Roll-to-roll Advanced Materials — Manufacturing Lab Consortium

Project period: FY16/17

Claus Daniel (consortium lead)

Co-PIs (Lab leads):
R2R: Gregory Krumdick (ANL), David Wood (ORNL), Ravi Prasher (LBNL), Michael Ulsh (NREL)
Water: Seth Snyder (ANL)
Industry partners: Matt Fronk (Kodak), Greg Mulholland (Citrine)

U.S. DOE Advanced Manufacturing Office Program Review Meeting

June 13, 2017

Argonne NATIONAL LABORATORY | Berkeley Lab | NREL NATIONAL RENEWABLE ENERGY LABORATORY | OAK RIDGE National Laboratory

EASTMAN Business Park | Kodak

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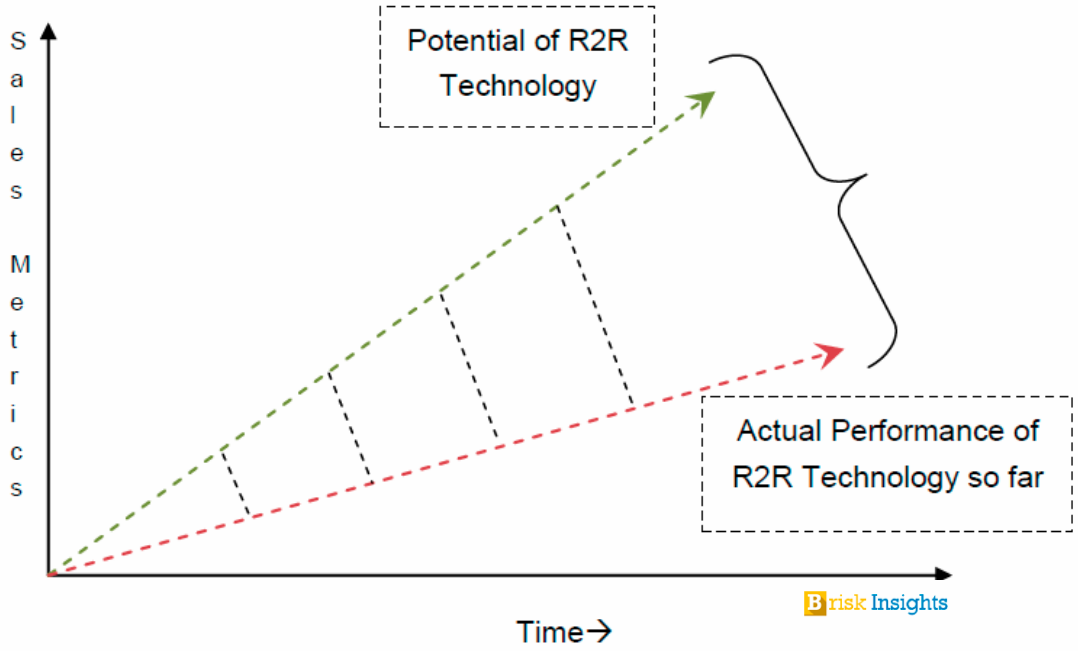
Project objective
Overcome technical limitations in batch processing and understand roll-to-roll manufacturing barriers and gaps

R2R Science Challenge: Linking Synthesis and Processing Variables to Device Performance

R2R Consortium Goal: Develop R2R Processing Science to Reduce Discovery-to-Devices Timeline



Enabling R2R potential
- Low manufacturing costs
- Low energy processes
- High volume production
- High throughput due to thinner membranes
- Compatible with many material platforms
- Large areas
- Varying feature sizes and dimensions

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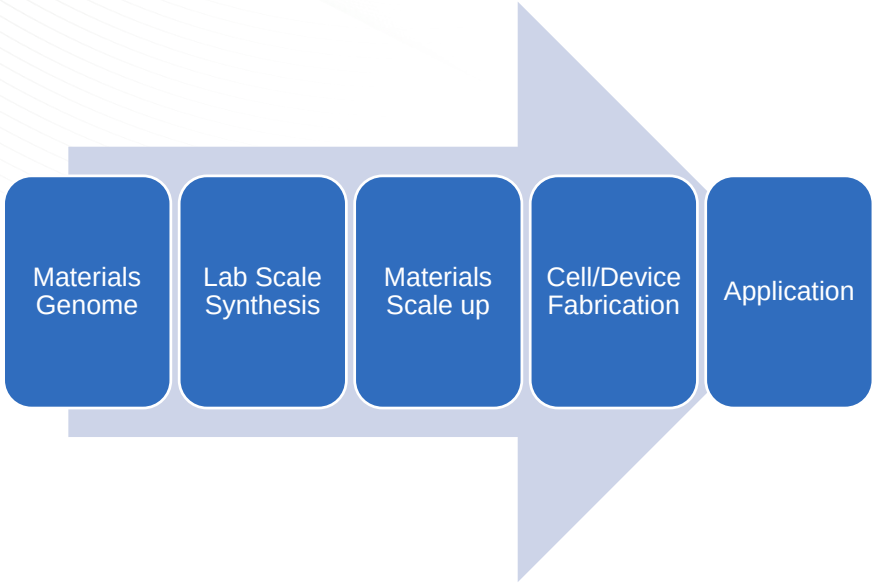
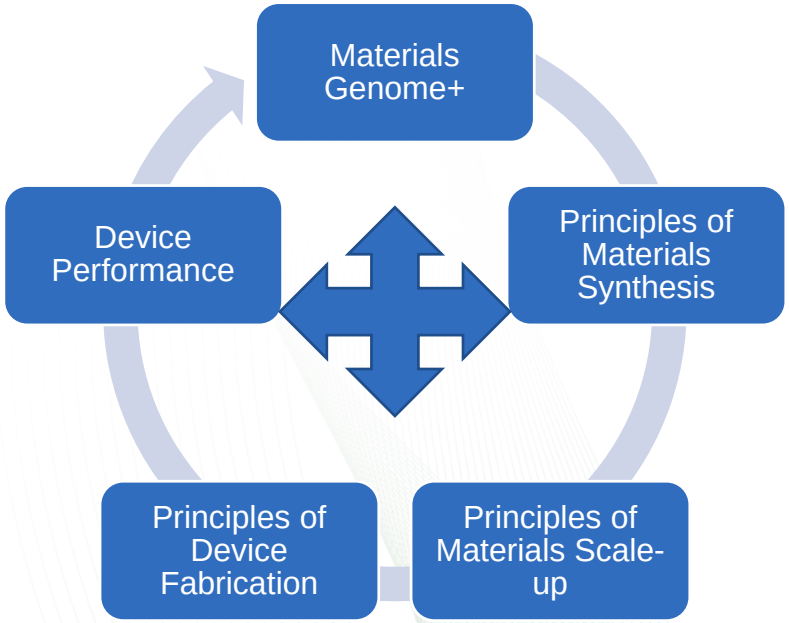
Technical innovation

4 lab consortium changes linear approach to AMM type approach for process development





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Technical Innovation

Utilization of combined national lab resources to solve complex problem

Materials synthesis
Device assembly and testing

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Materials processing
Materials characterization

Argonne NATIONAL LABORATORY

FedBizOpps Solicitation:
ORNL-R2RAMM-2017-02-02

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Modeling and simulation of process conditions and resulting performance

BERKELEY LAB

Metrology of coatings
Understand morphology and porosity

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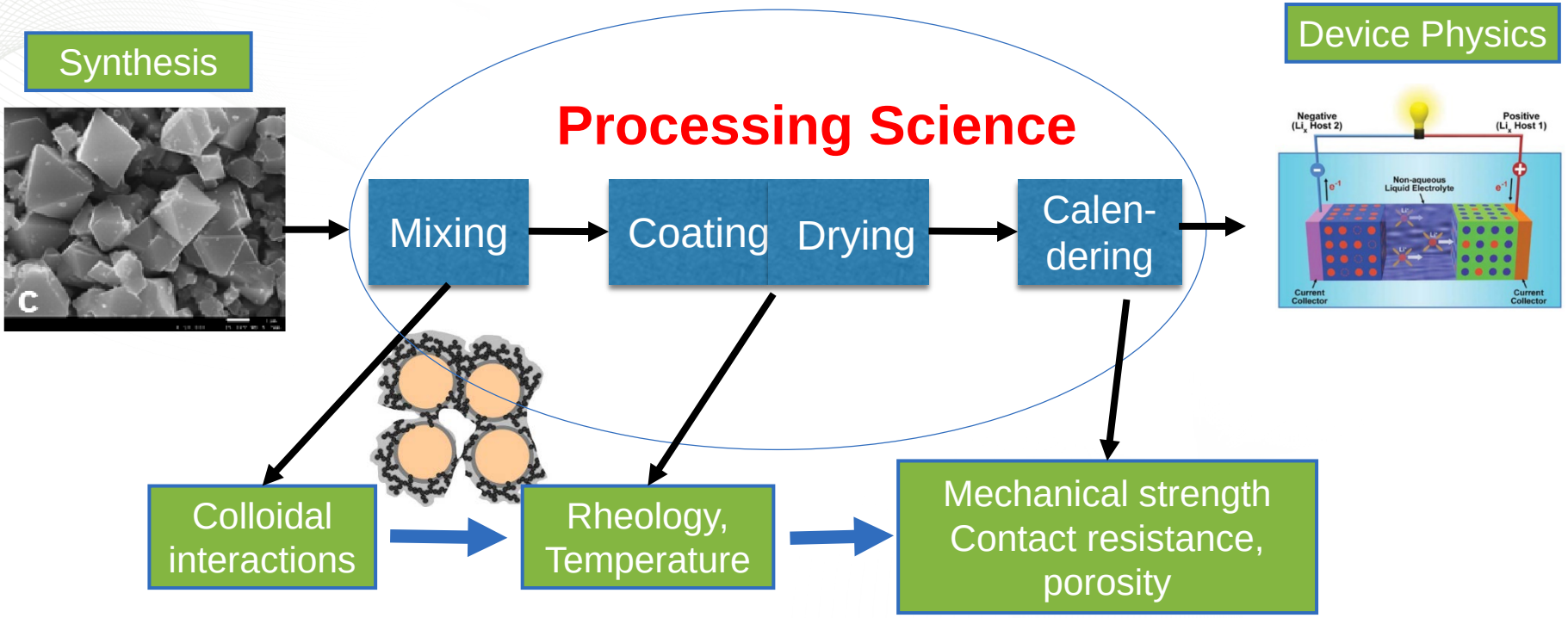
Technical Approach
Linking Material Properties to Device Performance



How do we link materials processes to device performance?

- Elucidate colloidal and rheological particle-polymer-solvent interactions in active layer ink formulation and mixing, to improve coating throughput, uniformity and quality
- Understand the physics of scalable coating and drying/curing processes and how they affect active layer morphology and device performance
- Determine the impact that process-based defects in active layer and substrate materials have on performance and lifetime of devices
- Study material-excitation interactions to facilitate the development of real-time instrumentation and measurement of active layer uniformity and properties

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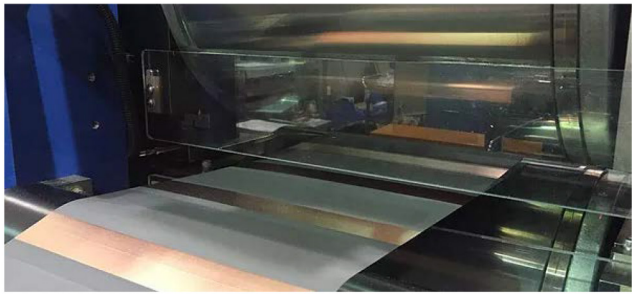
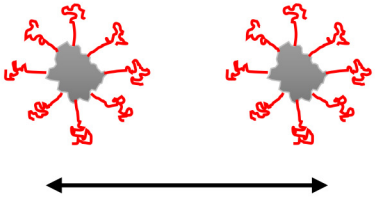
Technical Approach
Example batteries – contributions from all partners at every step

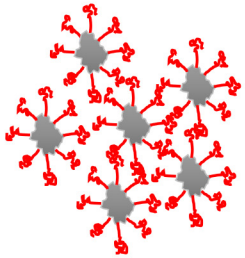
Mixing → Coating | Drying → Calendaring



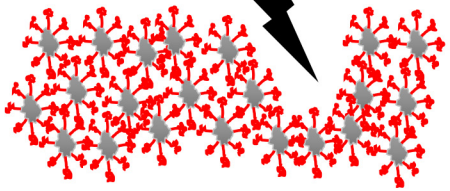
Colloidal interactions → Rheology, Temperature → Mechanical strength Contact resistance, porosity



Colloidal forces



network of colloids
Rheology
Speed of deposition
Dynamics of drying



morphologies of electrode
performance of battery

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Transition and deployment

Lab-industry Partnership started with ORNL-Kodak MOU and is spanning the network to assist commercialization

EASTMAN BUSINESS PARK – FROM POC TO COMMERCIAL SCALE

- Extensive suite of tools to assist small companies
- Key set of development apparatus to conduct early and mid-stage pilot work.
- Technical resources in IP friendly manner
- Scale-up through full manufacturing

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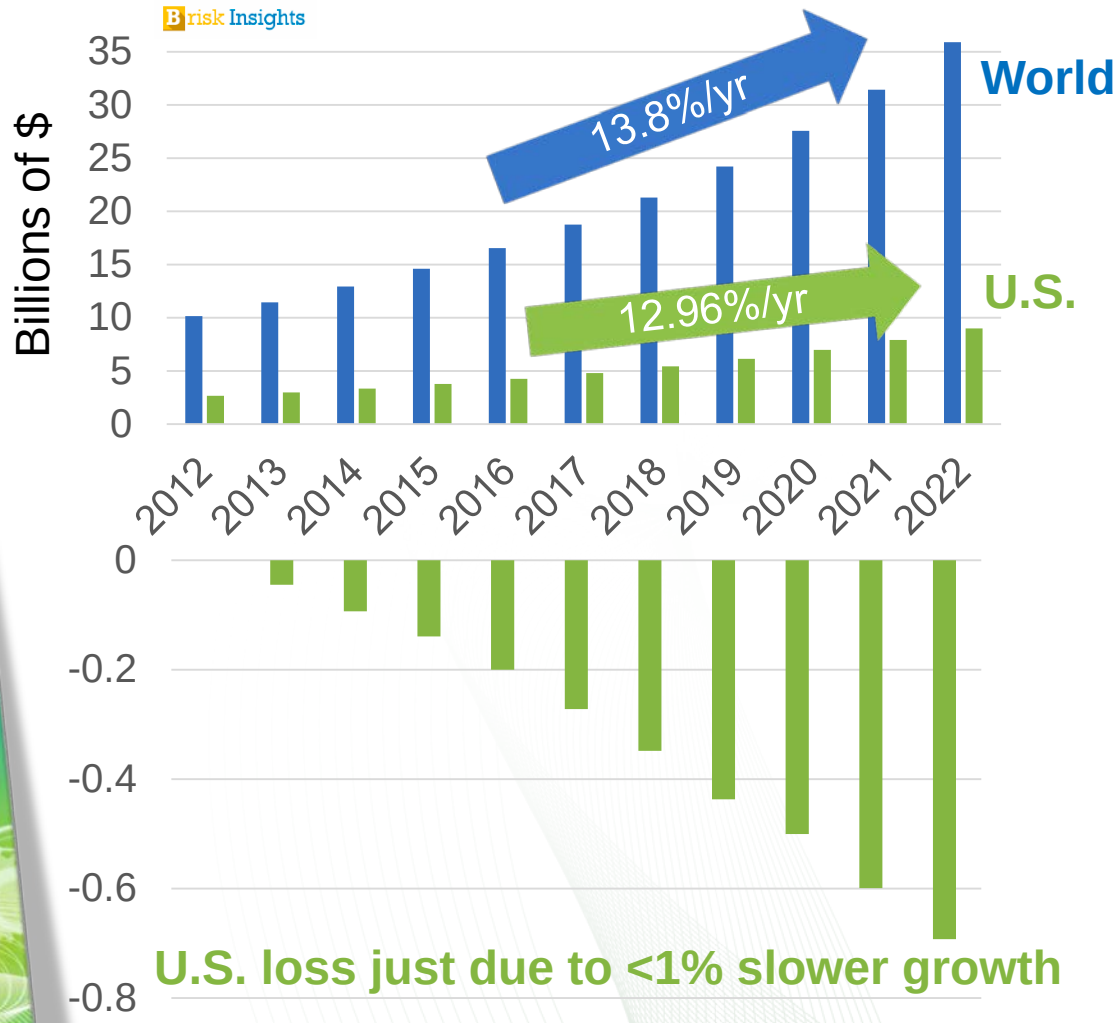
Measure of Success
Successful solutions to enable transition from batch to roll-to-roll processing and vastly increasing roll-to-roll manufacturing speed and reliability

Business as usual will result in a minimum loss of $3.3Bn by 2022 for the U.S. economy.

Mission innovation and clean energy development could easily triple the opportunity.



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Project management & budget
Current budget: $4.5M/year – full scope: $10M/year

$4.5M/year from AMO – Lab industry consortium (ORNL, LBNL, ANL, NREL, Kodak) with estimated $5M cost share and $40+M leveraged investments and programs

Project Support Energetics ($100k/year)

National Lab Core Funding ($2.952M/year)

Eastman Kodak Pilot Line ($48k/year)

$1.4M/year - CRADA Project Solicitation with 1:1 Cost Sharing for Tackling Specific Industry Problems

Consortium to Release Annual Solicitation on FedBizOpps.gov

Award annual projects to Individual Companies Based on Consortium Matchmaking

$1M additional funding for CRADAs on fuel cell specific topics to be coordinated through this effort

FY16 focus: Battery electrodes

FY17 focus: Battery electrodes, fuel cell membranes, water purification

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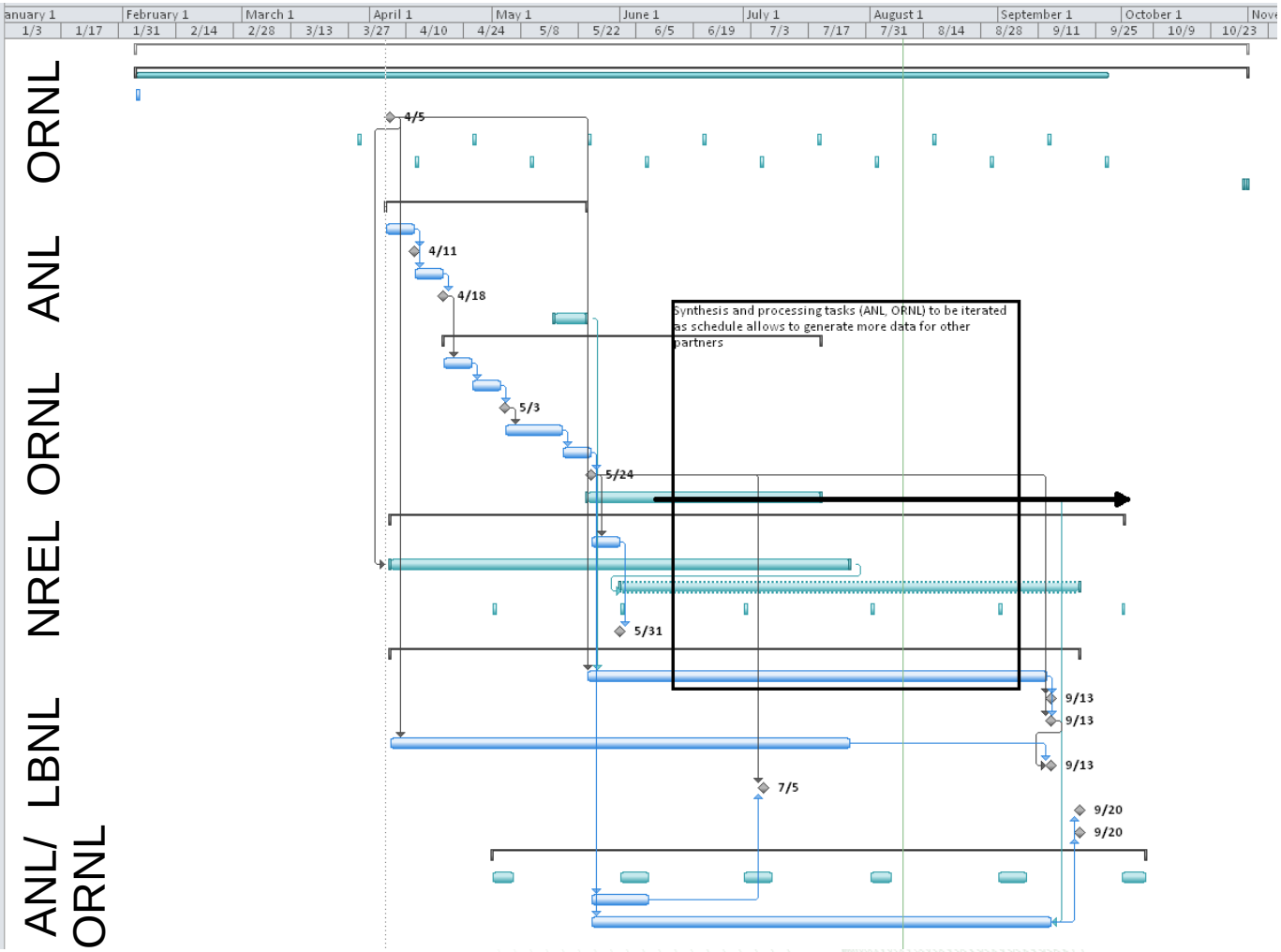
Schedule

Start: 4/4/2016

	Tas Mo	Task Name	Duratic	Sta
0		HVR2R lab consortium FY20	193 day	Th
1		1 Project management	193 days	Th
2		1.1 Preliminary team mee	1 day	Th
3		1.2 Project kick off	1 day?	Tu
4		1.3 Team meetings	121 days	Tu
12		1.4 DOE review meetings	121 days	Tu
20		2 Final report	1 day	Mo
21		3 Materials synthesis (ANL)	35 days	Tu
22		3.1 Identification of large	1 wk	Tu
23		3.2 Send 1 kg to ORNL	0 days	Mo
24		3.3 Identification of small	1 wk	Tu
25		3.4 Send 1 kg to ORNL	0 days	Mo
26		3.5 ANL send 5g sample o	6 days	Mo
27		4 Materials processing and c	66 days	Tu
28		4.1 Prepare slurry and coa	1 wk	Tu
29		4.2 Prepare slurry and coa	1 wk	Tu
30		4.3 Check coating areal we	1 day	Tu
31		4.4 Coating of matching a	2 wks	We
32		4.5 Build devices	1 wk	We
33		4.6 Send electrodes to NF	0 days	Tu
34		4.7 Prepare and ship smal	41 days	Tu
35		5 Coating characterization ar	128 days	We
36		5.1 Porosity diagnostic	1 wk	We
37		5.2 Install and start opera	4 mons	We
38		5.3 XRF trial as materials a	4 mons	We
39		5.4 Send XRF data as avail	110 days	Su
46		5.5 Send porosity diagnos	0 days	Tu
47		6 Modeling and simulation a	120 days	We
48		6.1 Droplet model study	4 mons	Tu
49		6.2 compare porosity grac	1 day?	Tu
50		6.3 compare porosity grac	1 day	Tu
51		6.4 develop preliminary r	4 mons	We
52		6.5 Modeling validation F	0 days	Tu
53		6.6 Determine ability of n	1 mon	We
54		6.7 Compare micro-struct	1 wk	We
55		6.8 Compare micro-struct	1 wk	We
56		7 Characterization and perfc	114 days	Su
57		7.1 X-ray tomography as s	114 days	Su
64		7.2 Coating materials char	2 wks	We
65		7.3 Device testing (ANL ar	4 mons	We



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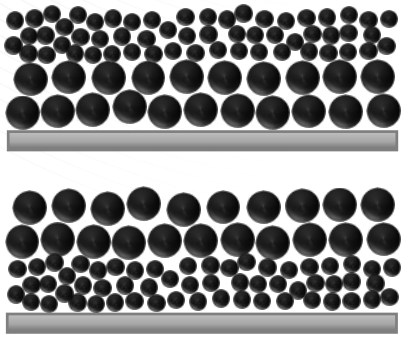
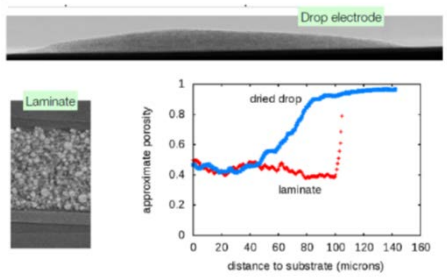
Results and accomplishments
From theory to full device with understanding of defects and performance limitations

for details – see three posters at the poster session

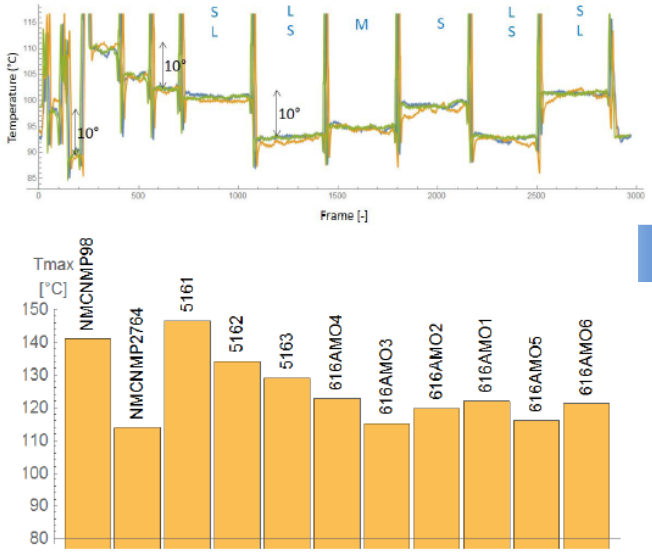
R2R processing and materials assumptions



Modeling, simulation, and in-situ observation



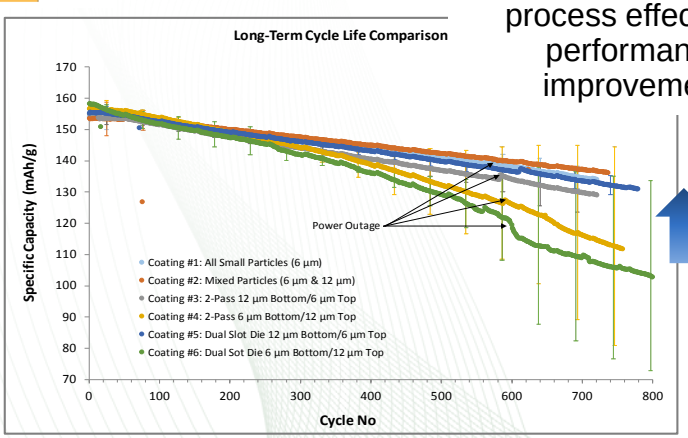
V. Srinivasan et al. J. ECS (2017)



Process validation
Defect and coating analysis

Final device

Understanding of process effect and performance improvement



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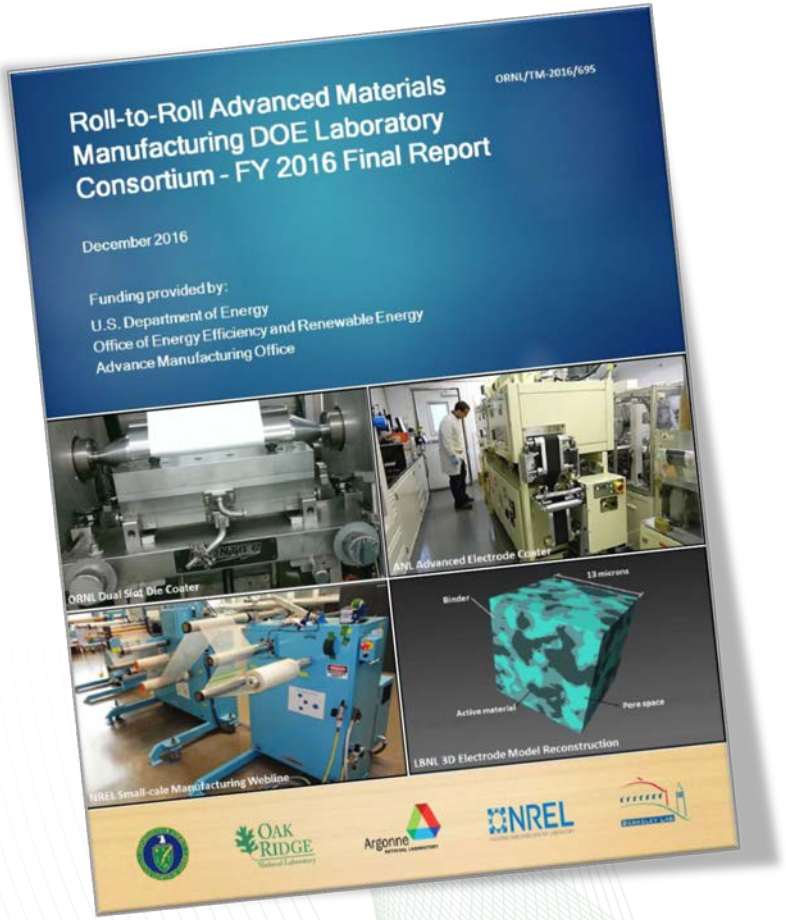
Questions?

Development Assistance Opportunity for Roll-to-Roll (R2R) Advanced Energy Materials Manufacturing – FedBizOpps.gov
Solicitation Number: ORNL-R2RAMM-2017-02-02
First co-hort selected, three negotiations starting with Fisker, Navitas, and Solar Windows Technologies



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