Roll-to-Roll Manufacturing of Solid Oxide Fuel Cells

TCF-20-20119

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23rd SOFC Project Review Meeting

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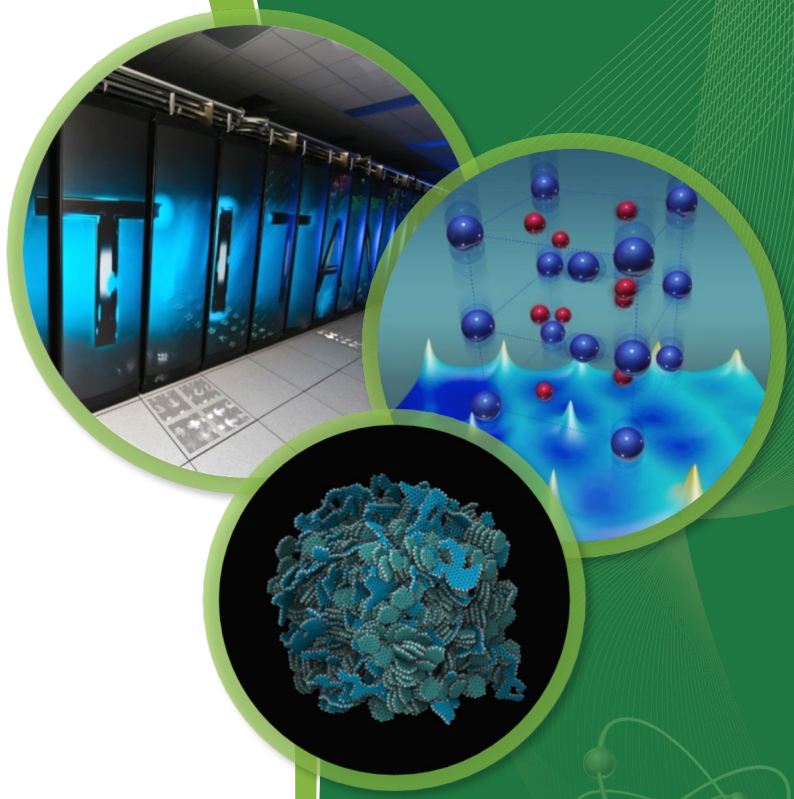

ORNL is managed by UT-Battelle
for the US Department of Energy

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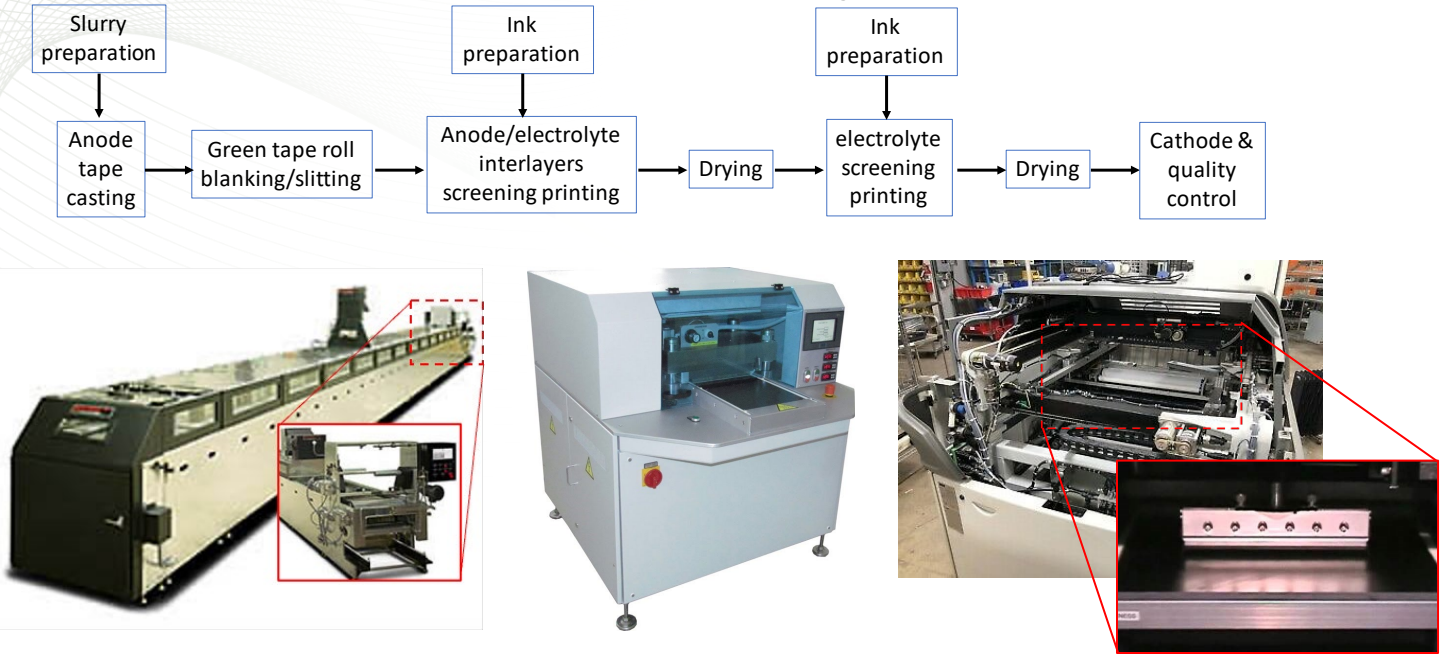
SOFC/SOEC manufacturing involves many steps and the manufacturing cost highly depends on the scale

An example of an EEA manufacturing process

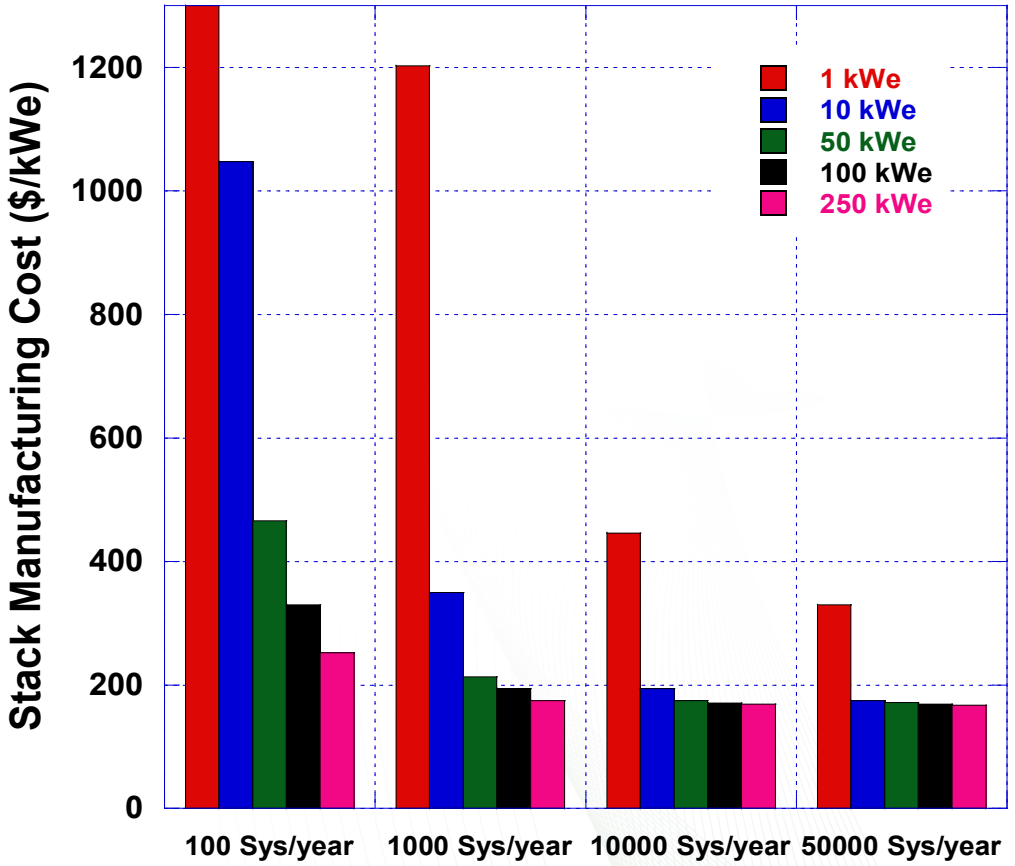


Electrode and electrolyte were coated via tape cast and screening printing in sheet-to-sheet manner

- Low manufacturing volume
- High manufacturing cost
- Conventional method throughput is typically 5-8 min/laminate

Manufacturing cost can be significantly reduced by increasing manufacturing volume and system size

Stack manufacturing cost variation with system size.



R. Scataglini, et. al., "A total cost of ownership model for solid oxide fuel cells in combined heat and power and power-only applications", Lawrence Berkeley National Laboratory, December 2015

Project goal and deliverables

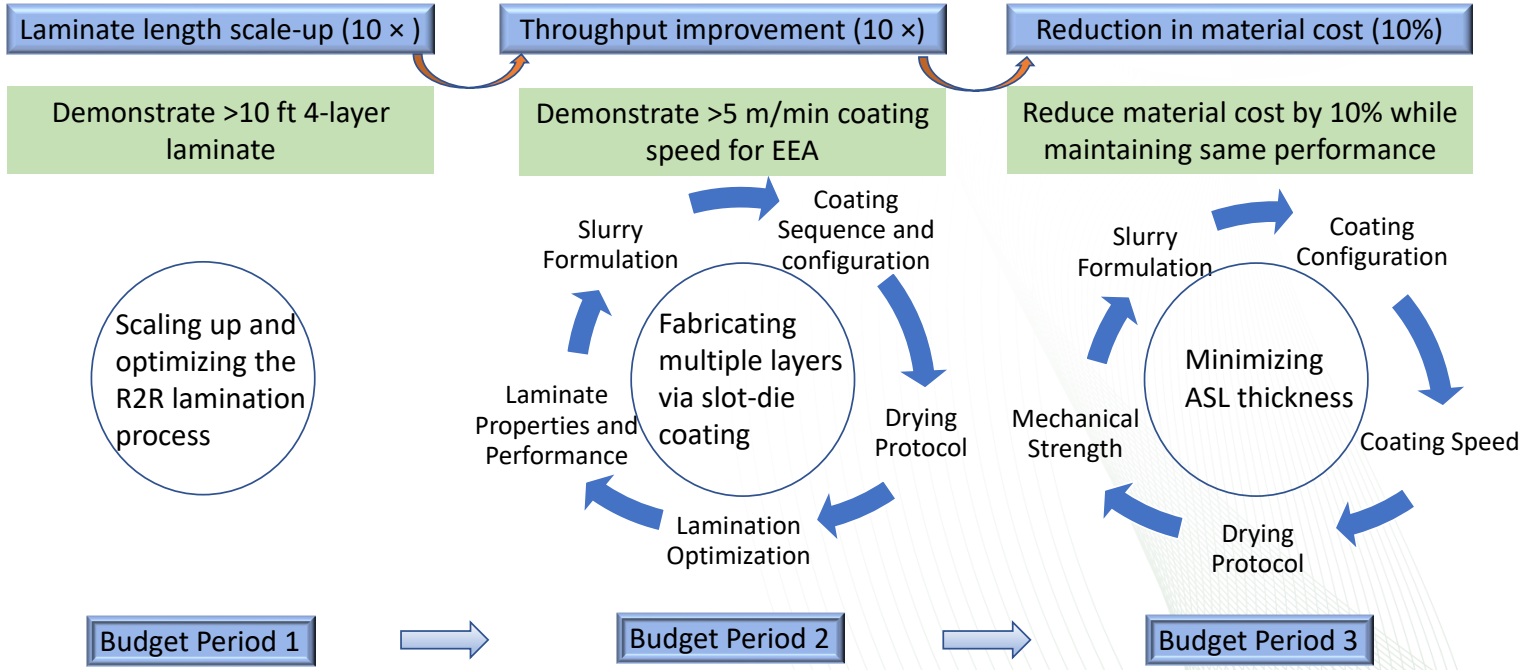
Goal: To further develop a high-volume electrode electrolyte assembly (EEA) production capability to significantly increase throughput of SOFC manufacture and reduce the manufacture cost by 30%

Approach:

- Optimize the lamination process using calendering
- Quantity scale-up of the lamination process to demonstrate > 10 ft of EEA
- Further increase EEA throughput via slot-die coating and demonstrate > 5 m/min coating of ASL (10X increase vs tape casting)
- Minimize the anode supported layer (ASL) thickness and reduce material cost by >10%

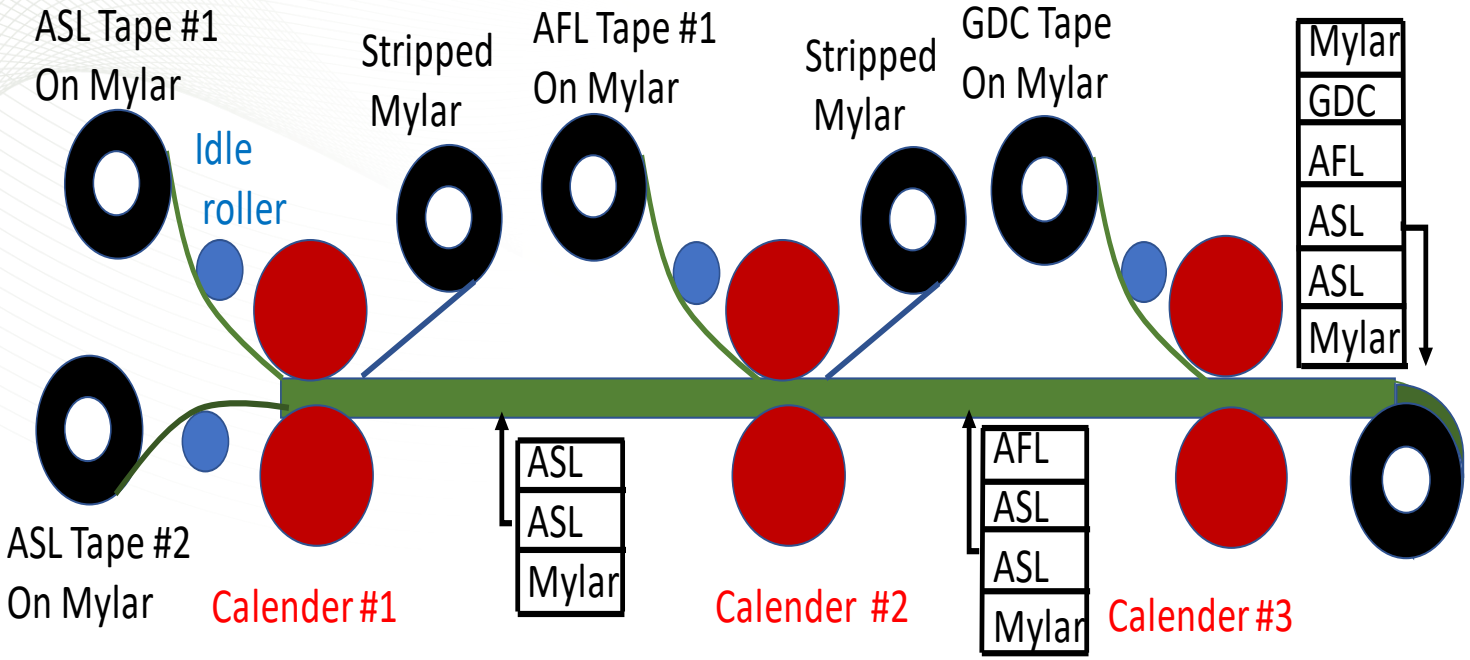
Deliverables:

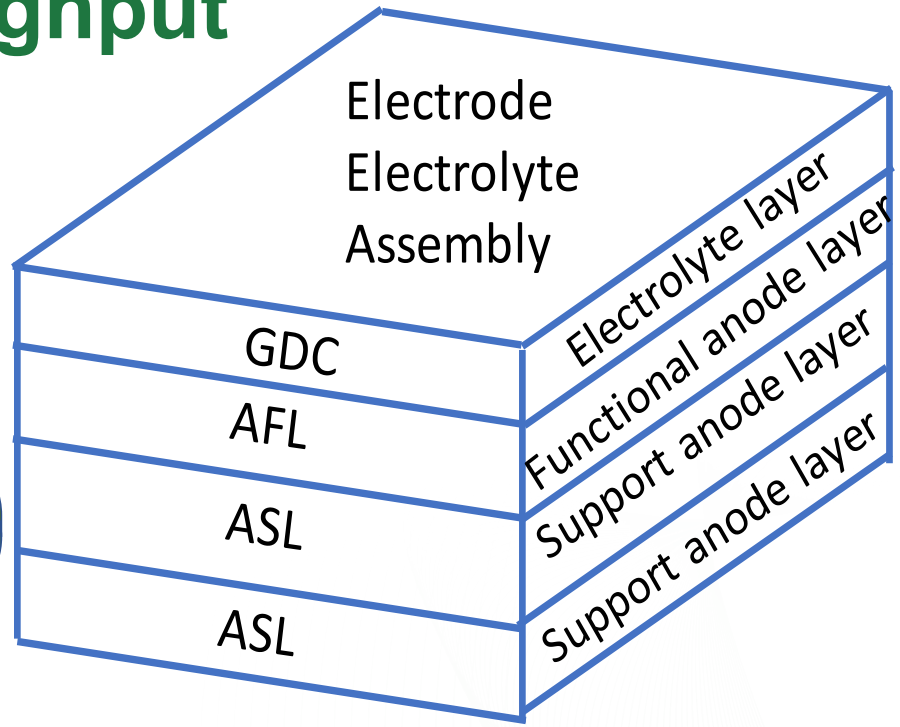
- **Budget Period 1:** Optimization of the lamination conditions and demonstration of >10 ft 4-layer EEA; sintering the EEA, characterizing the EEA morphology and properties, and testing the cell performance at ORNL and Redox.
- **Budget Period 2:** Fabricating multiple layers via slot-die coating, demonstration of >5 m/min in coating ASL, laminating them into EEA to reduce interfacial resistance, testing the cell performance and characterizing the laminate properties at ORNL & Redox.
- **Budget Period 3:** Further reducing SOFC cost by minimizing ASL thickness and enabling >10% material cost reduction

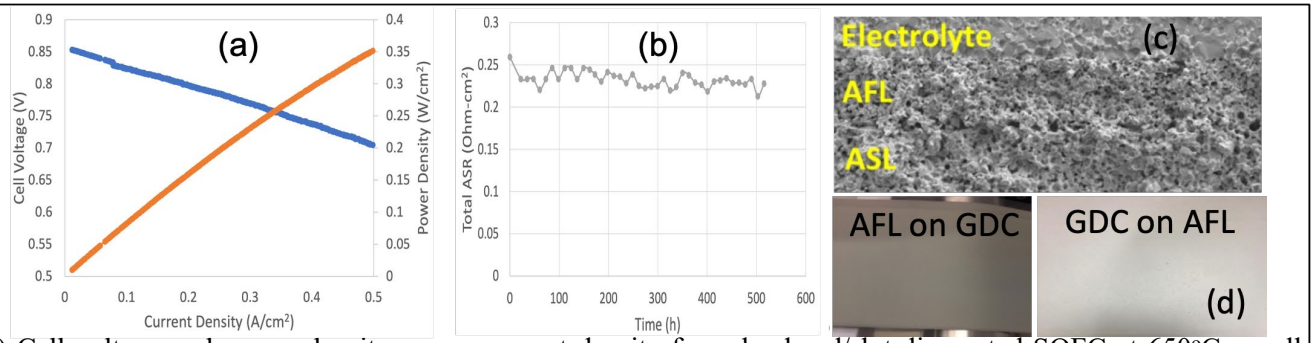


Work scope flow chart.

Roll-to-roll lamination process can produce electrode electrolyte assembly with high throughput





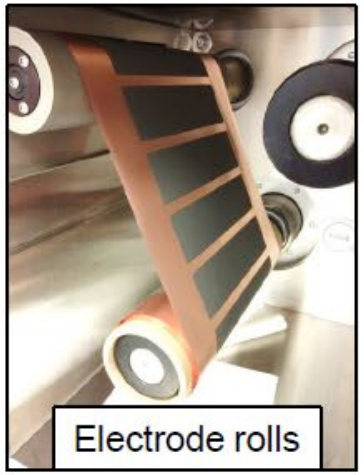


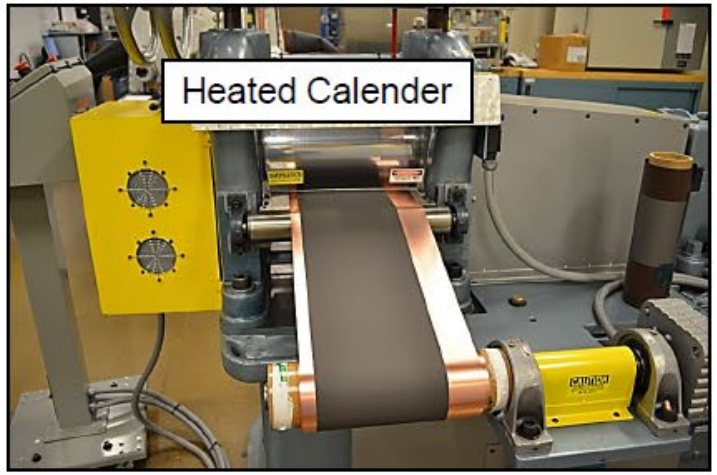
(a) Cell voltage and power density versus current density for calendered/slot-die coated SOFC at 650ºC— cell OCV is approximately the same as conventionally fabricated (Redox Gen-1) cell with similar GDC thickness; (b) Total cell impedance versus time (>500 hours) for calendered SOFC (no slot-die coating); (c) Cross-section of sintered (calendered) ASL-AFL-GDC; and (d) Example of slot-die coatings of AFL on slot-die coated GDC and GDC on slot-die coated AFL.

Previous proof-of-concept research (Small Business Vouchers (SBV) program) showed promising results

Roll-to-roll manufacturing capabilities at BMF

Battery electrode fabrication





- Planetary mixer
- ½ gallon

- Single and double sided
- Continuous and intermittent coating
- Capable of simultaneous multi-layer coating
- Up to 15 ft/min

- 9 drying zone including 2 IR zones

- 80,000 lbf
- Temperature up to 250°C
- Up to 15 m/min

Roll-to-roll manufacturing capabilities at BMF

Thin film mixer

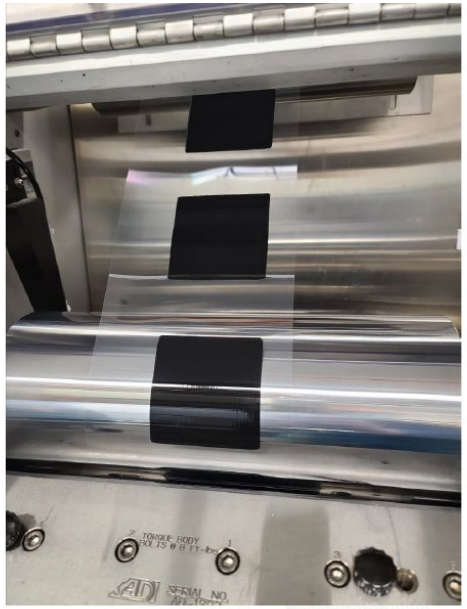
Bench top slot-die coater

Pilot scale slot-die coater

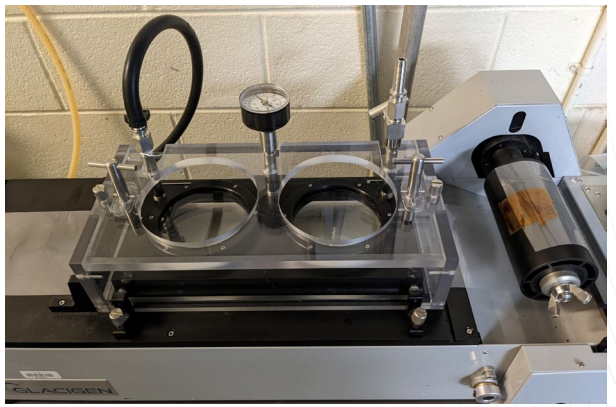
Electron beam curing

Heated calender

Patch coating



Two roll-to-roll freeze tape casters



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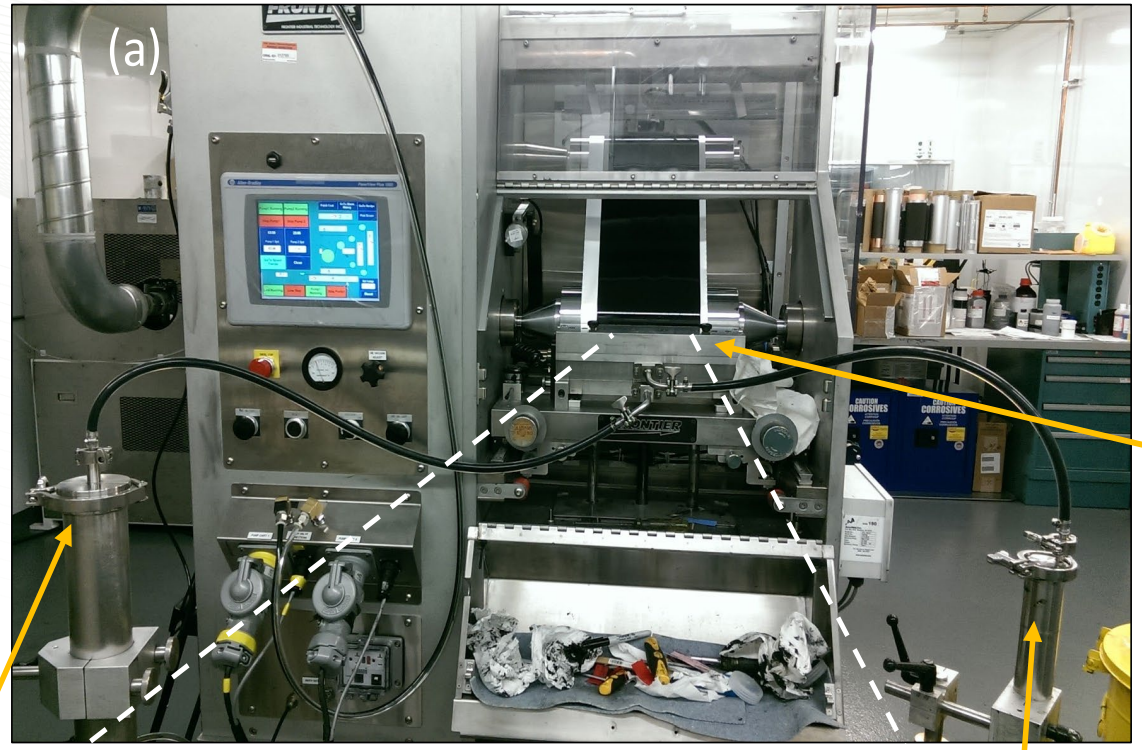
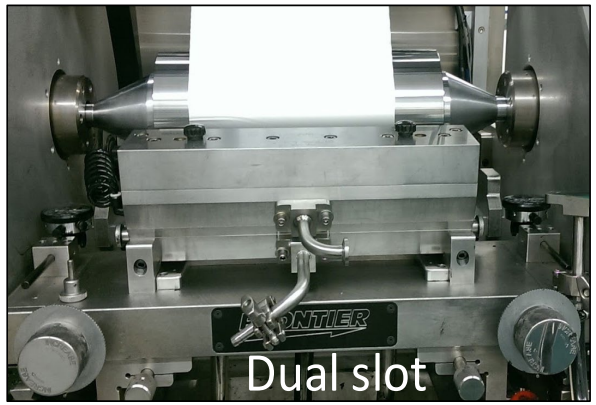
Pilot scale slot-die coater at ORNL

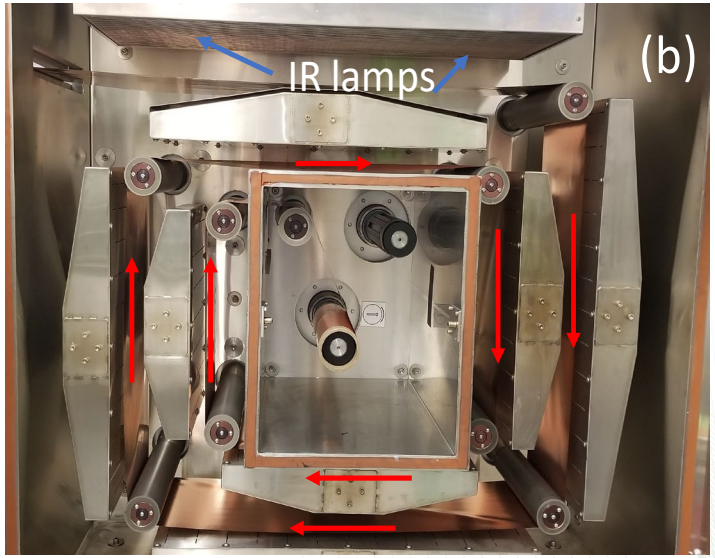




Slot Die

Slurry for Bottom Coating

Slurry for Top Coating

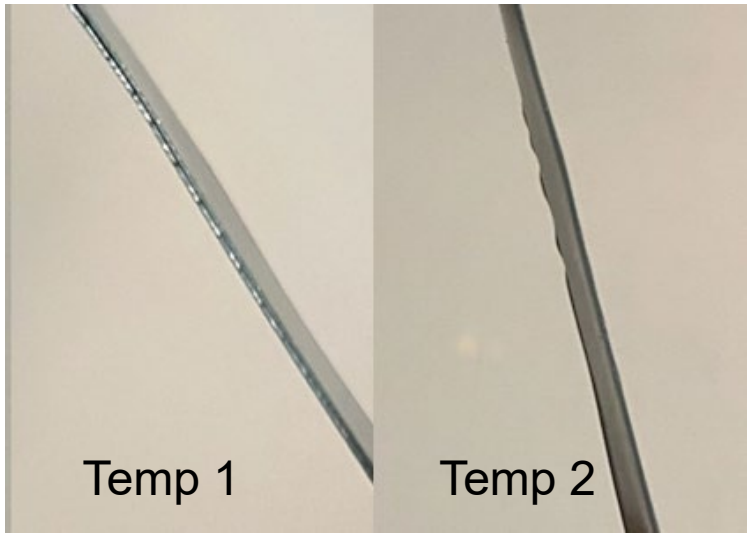


- Slot-die coating is a high precision and high throughput method to produce coating
- Dual slot-die can coat two layers simultaneously
- 9 drying zones provide flexibility to optimize drying protocols

Main accomplishments:

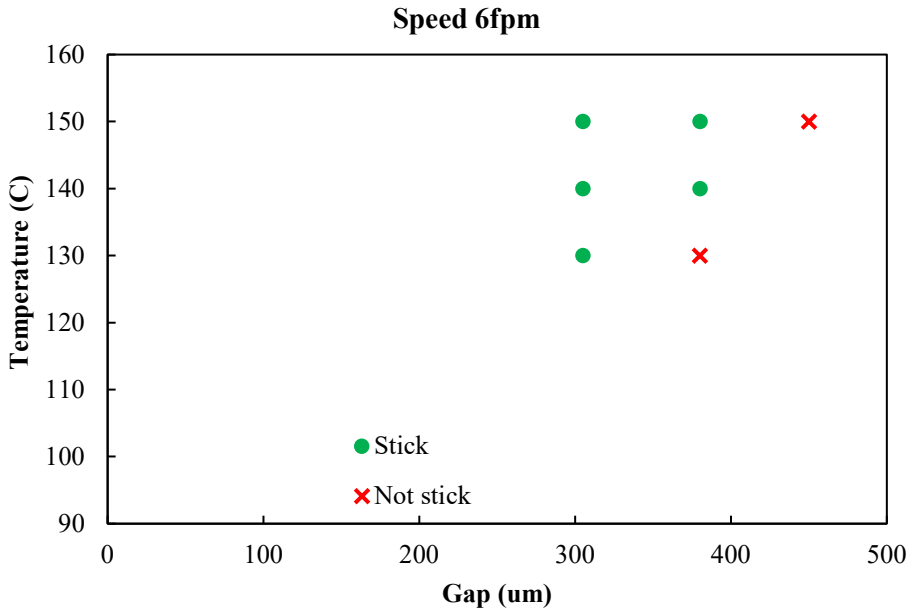
Project started in May 2022

- Fabricated ASL, AFL, and GDC green tapes via tape cast
- Started lamination of 2-layer ASL-ASL and 3-layer ASL-ASL-AFL at various gaps and temperature
- Coated AFL and GDC via slot-die coating

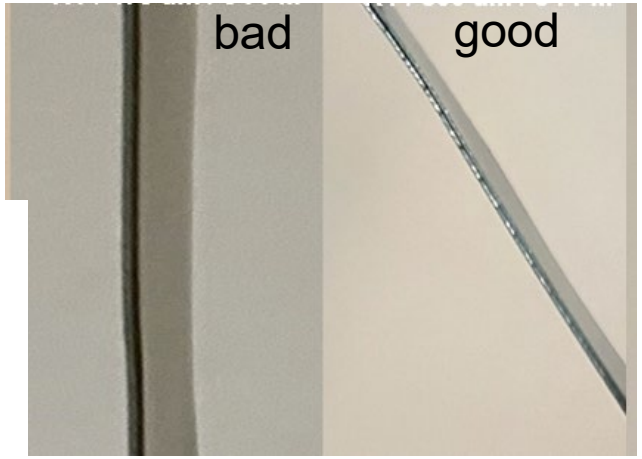


Calendering/lamination:

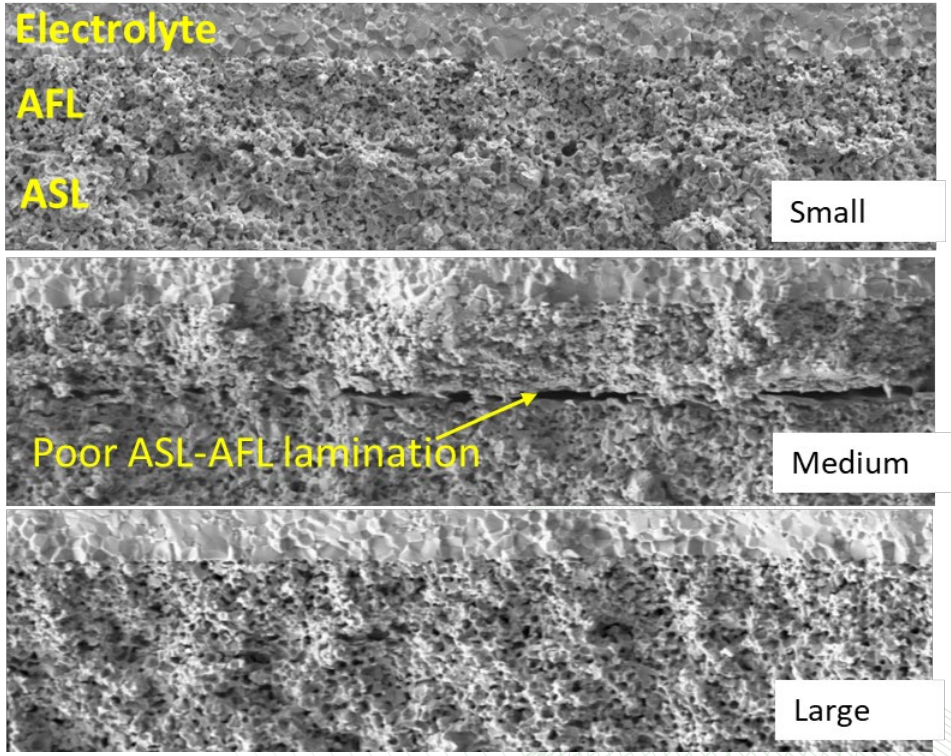
- Parameters to be investigated: temperature, gap, speed, sequence
- To determine a lamination window



An example of lamination conditions for ASL-ASL

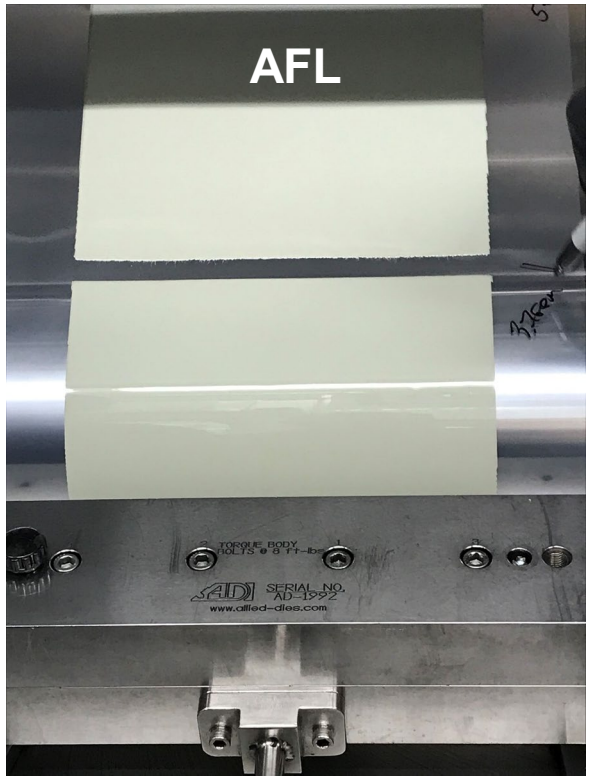


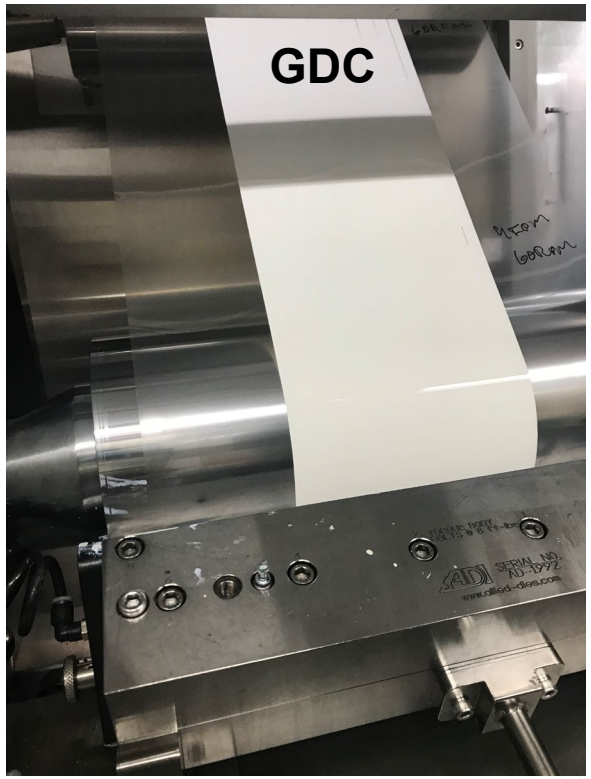
Previous SEM images from SBV project



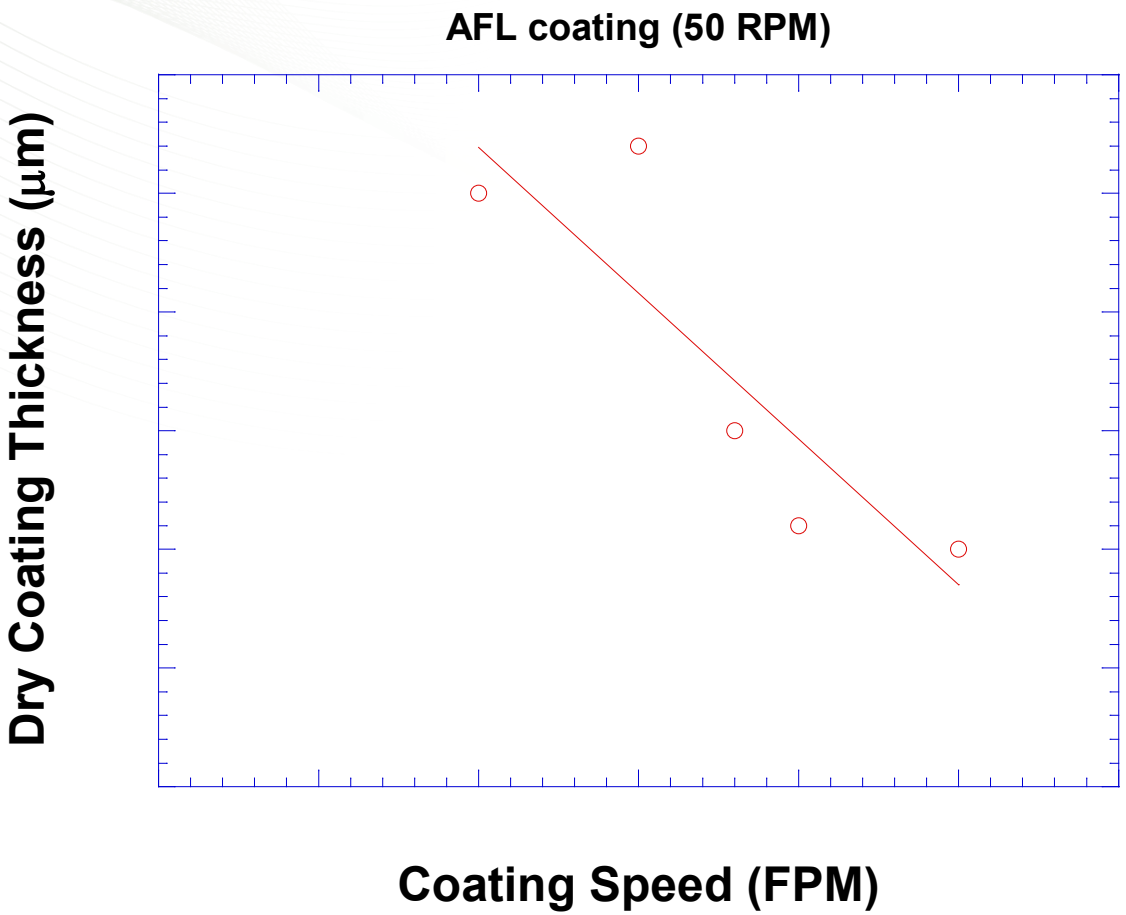
Fabricated AFL and GDC via Slot-Die Coating

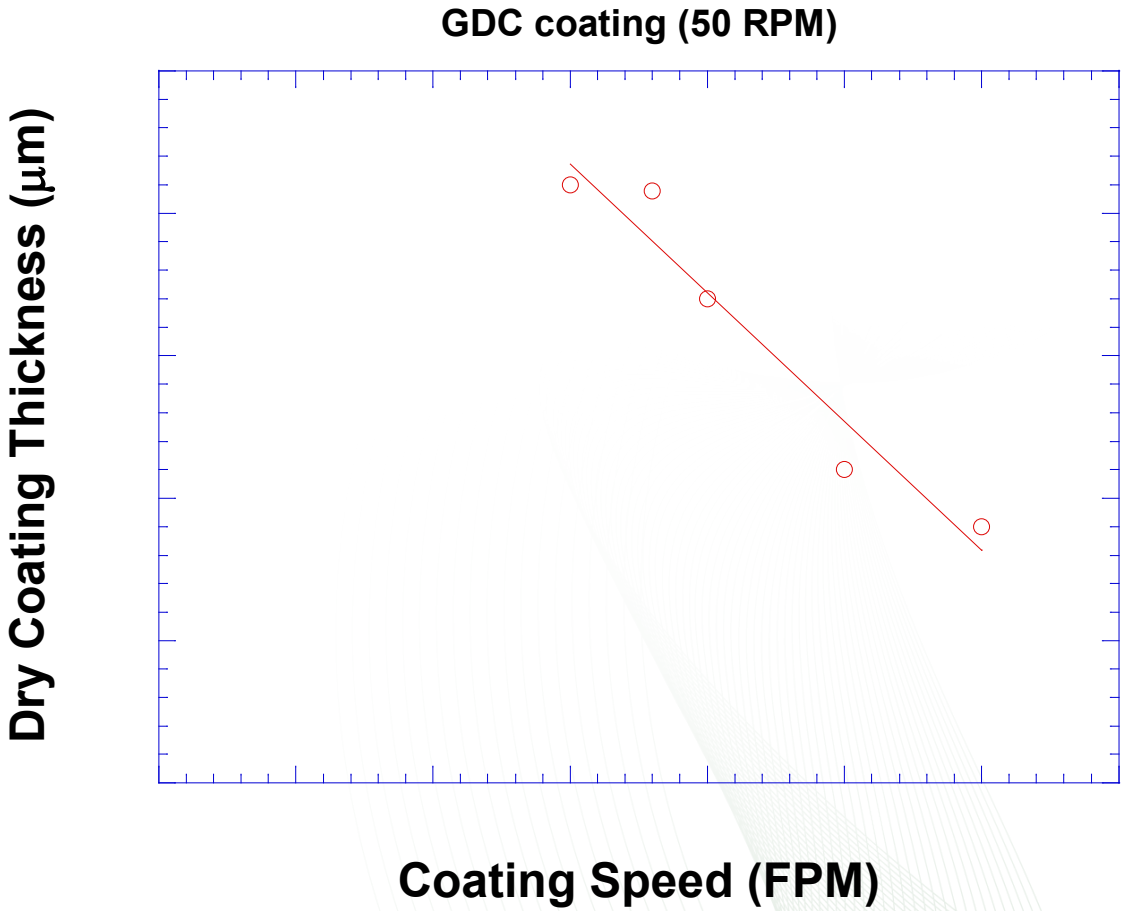
- Successfully developed slurry formulation for slot-die coating
- Fabricated both defect-free AFL and GDC with a very thin thickness
- Determining the coating window





Thin dry coating thickness of AFL and GDC is achieved





Coating defects in AFL

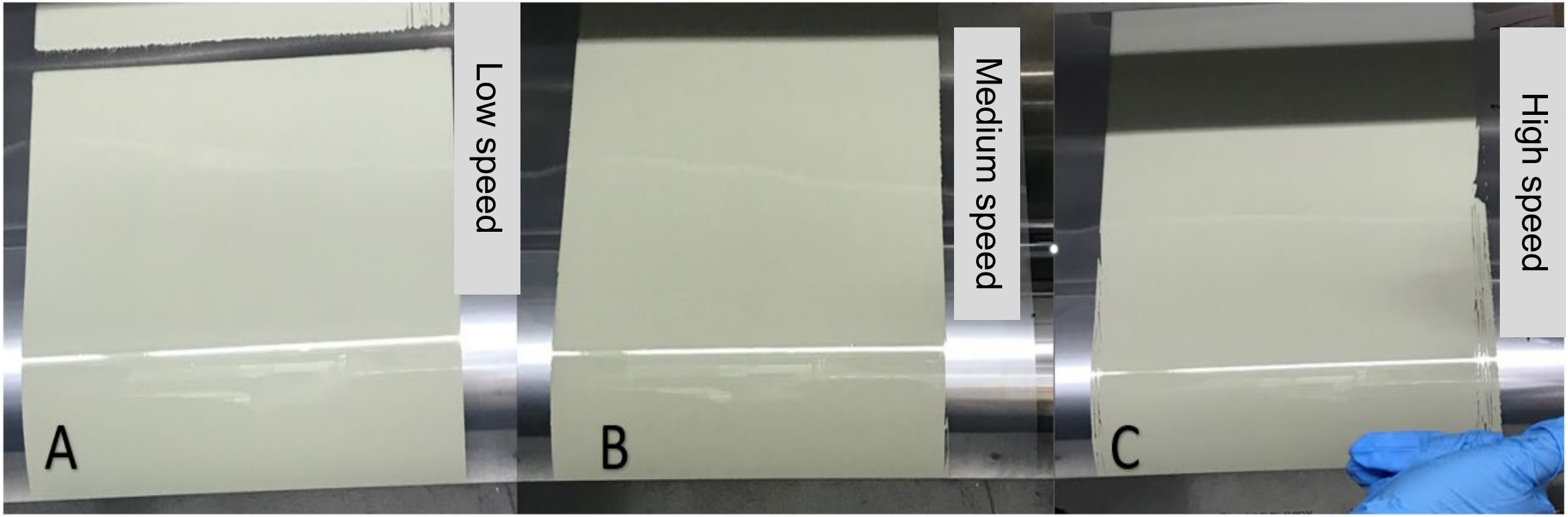


Figure 1. Edge effects / defects observed when moving outside of the stable coating window for the undiluted AFL coating:

(A) slow speed-uniform coating, (B) medium speed-edge defect noticeable, (c) high speed-major defects

Summary

- Fabricated ASL, AFL, and GDC green tapes via tape cast
- Started laminating 2-layer ASL-ASL and 3-layer ASL-ASL-AFL at various gaps and temperature
- Successfully coated very thin AFL and GDC layer via slot-die coating

FY23 plan

- Develop a lamination operation map for muti-layer EEA and determine an optimized condition for high throughout lamination
- Tune slurry formulation to fabricate defect free individual layer of ASL, AFL and GDC and muti-layer of their combinations
- Laminate the slot-die coated single or muti-layers into EEA
- Sinter the EEA and characterize the EEA morphology
- Assemble SOFC cells and evaluate electrochemical performance

Acknowledgements

- Office of Fossil Energy and Carbon Management
- Project manager: Evelyn Lopez
- ORNL Team
- Redox Power Systems Team