Stabilization of High Energy Lithium-ion Cathodes using Nanocomposite Coatings

EE-5A Advanced Manufacturing Office- Next Generation R&D Projects
(Award # TCF-CP-18-15788)

Argonne National Laboratory, IL / Forge Nano, CO

Anil Mane, Jason Croy, Jeffrey Elam, Argonne National Laboratory, IL
Arrelaine Dameron, Forge Nano, CO

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
[June 11-12, 2019]

Overview

Project Title: Stabilization of High Energy Li-ion Cathodes using Nanocomposite Coatings

Timeline:

Project Start Date: 10/01/2018

Budget Period End Date: 09/30/2019

Expected Project End Date: 06/30/2020

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$157,500	$150,000	$307,000	~50%

Barriers and Challenges:

- Limited life performance of Li-ion cells
- Transition metal dissolution during cell cycling
- Finding stable high energy density and long life cathodes
- New cathode materials stability at higher operating voltages (Fast charging application)
- To reduce costs, industry must use less cobalt (Co) in cathode, and stability becomes a challenge

Project Team and Roles:

- **ANL:** Anil Mane, Jason Croy, Jeffrey Elam
  Deposit ALD coatings on cathode powders, laminates and characterize, Testing of some in-house electrochemical properties recommendation for suitable process hardware, Supply coated cathode powders to Forge Nano
- **Forge Nano:** Arrelaine Dameron
  Make prototype cells, testing, market assessment

AMO MYPP Connection:

Addressed AMO Next Generation R&D Project, Technology Commercialization Funds (TCF) Program, Advanced R&D Projects Area

Lithium-ion battery

Market and Demands:

- Energy storage market projection in the next five years : **>$60 billion**
- A major portion of this market is rechargeable Li-ion battery which is a powerhouse for consumer electronics, electric vehicle, stationary storage applications, etc.
- **Demands:** reduce cost with increase in energy capacity, life performance and safety

Project Objectives:

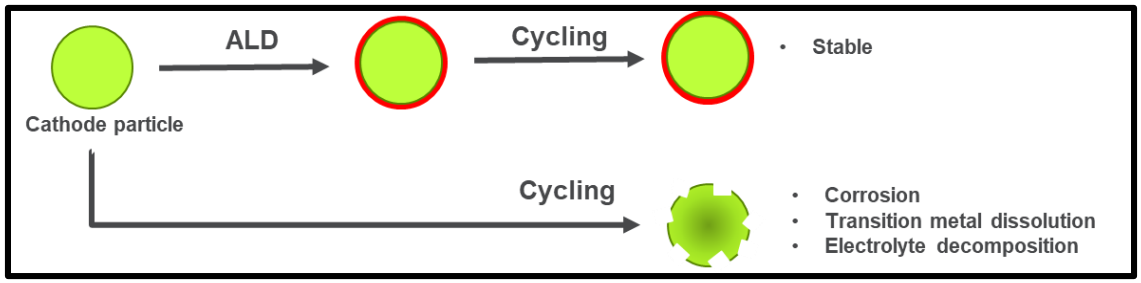
1) Develop robust, HF resistant thin barrier coatings for advanced cathodes (e.g. LCO, LMO, NMC family, layered-layered-spinels (LLS) and Ni-rich chemistries)

2) Demonstrate a 3x improvement in cells cycle life and <10% increase in cathode cost using ANL nanocomposite coatings

Technical Innovation

Atomic layer deposition (ALD) for Li-ion battery components:

ALD cathode coatings evaluated so far are metal oxides (e.g. Al_2O_3, TiO_2, ZrO_2)



Limitations:

- Metal oxides are typically electrical insulators, and this reduces charge/discharge rate
- Metal oxides can be corroded by the HF generated in the battery during cycling
- Many ALD coatings are not scalable

Proposed Approach:

Evaluate ALD metal fluoride nanocomposite coatings[1-3] as cathode coatings

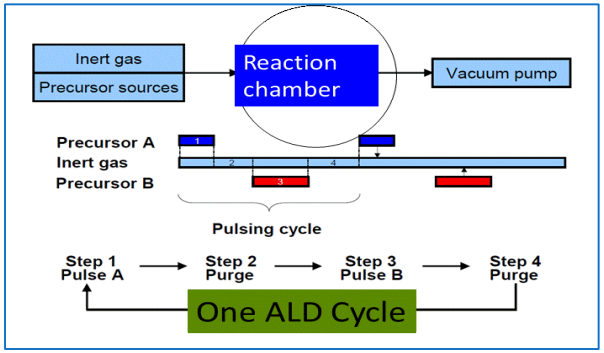
- These nanocomposite coatings are electrical conductors
- Nanocomposite coatings are resistant to HF
- Nanocomposite ALD is scalable

[1] *METAL FLUORIDE PASSIVATION COATINGS PREPARED BY ATOMIC LAYER DEPOSITION ON LIC002 FOR LI-ION BATTERIES* 2016. Mane *et.al,* US 2016/0260962 Al.
[2] COMPOSITE BILAYER COATINGS FOR HIGH CAPACITY CATHODES AND ANODES, Mane *et.al.* Patent submitted (ANL-IN-18-001 / 051583-0831).
[3] Park, J.S., et al., Atomic Layer Deposition of Al–W–Fluoride on LiCoO2 Cathodes: Comparison of Particle- and Electrode-Level Coatings. ACS Omega, 2017. **2**(7): p. 3724-3729.

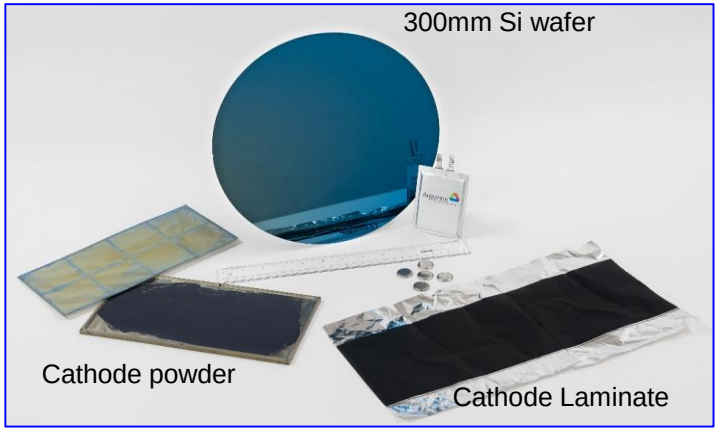
Technical Approach

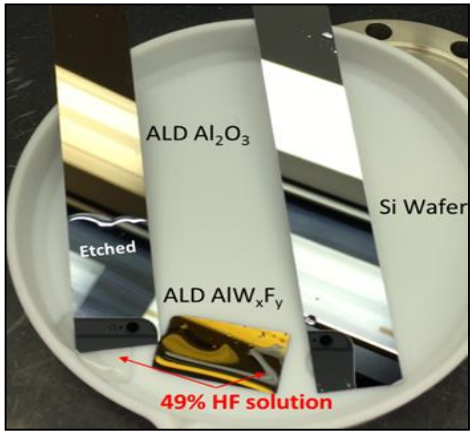
- **Developed cathode-specific ALD nanocomposite coatings**
- **Coated cathode powders and laminates with ALD nanocomposite thin films such as LCO, NMC532, NMC622, NMC811, NMC955 and LLS**
- **Characterized nanocomposites and cathodes: XPS, XRF, Microscopy**
- **Prepared and tested full cells using coated cathodes (Dr. Jason Croy, CSE, ANL)**

Atomic layer deposition (ALD)



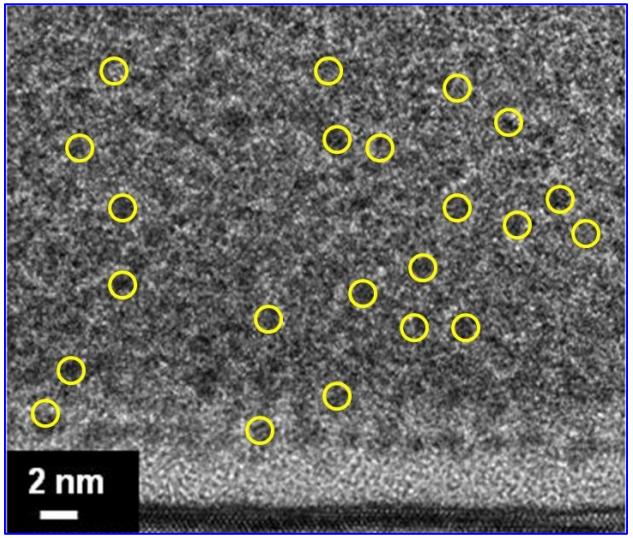
Nanocomposite coated items



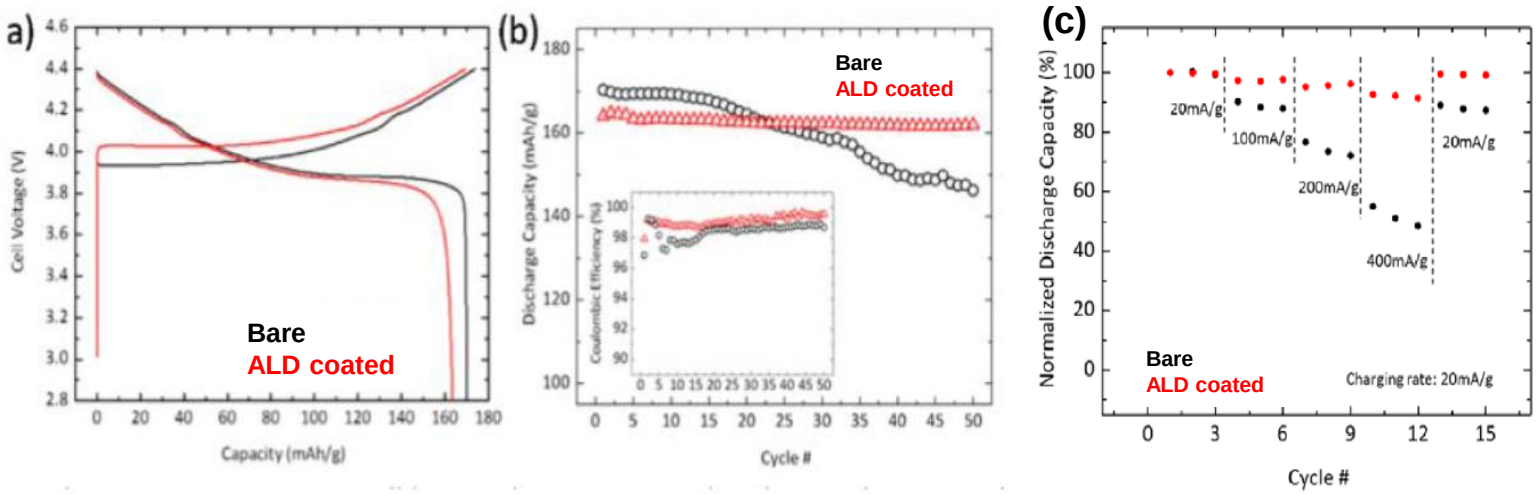


ALD nanocomposite coating are HF etch resistant

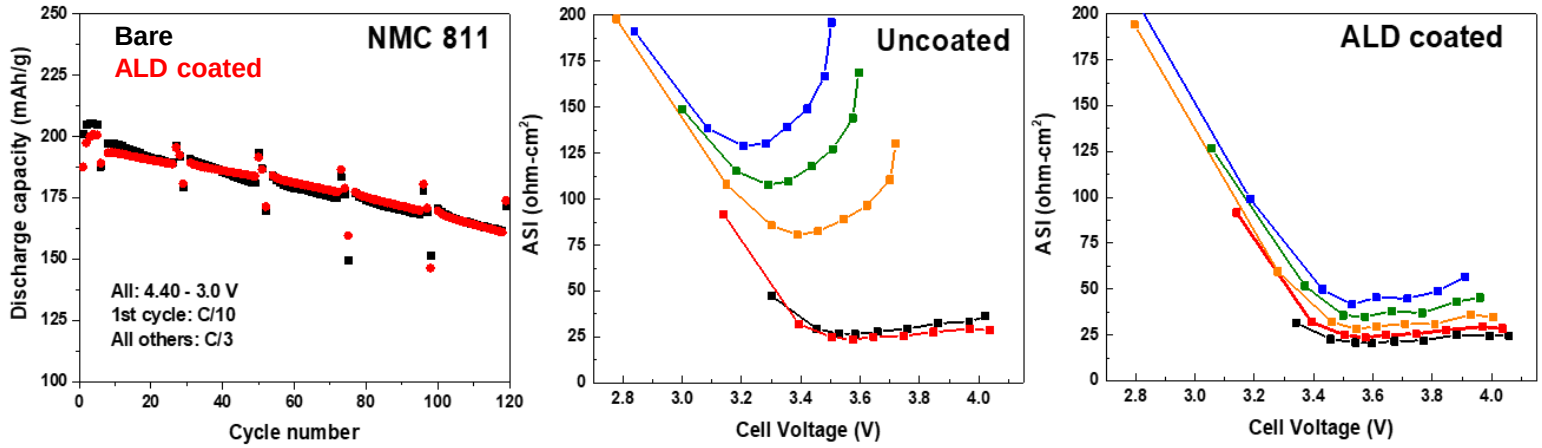
ALD nanocomposite coating:
Embedded metal nanoparticles in amorphous metal oxyfluoride matrix



Results



ALD nanocomposite coating improves stability and rate performance of $LiCoO_2$ cathode cells



ALD nanocomposite coating reduces/maintain the impedance of NMC811 cathode cells

Accomplishments

- **Developed HF resistant nanocomposite coatings by ALD**
- **Successfully coated and tested of variety of cathodes**
- **Coating feasibility tested on both powder and laminates**
- **Performance of ALD nanocomposite coated cathodes shows 2-3x life time improvement NMC cathodes and low cobalt cathodes**
- **Established partnership with Forge Nano for ALD process scale-up and prototype testing and risk mitigation strategies**

Technology Transition

- **Two patent applications submitted**
- **Work will present in 2019 ECS conference**
- **CRADA project with Forge Nano will evaluate new nanocomposites, assess scalability, estimate manufacturing cost**
- **TRL 5-6 anticipated by end of the project**
- **Technology transfer will occur through follow-on projects**