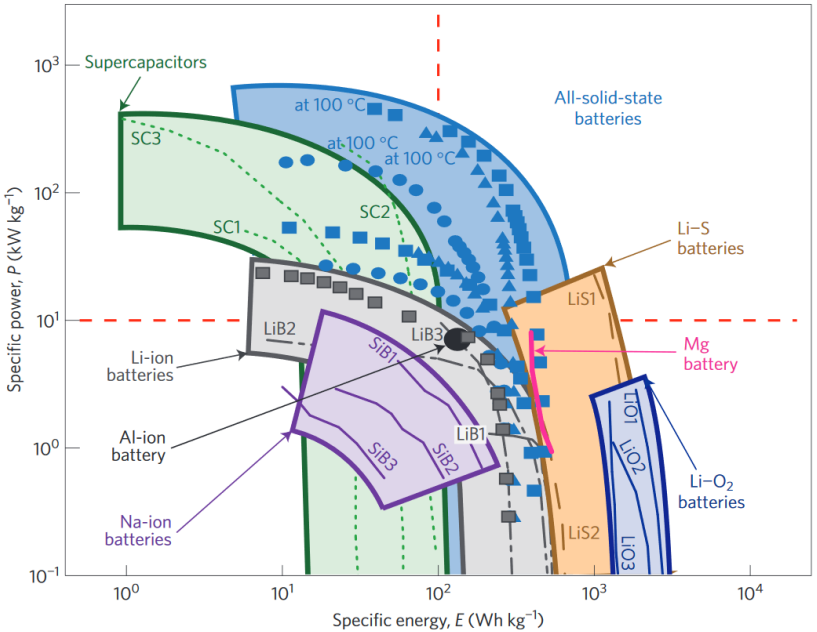
Problem Description

a) Future missions like the Mars Helicopter have pushed the limits of what is achievable using conventional Li-ion batteries

b) Specific energy and specific power must improve for missions like this to be successful

c) Li-ion technology has plateaued, and is unlikely to improve significantly in the future

d) Rechargeable lithium metal batteries provide a potential breakthrough in specific energy and specific power



Y. Kato et al., Nat. Energy. *1* (**2016**) 1–7. doi:10.1038/nenergy.2016.30.

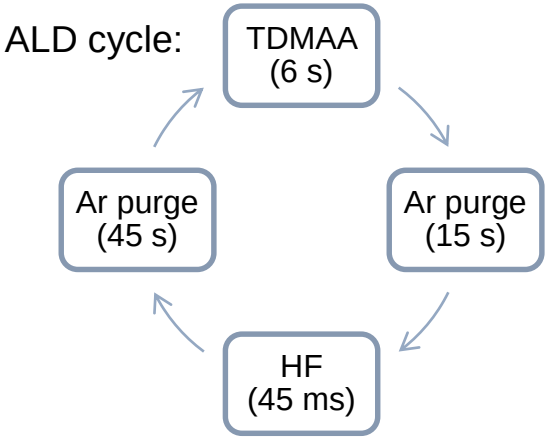
Methodology

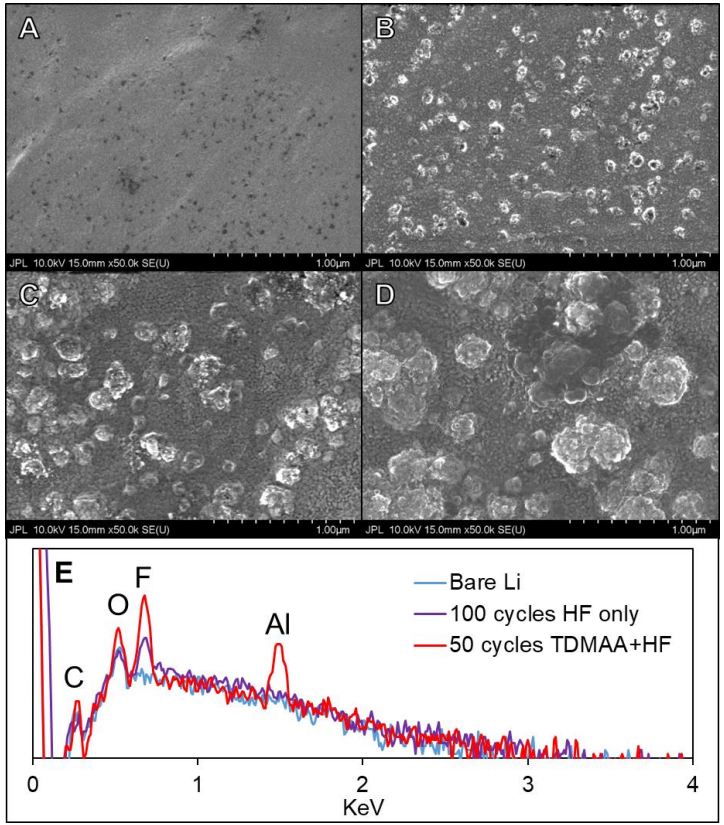
a) Develop and optimize coatings (AlF_3, LiF, Li_xAlF_y) for lithium metal

b) Analyze coatings using a variety of techniques: GIXRD, SEM, EDS, EIS

c) Test coated lithium in coin cells using liquid electrolyte

d) Build two iterations of solid state cells





SEM images of bare lithium foil (A) lithium coated with 20 (B) 50 (C) and 100 (D) cycles of AlF_3 at 162 °C. Overlaid EDS spectra of bare lithium, 100 cycles of HF only, and 50 cycles of TDMAA and HF at 162 °C (E).

Results

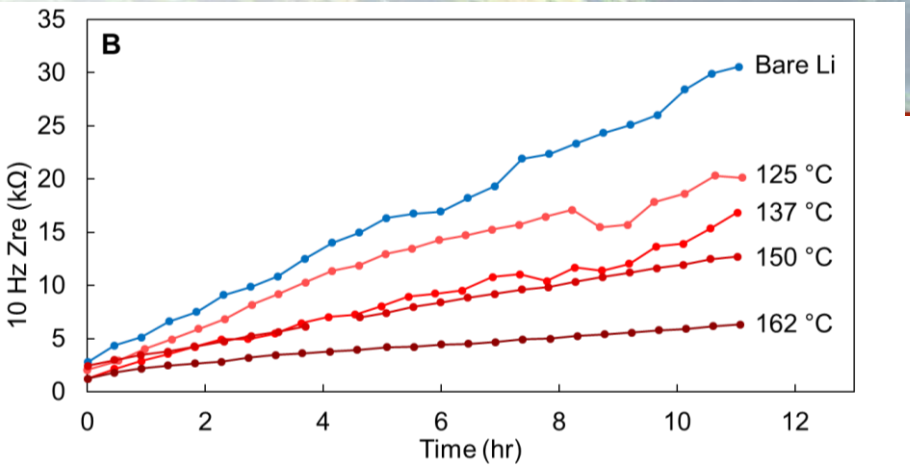
a) Demonstrated effective coating of AlF_3, LiF and Li_3AlF_6 directly on lithium metal
   a) GIXRD indicates AlF_3 films are amorphous
   b) SEM images show development of nodules of AlF_3 decorating the surface
   c) Nodules increase in size with increasing number of ALD cycles
   d) EDS analysis shows expected film composition on both smooth surfaces and nodules

b) Demonstrated drastic improvement in reactivity of AlF_3-coated lithium towards acetonitrile-based electrolyte by EIS
   a) Coating at higher temperature produces more protective film

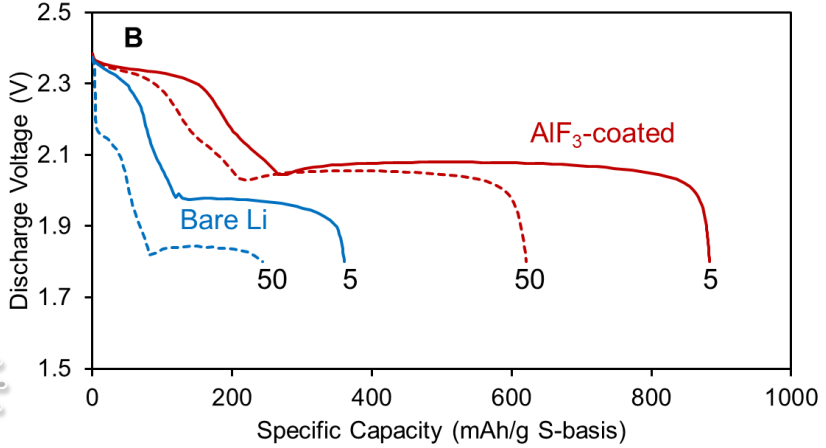
c) AlF_3-coated Li/S cells demonstrate significant capacity improvement and capacity retention compared to bare Li/S cells

d) LiF and Li_3AlF_6 films did not produce improvements in electrochemical systems

e) Solid state cells were fabricated with coated lithium
   a) Cells displayed reasonable voltage, but could not be cycled



10 Hz Z_{re} extracted from EIS data over time for bare lithium and lithium coated with 50 cycles of AlF_3 at 125, 137, 150 and 162 °C. The lines are visual guides.



Discharge traces for cycles 5 (solid lines) and 50 (dotted lines) for bare lithium (red) and AlF_3-coated lithium (blue) cells during cycling.

Publications and References

Publication:

1. John-Paul Jones, John Hennessy, Keith J. Billings, Frederick C. Krause, Jasmina Pasalic, Ratnakumar V. Bugga. “Communication — Atomic Layer Deposition of Aluminum Fluoride for Lithium Metal Anodes” *Journal of the Electrochemical Society*, **2020**, *167*, 060502. DOI:10.1149/1945-7111/ab7c39

References:

1. Kato, Y.; Hori, S.; Saito, T.; Suzuki, K.; Hirayama, M.; Mitsui, A.; Yonemura, M.; Iba, H.; Kanno, R. High-Power All-Solid-State Batteries Using Sulfide Superionic Conductors. *Nat. Energy* **2016**, *1* (4), 1–7. https://doi.org/10.1038/nenergy.2016.30.