Roll-to-Roll Advanced Materials Manufacturing (R2R AMM) DOE Laboratory Collaboration

Claus Daniel, Collaboration Lead, Presenter

Co-Principal Investigators/Lab Leads:
David Wood (ORNL), Gregory Krumdick (ANL), Michael Ulsh (NREL), Vince Battaglia (LBNL), Randy Schunk (SNL)

U.S. DOE Advanced Manufacturing Office
2019 Annual Peer Review Meeting
Arlington, VA
June 12, 2019

For more details see posters in Tuesday poster session: 6, 20, 21

OAK RIDGE National Laboratory | Argonne NATIONAL LABORATORY | NREL NATIONAL RENEWABLE ENERGY LABORATORY | BERKELEY LAB | Sandia National Laboratories

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Project start date: October 2019
- Projected end date:
  - Core Projects: September 2021
  - CRADAs: October 2019*
- Project completion for FY19
  - Core Projects: 30%
  - CRADA Projects: ~80%

Barriers*

- Continuous processing
- Registration and alignment challenges
- Materials compatibility
- Stoichiometry control
- Availability of materials data

* AMO MYPP for FY 2017-2021, June 2017 draft, section 3.1.8

FY 19 Budget

- Core lab work: $3,000K per year
- CRADA work: $1,150K plus $1,150K non-federal cost share

Partners

- ORNL, ANL, NREL, LBNL, SNL
- Navitas Systems
- Fisker, Inc.
- SolarWindow Technologies, Inc.
- Proton OnSite*

* Pending contract award

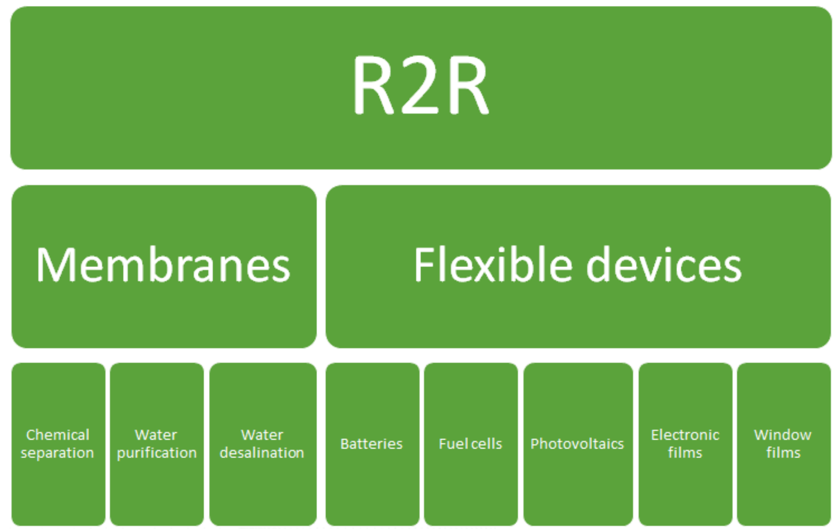
Project Objectives

- AMO MYPP Target 8.1: Develop technologies to reduce the cost per manufactured throughput of continuous R2R manufacturing processes for selected products by 50% concurrent with a 10X production capacity increase compared to 2015 typical technology.
  - Develop in-line multilayer coating technology with yields greater than 95% for a wide-range of applications.
  - Technological focus areas are the process science on multi-layered coating deposition and drying/curing, its associated fundamental kinetics, modeling and simulation, and metrology to understand quality and defects.
- AMO MYPP Target 8.2: Develop in-line instrumentation tools that will evaluate the quality of single and multi-layer materials in-process with respect to final product performance and functionality against performance specifications at a 100% level.
  - Develop in-line quality control technologies and methodologies for real-time identification of defects and expected product properties "in-use/application" during continuous processing.
- Complete the technology transfer of continuing collaborative research and development agreements (CRADAs) with industry.

Technical Innovation

- Materials currently made using time-consuming, inefficient batch processes can be manufactured at significantly lower costs (as much as 80%) using a continuous roll-to-roll process.

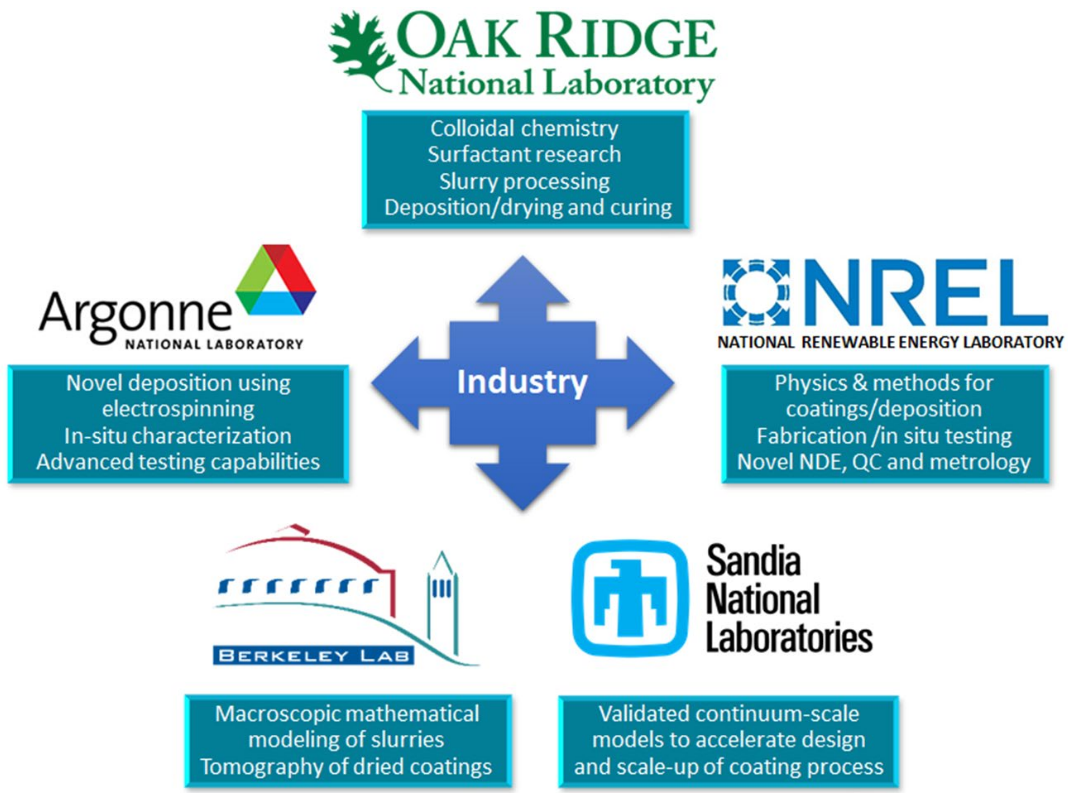
- Successful energy-efficient, cost-effective production of novel technologies will be facilitated through a collaborative effort involving multiple DOE laboratories with unique capabilities. Applications are:
  - functional coatings
  - filtration applications
  - flow batteries for grid applications
  - fuel cell membranes
  - platinum group metal-free catalysts
  - electrodes for electrochemical CO_2 reduction concepts
  - water filtration and purification



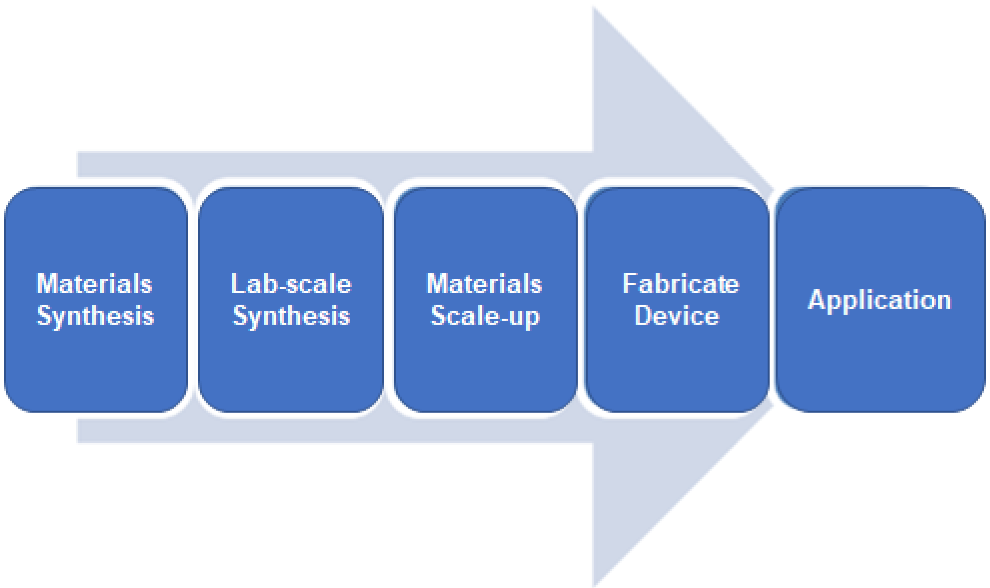
- Developing roll-to roll manufacturing capabilities that are energy efficient, have low environmental impact, ultra-low cost and are employed to manufacture technologies for energy saving applications will have a “global impact”.

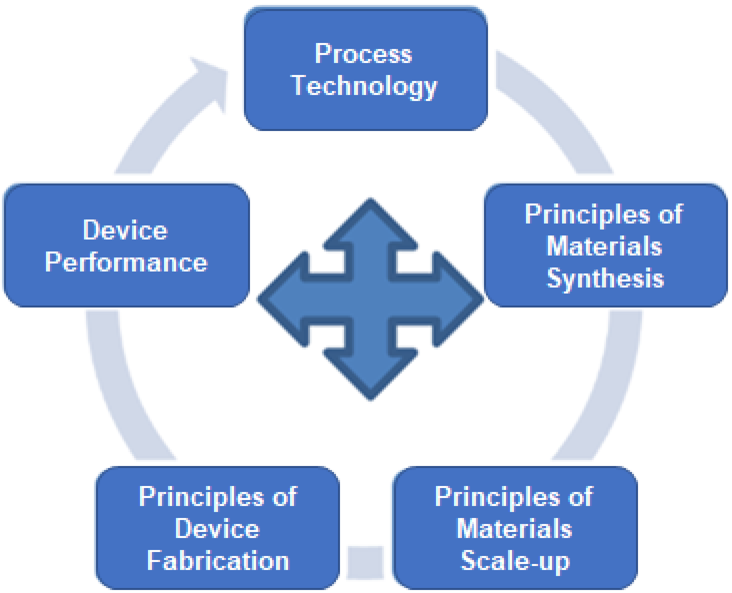
Project / Technical Approach

A collaboration of five DOE labs and industry partners that address challenges in colloidal chemistry, slurry processing, novel deposition, *in situ* characterization and testing, physics and methods of coatings, novel NDE-QC-metrology techniques, macroscopic mathematical modeling of slurries, tomography of coatings, and continuum-scale models to accelerated the design and scale-up of coating processes for continuous roll-to-roll manufacturing



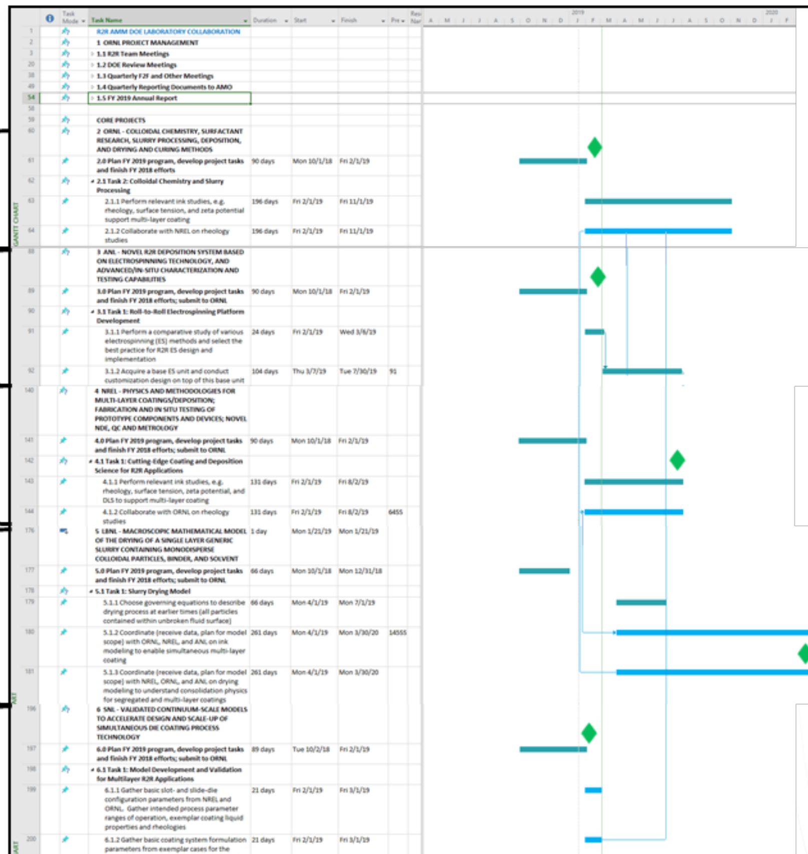
Change from a Linear Approach to An Advanced Materials Manufacturing Approach





Project Tasks and Milestones

- Bi-weekly team meetings are held to review progress on each task.
- DOE Technical Managers attend every other team meeting to receive updates.



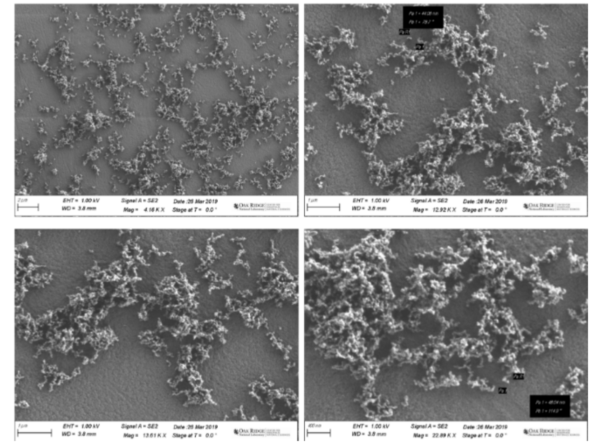
#	Task Name	Duration	Start	Finish	Pre
1	R2R AMM DOE LABORATORY COLLABORATION				
2	1 ORNL PROJECT MANAGEMENT				
3	1.1 R2R Team Meetings				
20	1.2 DOE Review Meetings				
38	1.3 Quarterly F2F and Other Meetings				
49	1.4 Quarterly Reporting Documents to AMO				
54	1.5 FY 2019 Annual Report				
58					
59	CORE PROJECTS				
60	2 ORNL - COLLOIDAL CHEMISTRY, SURFACTANT RESEARCH, SLURRY PROCESSING, DEPOSITION, AND DRYING AND CURING METHODS				
61	2.0 Plan FY 2019 program, develop project tasks and finish FY 2018 efforts	90 days	Mon 10/1/18	Fri 2/1/19	
62	2.1 Task 2: Colloidal Chemistry and Slurry Processing				
63	2.1.1 Perform relevant ink studies, e.g. rheology, surface tension, and zeta potential support multi-layer coating	196 days	Fri 2/1/19	Fri 11/1/19	
64	2.1.2 Collaborate with NREL on rheology studies	196 days	Fri 2/1/19	Fri 11/1/19	
88	3 ANL - NOVEL R2R DEPOSITION SYSTEM BASED ON ELECTROSPINNING TECHNOLOGY, AND ADVANCED/IN-SITU CHARACTERIZATION AND TESTING CAPABILITIES				
89	3.0 Plan FY 2019 program, develop project tasks and finish FY 2018 efforts; submit to ORNL	90 days	Mon 10/1/18	Fri 2/1/19	
90	3.1 Task 1: Roll-to-Roll Electrospinning Platform Development				
91	3.1.1 Perform a comparative study of various electrospinning (ES) methods and select the best practice for R2R ES design and implementation	24 days	Fri 2/1/19	Wed 3/6/19	
92	3.1.2 Acquire a base ES unit and conduct customization design on top of this base unit	104 days	Thu 3/7/19	Tue 7/30/19	91
140	4 NREL - PHYSICS AND METHODOLOGIES FOR MULTI-LAYER COATINGS/DEPOSITION; FABRICATION AND IN SITU TESTING OF PROTOTYPE COMPONENTS AND DEVICES; NOVEL NDE, QC AND METROLOGY				
141	4.0 Plan FY 2019 program, develop project tasks and finish FY 2018 efforts; submit to ORNL	90 days	Mon 10/1/18	Fri 2/1/19	
142	4.1 Task 1: Cutting-Edge Coating and Deposition Science for R2R Applications				
143	4.1.1 Perform relevant ink studies, e.g. rheology, surface tension, zeta potential, and DLS to support multi-layer coating	131 days	Fri 2/1/19	Fri 8/2/19	
144	4.1.2 Collaborate with ORNL on rheology studies	131 days	Fri 2/1/19	Fri 8/2/19	64SS
176	5 LBNL - MACROSCOPIC MATHEMATICAL MODEL OF THE DRYING OF A SINGLE LAYER GENERIC SLURRY CONTAINING MONODISPERSE COLLOIDAL PARTICLES, BINDER, AND SOLVENT	1 day	Mon 1/21/19	Mon 1/21/19	
177	5.0 Plan FY 2019 program, develop project tasks and finish FY 2018 efforts; submit to ORNL	66 days	Mon 10/1/18	Mon 12/31/18	
178	5.1 Task 1: Slurry Drying Model				
179	5.1.1 Choose governing equations to describe drying process at earlier times (all particles contained within unbroken fluid surface)	66 days	Mon 4/1/19	Mon 7/1/19	
180	5.1.2 Coordinate (receive data, plan for model scope) with ORNL, NREL, and ANL on ink modeling to enable simultaneous multi-layer coating	261 days	Mon 4/1/19	Mon 3/30/20	145SS
181	5.1.3 Coordinate (receive data, plan for model scope) with NREL, ORNL, and ANL on drying modeling to understand consolidation physics for segregated and multi-layer coatings	261 days	Mon 4/1/19	Mon 3/30/20	
196	6 SNL - VALIDATED CONTINUUM-SCALE MODELS TO ACCELERATE DESIGN AND SCALE-UP OF SIMULTANEOUS DIE COATING PROCESS TECHNOLOGY				
197	6.0 Plan FY 2019 program, develop project tasks and finish FY 2018 efforts; submit to ORNL	89 days	Tue 10/2/18	Fri 2/1/19	
198	6.1 Task 1: Model Development and Validation for Multilayer R2R Applications				
199	6.1.1 Gather basic slot- and slide-die configuration parameters from NREL and ORNL. Gather intended process parameter ranges of operation, exemplar coating liquid properties and rheologies	21 days	Fri 2/1/19	Fri 3/1/19	
200	6.1.2 Gather basic coating system formulation parameters from exemplar cases for the multilayer coating models (NREL and ORNL).	21 days	Fri 2/1/19	Fri 3/1/19	

Note: Chart truncated for illustrative purposes

Vertical lines represent connected collaborative efforts between the 5 labs where materials and/or data are exchanged

Results and Accomplishments – Colloidal Chemistry and Slurry Processing

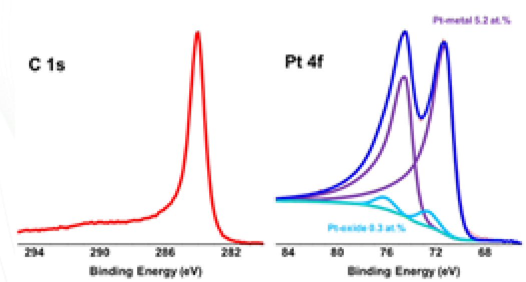
- Surface chemistry for Pt/C particles was assessed using EDS and XPS and the average carbon primary particle size was determined to be approximately 50 nm.
- Elemental analysis showed a uniform distribution of platinum on the surface of the carbon particles.
- Zeta potential measurements were performed on colloidal suspensions of Pt/C particles dispersed in water, isopropyl alcohol, and Nafion D2020. Zeta potential decreases when the isopropyl alcohol content is increased.



SEM images of the carbon particles coated with Pt catalyst; C primary particle size is approximately 50 nm

Surface Composition (at.%)

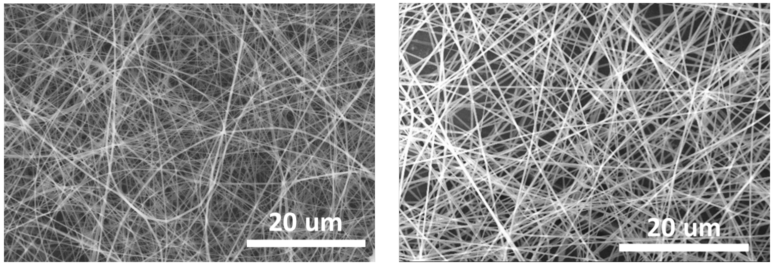
	C	O	Pt	N
C-Pt	87.8	6.7	5.5	trace



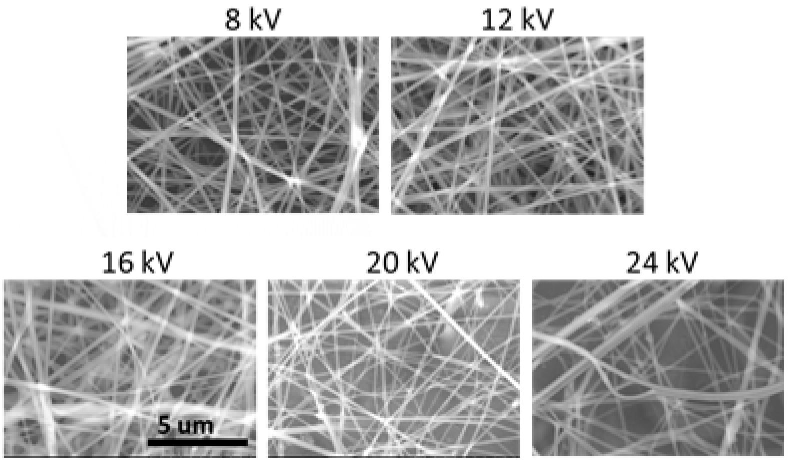
XPS core data analysis and the element at% on the surface of the particles

Results and Accomplishments – Electrospinning Recipe, Materials and Platform Development

- Demonstrated that water and acetic acid provided structurally-sound electrospinning (ES) nanofibers and organic solvents resulted in thicker fibers with the fiber diameter being dependent on the feed rate
- Conducted studies of various ES methods and steady-shear rheology for ES ionomer/catalyst slurries
- Developed optimum ES recipes and demonstrated LLZO and LSCF precursor nanofibers
- Developed sintering path to convert LLZO precursor nanofibers to ceramic nanofibers with desirable crystal structure
- Correlated agglomerate size changes of a catalyst to cell performance by combining the x-ray scattering data with TEM and in-situ electrochemical testing



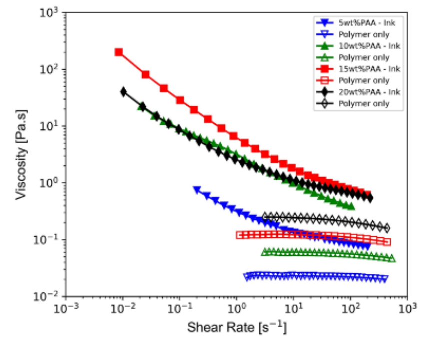
SEM images of as-spun polymer precursor nanofibers of LLZO (left) and LSCF (right)



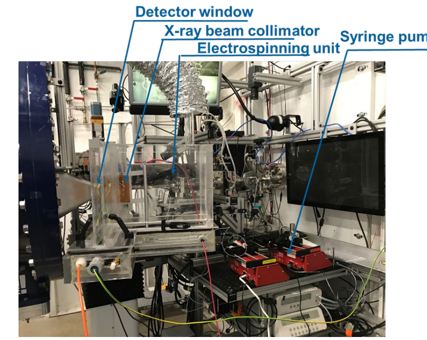
SEM images of the as-spun LLZO polymer precursor nanofibers that were synthesized under different voltages

Results and Accomplishments – Fabrication & In Situ Testing of Prototype Devices

- Performed initial rheology studies of ES slurries using polyacrylic acid (PAA) as the carrier polymer demonstrating the ionomer/PAA slurries are all Newtonian across the range of PAA solids loadings and the ionomer/particle/PAA slurries are all shear-thinning



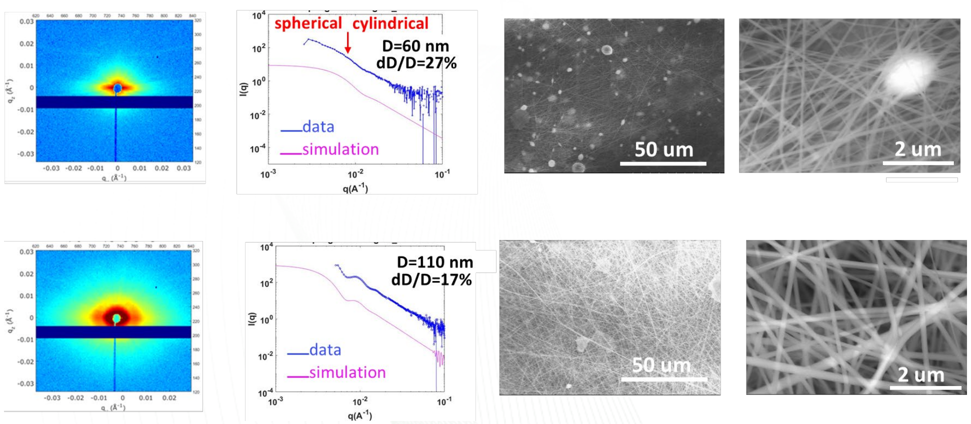
Steady-shear rheology of ionomer/PAA and ionomer/particle/PAA slurries



ES unit mounted at 12-ID-B beamline of APS for in-situ SAXS study of ES process

- Demonstrated SAXS to be capable of capturing electrospun nanofiber morphology features. The fiber diameters derived from SAXS data gave good consistency with SEM characterization.

- Demonstrated USAXS-SAXS-WAXS to be a powerful in-situ technique to study the dispersion of fuel cell catalyst inks



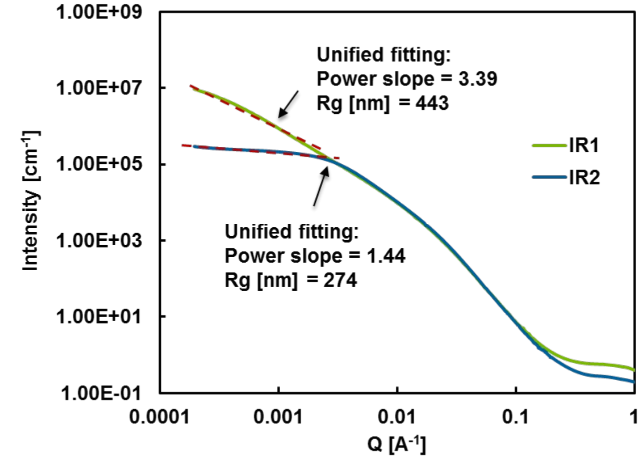
2D-SAXS data (left), intensity profile (middle), SEM images (right) of two LLZO nanofiber samples wtih different morphologies and diameters

Results and Accomplishments - Advanced Ink and Membrane Characterization

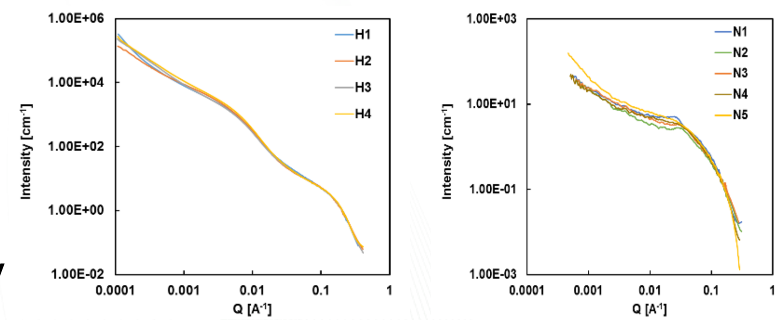
- Performed USAXS data on iridium oxohydroxide (IrO_x) catalyst-ionomer inks with different dispersion formulations and solvent compositions

- Demonstrated a lower population of agglomerates as the aggregates are uniformly distributed in the catalyst ink indicating a reduction in the agglomerate size with the addition of ionomer, which correlates with known rheological behavior showing that the unsupported catalyst ink is stabilized against agglomeration by ionomer

- Investigated ink formulations for the effect of solvent and ionomer on the structure-rheology correlation of Pt/Vulcan and Pt/HSC inks.



USAXS profiles and fitting results for IrO_x inks with and without ionomer



USAXS profiles of Pt/Vulcan or Pt/HSC ionomer inks using various solvent ratios and ionomer contents

Argonne NATIONAL LABORATORY | NREL NATIONAL RENEWABLE ENERGY LABORATORY | BERKELEY LAB | Sandia National Laboratories | OAK RIDGE National Laboratory | NATIONAL TRANSPORTATION RESEARCH CENTER | MANUFACTURING DEMONSTRATION FACILITY

Results and Accomplishments - Cutting-Edge Coating & Deposition Science

- Developed an empirical ink/coating model for multi-layer slide die coating
  - Conducted a process window analysis for a two-layer construction (i.e. membrane + one electrode)
  - Model predicts that the target total thickness is achievable
- Performed blade coating of single-layer membranes to understand the efficacy of coated ionomer layers with respect to membrane functionality (precursor study to multilayer coating)
  - Cast membrane thicknesses were within the intended range for several electrochemical applications
  - Conductivities were comparable to a commercially available comparator (Nafion)

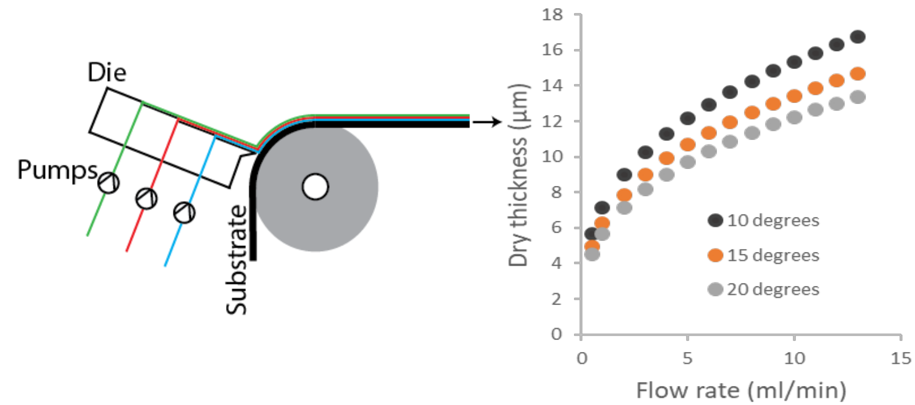
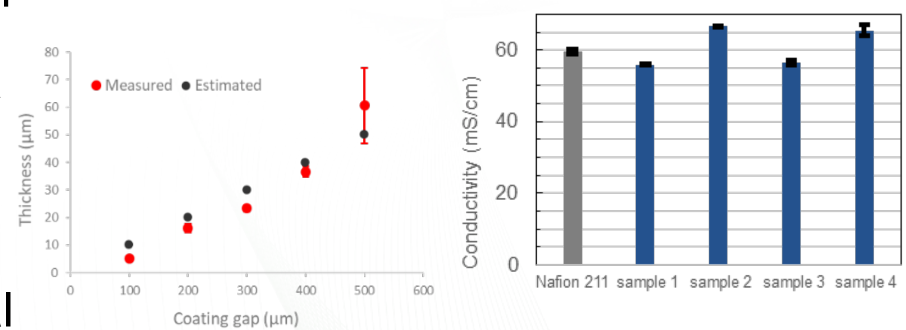


Diagram of a three-layer slide die flow (left) and results of empirical process window model for total dry thickness of a two-layer slide die coating as a function of flow rate (right)

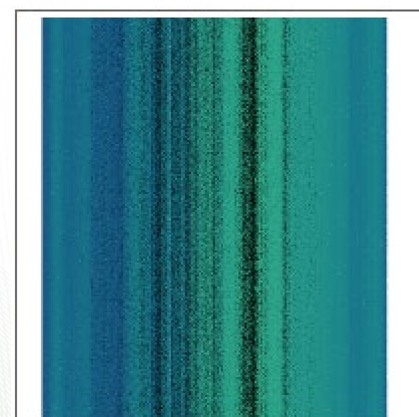


Cast membrane thickness as a function of coating gap (left) and proton conductivity of the cast membranes compared to a commercially available membrane (right)

Results and Accomplishments - Novel NDE, QC, and Metrology Methods

- Continued to study multi-spectral techniques for in-line real-time imaging of thickness of commercially available, proprietary, and experimental polymer films for various applications, including barrier films and energy conversion
  - Performed UV-Vis and near-IR fast spectroscopy (single-point) to establish feasibility of the method on a range of membrane materials and structures
  - One output is that membranes thicker than ~50 μm (required for many applications) will require a higher wavelength range than our current imager
  - Performed thickness imaging in-line on a 100+ meter roll with several membrane materials

NREL metrology web-line with multi-spectral imager, multiple light source, and membrane web path (below) in a reflectance configuration for thickness imaging

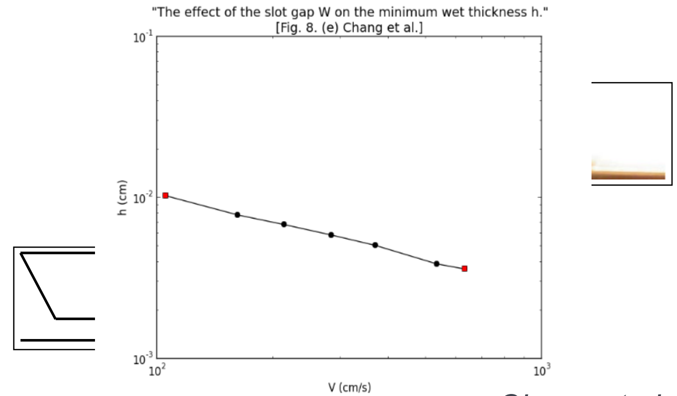


In-line thickness map of a commercial barrier film

Argonne National Laboratory | NREL National Renewable Energy Laboratory | Berkeley Lab | Sandia National Laboratories | Oak Ridge National Laboratory | National Transportation Research Center | Manufacturing Demonstration Facility

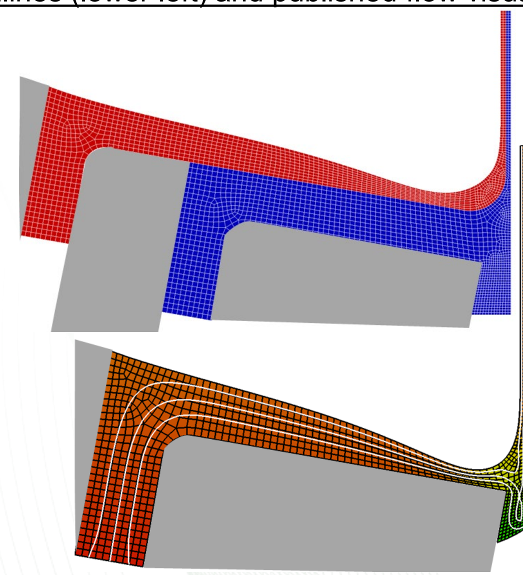
Results and Accomplishments – Model Development & Validation for Multilayer R2R Applications

- *Purpose: Validated models and user-friendly workflows for multilayer slide- and slot-coating processes.* Models will provide valuable design tool for ink-tuning/selection, process parameter space understanding, and process operating window prediction.
- *Results*: Completed initial single-layer slot-die model and workflow and single- and two-layer slide-die process models.
- *Next steps*: Guide ink-design work of NREL slide-coating exemplar with single layer model (rheologies, process parameters). Demonstrate/validate two-layer slot-die deposition model with ORNL coating trials. Begin work on multilayer drying models for dry/cure/oven process design



Chang et al. (2007)

Single-layer slot-die deposition model validation: Pattern of streamlines (lower left) and published flow visualization



Slide coating: two-layer and single-layer predicted pattern of flow and free surface shapen

CRADA Projects

★ FedBizOpps.gov Federal Business Opportunities

E·GOV USA.gov

Home | Getting Started | General Info | Opportunities | Agencies | Privacy

Buyers: Login | Register Vendors: Login | Register Accessibility

ORNL Development Assistance Opportunity for Roll-to-Roll (R2R) Advanced Energy Materials Manufacturing

Solicitation Number: ORNL-R2RAMM-2017-02-02
Agency: Department of Energy
Office: Oak Ridge National Laboratory - UT Battelle LLC (DOE Contractor)
Location: Oak Ridge National Laboratory

Print | Link

Notice Details | Packages

Return To Opportunities List | Watch This Opportunity

Complete View
- Original Synopsis
  Special Notice
  Feb 02, 2017
  2:31 pm
- Changed
  Feb 03, 2017
  12:16 pm

Solicitation Number:
ORNL-R2RAMM-2017-02-02

Notice Type:
Special Notice

Synopsis:
Added: Feb 02, 2017 2:31 pm Modified: Feb 03, 2017 12:15 pm Track Changes

Description

UT-Battelle, LLC, acting under its Prime Contract No. DE-AC05-00OR22725 with the U.S. Department of Energy (DOE) for the management and operation of the Oak Ridge National Laboratory (ORNL), conducts research and development (R&D) in support of the DOE Advanced Manufacturing Office (AMO) and Fuel Cell Technologies Office (FCTO) in conjunction with its R2R Advanced Materials Manufacturing (AMM) Consortium partners Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), the National Renewable Energy Laboratory (NREL), and the Eastman Kodak Company. The AMO AMM Consortium's mission is to assist U.S. manufacturers in the areas of energy storage and conversion, flexible electronics and displays, energy efficiency, and water purification, and develop a robust associated domestic materials and components supply chain. Only projects that have a strong likelihood of creating jobs domestically, reducing air pollutants, petroleum use, and greenhouse gas (GHG) emissions, and boosting system and device energy efficiency are of interest. The selected projects will be conducted under joint Cooperative Research and Development Agreements (CRADAs) between ORNL, ANL, LBNL, NREL, and the industrial partners.

Projects shall focus on advanced materials and component development, synthesis and processing methods, and quality control and metrology in the specific areas of:

ALL FILES
- Printable Notice of Opportunity
  Feb 02, 2017
  AMO-AMM_CRADA-Solici...
- CRADA Template
  Feb 02, 2017
  Roll_to_roll_consort...
- Roll to Roll Consortium Fact Sheet
  Feb 02, 2017
  R2R_AMM_DOE_Lab_Cons...

GENERAL INFORMATION

Notice Type:
Special Notice

Original Posted Date:
February 2, 2017

Posted Date:
February 3, 2017

Response Date:
-

Original Response Date:
-

Archiving Policy:
Manual Archive

Original Archive Date:
-

Archive Date:

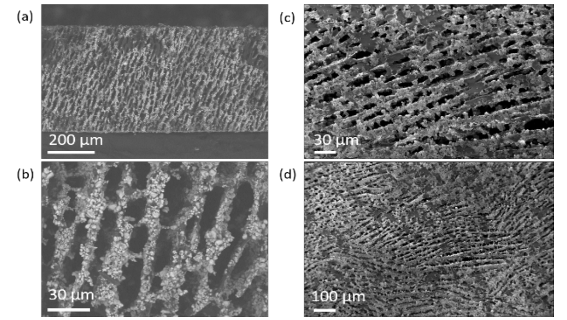
Fisker/LBNL/ORNL: Three-Party CRADA Begins to Demonstrate All-Solid-State LIB Processing

Achievement

Within the framework of the AMO R2R AMM Collaboration, Fisker, Inc. has partnered with LBNL and ORNL to demonstrate all-solid-state batteries based on LLZO separators and cathode scaffolds, and scaled the freeze casting process to the pilot level at ORNL.

Significance and impact

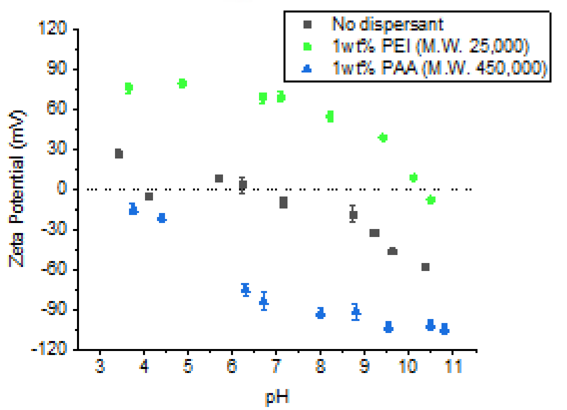
The freeze casting process will be used to enable the high-volume manufacturing of all-solid-state LIBs based on the LLZO electrolyte. These types of LIBs utilize ultra-high-energy-density Li metal anodes, low-cost solid electrolytes, and high-voltage composite cathodes. High-speed scaling of this methodology will assist in achieving the DOE ultimate targets of $80/kWh, 500 Wh/kg, and 10-min charging.



Freeze tape cast LLZO green tapes. (a),(b), fracture surface SEM images of green tapes produced at LBNL. (c),(d), surface SEM images of green tapes

Details and next steps

- Fabricated small-scale slurries at LBNL and ORNL to produce freeze tape cast 2-3 inch porous layers.
- Assessed slurry stability visually and characterized the final pore structure via SEM.
- Measured the surface charge of LLZO particles with and without the presence of dispersants via zeta potential measurements.
- Sputter LiPON interlayers and Li metal anodes.



Zeta potential of LLZO (from NEI) in the presence/absence of dispersants

Navitas/ORNL/NREL: Three-Party CRADA Begins to Demonstrate R2R Production of Advanced Separator and Lithium Ion Batteries

Achievement

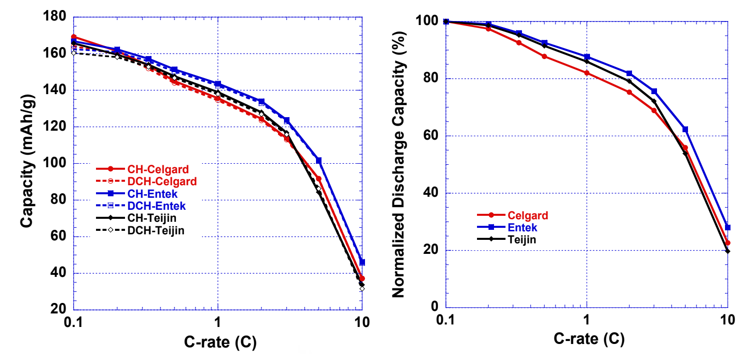
Within the framework of the AMO R2R AMM Collaboration, Navitas Systems, Inc. has partnered with ORNL and NREL to demonstrate R2R production of advanced separator for lithium ion batteries.

Significance and impact

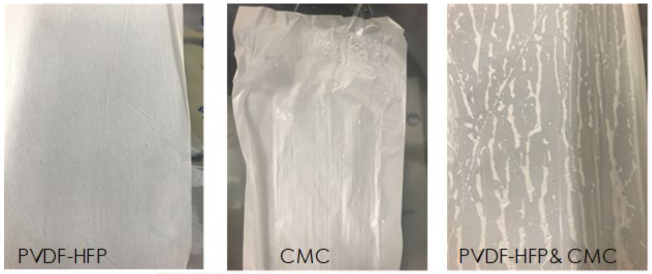
A R2R method will be developed to fabricate the separator, which replaces the conventional discrete operations and enables superior safety, high throughput and low manufacturing cost. According to BatPac, the separator accounts for 6-10% of LIB cost. A 10% increase in electrified powertrains will reduce U.S. oil consumption by 3%, total U.S. energy use by 1%.

Details and next steps

- Completed rate performance testing of the two separators in full coin cells consisting of NMC622 and graphite.
- Prepared 3 formulations of slurries with a binder (PVDF-HFP, CMC, or a combination of the two) in a solvent (NMP, DI-H2O or a mixture of the two) and dispersed a ceramic (Al2O3) in the binder solution. PVDF-HFP in NMP solvent had no significant agglomeration.
- Developed inks of suitable viscosity for spraying and NREL performed initial ink formulation with the ORNL recipe.
- Preparing for patterned spray coating of the separator substrate.



Rate performance comparison with three separators a) capacity vs C-rate and b) normalized discharge capacity vs C-rate



Ceramic coating on separator with various binders

SolarWindow Technologies/NREL/ANL: Three-Party CRADA Begins to Demonstrate Diffractive Multiplexing for High-Throughput Roll-to-Roll Laser Patterning of Flexible Organic Photovoltaic Modules

Achievement

Within the framework of the AMO R2R AMM Collaboration, SolarWindow Technologies Inc. has partnered with NREL and ANL to demonstrate diffractive multiplexing for high-throughput R2R laser patterning of flexible organic photovoltaic modules

Significance and impact

Multiplexing for R2R laser scribing based on a diffractive optical element will be developed to:

1) Drastically reduce up-front capital and on-going operational costs vs. many-laser/optics systems, and
2) Dramatically increase process speeds over galvanometer step-and-scan systems

Details and next steps

- Selected the NREL metrology line as the system for integration of the R2R Multiplex Scribing Technology, obtained approval of the laser enclosure and begin building and aligning the scribing optics system.
- Optimized P1 scribing and initiated P2 scribing optimization and used R2R deposition to coat approximately six meters of material with several layers. Initial results confirmed the P1 scribes effective with complete removal of the conductive oxide layers.

Front of the laser safety enclosure built onto the NREL diagnostic roll-to-roll system

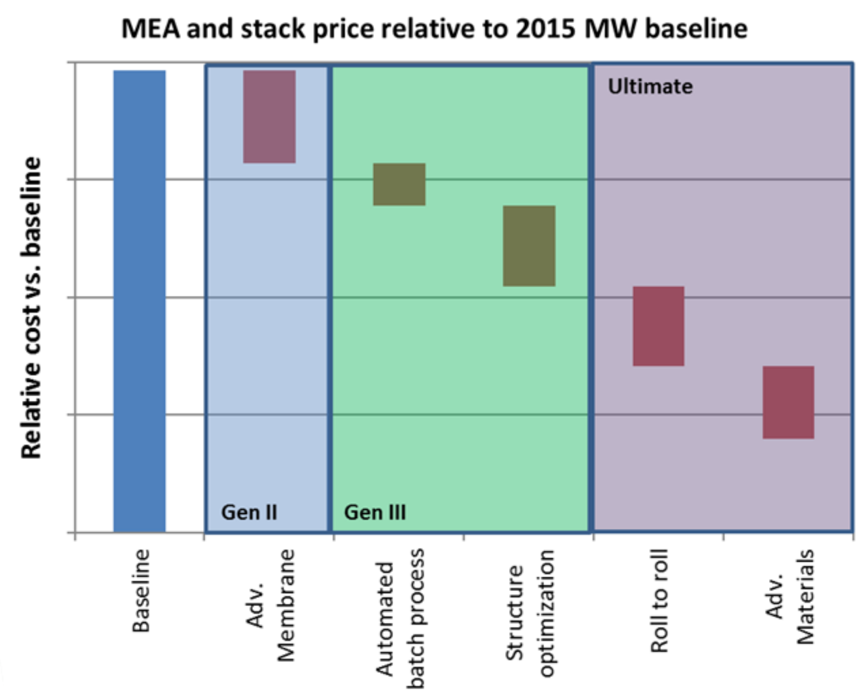
Proton OnSite/NREL/ORNL/ANL: Four-Party CRADA Begins to Research R2R Manufacturing of Electrolysis Electrodes

Achievement

Within the framework of the AMO R2R AMM Consortium, Proton OnSite has partnered with NREL, ORNL, and ANL to research R2R manufacturing of advanced (low loading and directly coated onto membrane) electrolysis electrodes for low-cost hydrogen production.

Significance and impact

Ink characterization and optimization, R2R coating, advanced electrode characterization, and metrology development capabilities of the Consortium will be brought to bear. Overall goals of this development effort are to reduce the manufacturing labor for the membrane electrode assembly (MEA) by a factor of 15-20 and the overall cost of the MEA by over 60%. A secondary goal is to enable integration of thinner membranes due to the improved uniformity in electrode thickness.



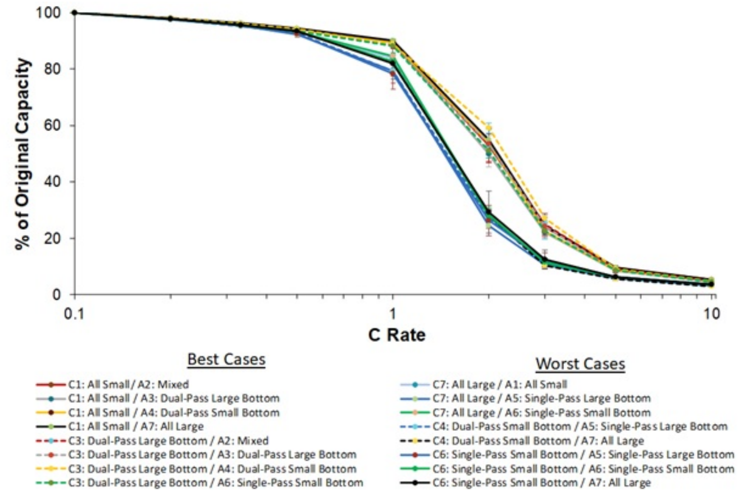
Proton MEA cost waterfall chart

Details and next steps

- CRADA to be approved and executed.

Transition (beyond DOE assistance)

Results of experimentation and computational modeling will be made available to commercial and industrial organizations through open sources.



Experimental data and computational models will be shared with industry partners, as requested, and in open publications for use by any companies with similar technologies.

Argonne NATIONAL LABORATORY
NREL NATIONAL RENEWABLE ENERGY LABORATORY
BERKELEY LAB
Sandia National Laboratories
OAK RIDGE National Laboratory | NATIONAL TRANSPORTATION RESEARCH CENTER | MANUFACTURING DEMONSTRATION FACILITY

Transition: Information dissemination (FY19)

- Batch and Continuous Methods for Evaluating the Physical and Thermal Properties of Films, Bhushan Lal Sopori, Michael Joseph Ulsh, Przemyslaw Rupnowski, Guido Bender, Michael Mihaylov Penev, Jianlin Li, David L Wood III, Claus Daniel, US Patent App. 15/554,551, 2018

- Park, J., N. Kariuki, D. J. Myers, S. A. Mauger, K. C. Neyerlin, and M. Ulsh, “In Situ X-Ray Scattering Characterization of PEMFC Catalyst Ink Microstructure during Ink Processing”, 233rd Electro Chemical Society Meeting, , MA2018-01 1794, 2018.

- Rupnowski, P., M. Ulsh, B. Sopori, B.G. Green, D.L. Wood III, J. Li, Y. Sheng. “In-line monitoring of Li-ion battery electrode porosity and areal loading using active thermal scanning – modeling and initial experiment.” *J. Power Sources*, 375, p.138-148, 2018.

- Zhange Feng, Pallab Barai, Jihyeon Gim, Ke Yuan, Yimin A. Wu, Yuanyuan Xie, Yuzi Liu, and Venkat Srinivasan, “In Situ Monitoring of the Growth of Nickel, Manganese, and Cobalt Hydroxide Precursors during Co-Precipitation Synthesis of Li-Ion Cathode Materials”. *Journal of The Electrochemical Society*, 165 (13) A3077-A3083 (2018)

- Daniel, Claus; Wood III, David; Krumdick, Gregory; Ulsh, Michael; Battaglia, Vince; Crowson, Fred “Roll-to-Roll Advanced Materials Manufacturing DOE Laboratory Collaboration - FY2018 Final Report”, ORNL/SPR-2019/1066, January 2019. DOI: 10.2172/1502542

- Barai, P.; Feng, Z.; Kondo, H.; Srinivasan, V. “Multiscale Computational Model for Particle Size Evolution during Coprecipitation of Li-Ion Battery Cathode Precursors, *J. Phys. Chem.* B, March 19, 2019, 123 (15), pp 3291–3303, DOI: 10.1021/acs.jpcb.8b12004
- S.A. Mauger, C.F. Cetinbas, J.H. Park, K.C. Neyerlin, R.K. Ahluwalia, D.J. Myers, S. Khandavalli, L. Hu, S. Litster, M. Ulsh, “Control of Ionomer Distribution and Porosity in Roll-to-Roll Coated Fuel Cell Catalyst Layers”, 2018 Fuel Cell GRC, 2018
- S.A. Mauger, C.F. Cetinbas, J.H. Park, K.C. Neyerlin, R.K. Ahluwalia, D.J. Myers, S. Khandavalli, L. Hu, S. Litster, M. Ulsh, “Control of Ionomer Distribution in Roll-to-Roll Coated Fuel Cell Catalyst Layers”, 19th International Coating Science and Technology Symposium, 2018.

For more details see our posters

- Tuesday poster session – 5-7 pm

21	**Roll to Roll Manufacturing**	AMM-R2R - Roll-to-Roll Manufacturing Science and Applications: From Ideal Materials to Real-World Devices	Gregory Krumdick
20		AMM-R2R - Roll-to-Roll Manufacturing Science and Applications: Accelerate R2R Materials Manufacture for Energy Storage and Generation	Mike Ulsh
6		AMM-R2R - Applied Materials Genome Initiative - From Ideal Materials to Real-World Devices	Vince Battaglia

Questions?

Acknowledgments

Sponsors

AMO: Valri Lightner, Isaac Chan, Brian Valentine, Bob Gemmer

FCTO: Sunita Satyapal, Nancy Garland, Shukhan Chan

Contributors

Claus Daniel, Michael Ulsh, David Wood, Vince Battaglia, Greg Krumdick, Randy Schunk, Jianlin Li, Jaswinder Sharma, Georgios Polyzos, Bryant Polzin, Jae Hyung Park, Deborah Myers, Donna Brunner, Erik Dahl, Yuepeng Zhang, Peter Rupnowski, Scott Mauger, Maikel van Hest, Kenneth C. Neyerlin, Bertrand Tremolet de Villers, Marca Doeff, Eongyu Yi, Kenneth Higa, Fred Crowson