

Roll to roll advanced materials manufacturing lab consortium

Project ID: MN018

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2017 U.S. DOE Hydrogen and Fuel Cells Program Annual Merit Review

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Overview

Timeline and Budget

- Project Start Date: 10/01/2016
- FY17 DOE/FCTO Funding: \$1M (for CRADA work) leveraging \$4M of AMO funding
- Anticipated recipient share: \$1M
- FY17 spent: \$0 of FCTO

Partners

- ORNL, ANL, LBNL, NREL
- Eastman Business Park
- Industry partners as selected through open CRADA call

Barriers

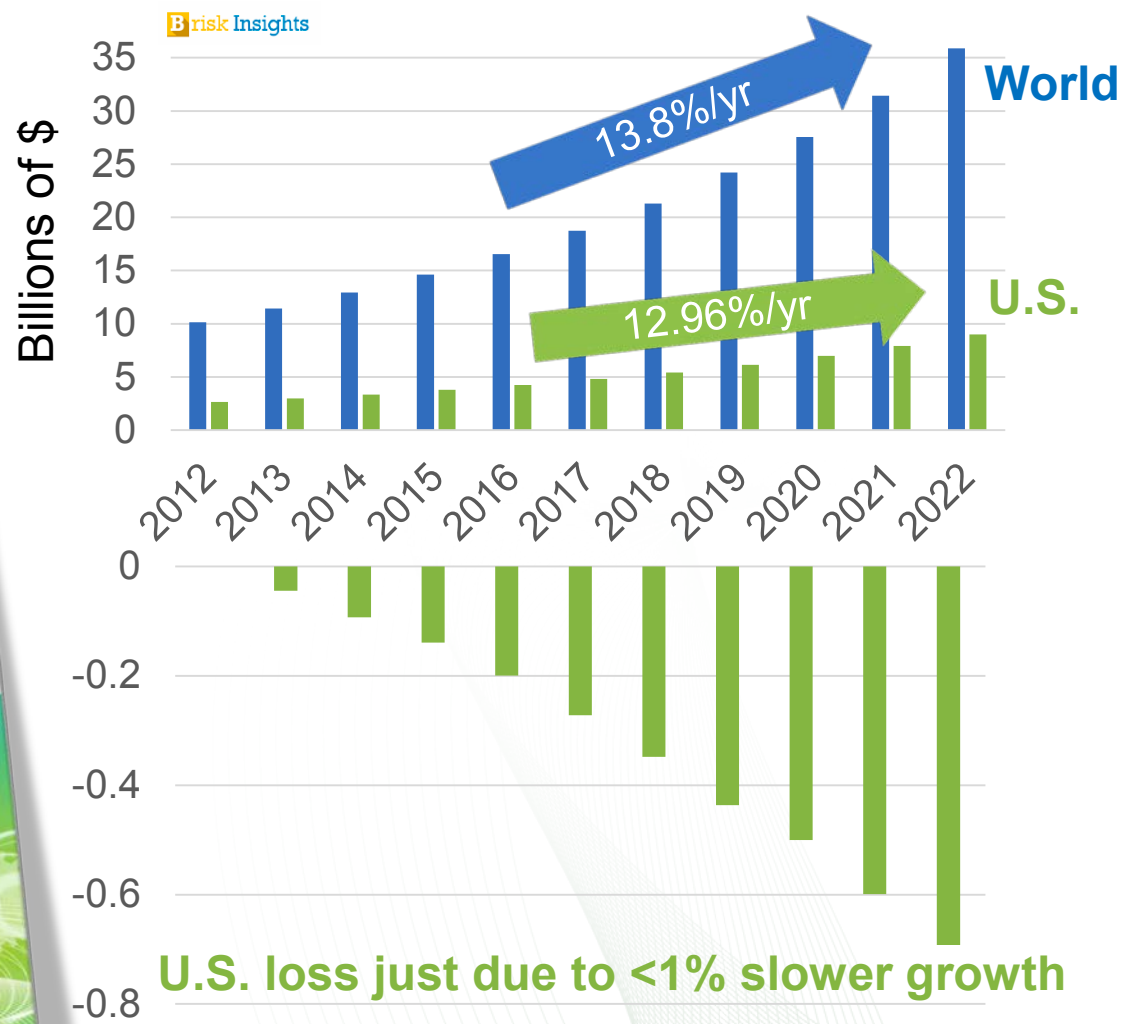
- High cost of manufacturing
- Goals:
 - Utilize roll to roll manufacturing to reduce the cost of automotive fuel cell stacks at high volume (500,000 units/year) from the 2008 value of \$38/kW to \$20/kW by 2020.
 - Integrate roll to roll with fabrication and assembly processes to produce compressed hydrogen pressure vessels to enable a total onboard storage system cost of \$10/kWh for widespread commercialization of hydrogen fuel cell vehicles across most light-duty platforms by 2020, with an ultimate target of \$8/kWh.

Relevance and motivation

Roll to roll manufacturing development is a \$10Bn opportunity for the U.S.

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

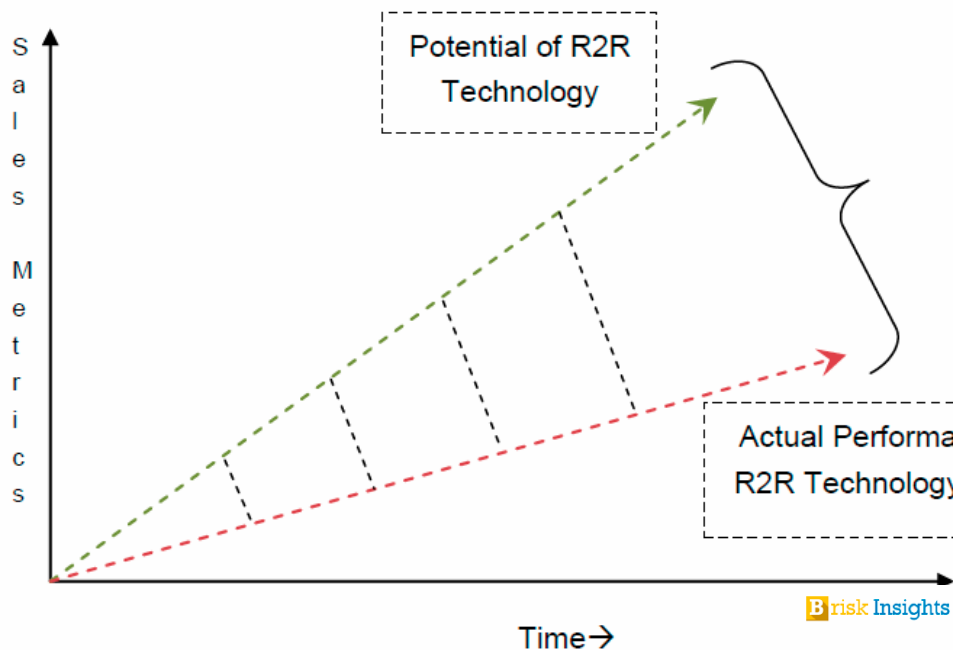
Mission innovation and clean energy development could easily triple the opportunity.



Relevance Needs for R2R development

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



Brisk Insights recommendations:

- Establish standardized infrastructure.
- Establish parameters affecting defects control and throughput for various processes
- Establish pilot-line facilities for development and optimization of full processes
- Carefully address equipment and quality concerns

Approach

Our current effort in short (\$4M AMO/\$1M FCTO)

- Lab-industry consortium will enable the United States to capture a substantial portion of this \$10Bn opportunity on membranes and flexible devices
- Growth and cost reduction limitation and competitiveness limited primarily by limited R2R integration, production yield, and limitation of advanced technologies
 - **Goals depending on technology area:**
 - Increase throughput by 5x and reduce production footprint
 - Reduce energy consumption by 2x
 - Increase production yield by 2x
 - Enable substantial shift of manufacturing to the United States by assisting in the development of a domestic supply chain
- EERE as a whole will substantially benefit from AMM Consortium through integration and leveraging of solutions to program office specific applications.
- MRL2-5 tackled in core programs at national laboratories with an industrial CRADA program to move to MRL7.

Approach

Lab-industry consortium funding structure

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

Project Management (\$100k/year)
National Lab Core Funding (\$2.452M/year)
Eastman Kodak Pilot Line (\$48k/year)

\$2.4M/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

Approach

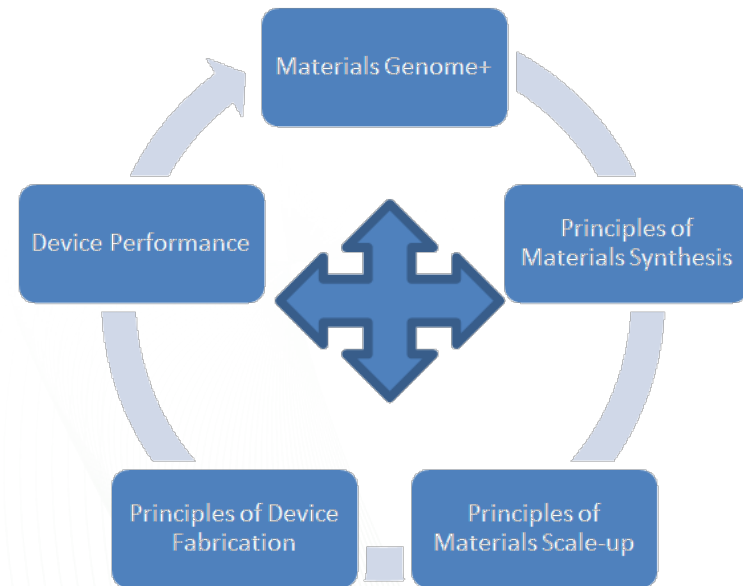
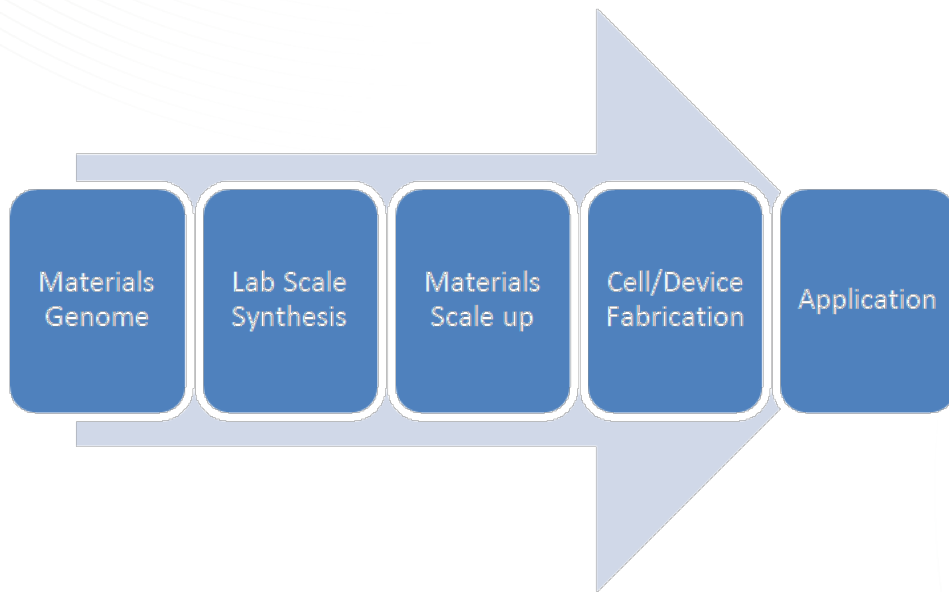
Lab-industry Partnership started with ORNL-Kodak MOU and is spanning the network to assist commercialization



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

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



CRADA solicitation selection process

- FedBizOps solicitation
- Pre-negotiated CRADA with no negotiation with industry
- Short response time from industry
 - Selection criteria
 - MRL level and potential change in MRL due to proposed barrier being removed
 - Technology alignment with EERE and consortium
 - Application of primary metrics of success: Throughput, energy, yield
- Recommendation for funding provided to DOE for final selection
- 10-18 month execution on CRADAs

Key applications for investments by DOE

R2R

Membranes

Flexible devices

Chemical separation

Water purification

Water desalination

Batteries

Fuel cells

Photovoltaics

Electronic films

Window films

Two examples in numbers

Batteries

- Baseline technology cell cost
 - 2.5x of target of \$100-125/kWh (with state-of-the-art materials and processing)

Fuel cells

- Polymer electrolyte fuel cell stacks
 - 10x of target of \$30/kW (in today's volumes without novel HV-R2R manufacturing)

Novel R2R manufacturing technologies will enable cost reduction while VTO/FCTO investments in new materials and electrodes increase energy density, power density, and reliability.

Fuel cells/Electrolysis

- Status:

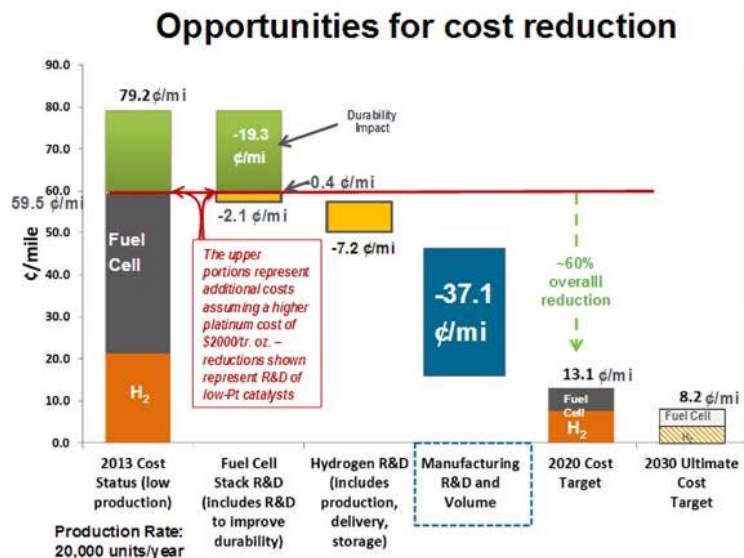
- R2R is the only manufacturing process platform that will meet cost and volume targets
- R2R enables conversion of multiple dissimilar materials into a multi-layer cell
- All DOE-sponsored cost analyses for high volume production of MEAs/cells assume R2R processing.

- Cost reduction need: 60 cents/mile in 2013 to 13 cents/mile in 2020

- Barriers:

- Registration
- integrated gasketing and multi-layer structures
- proving-out low-Pt concepts
- in-line quality control
- demonstrating different layer structures at high volume
- controlling ionomer distribution in the electrode as a function of process parameters
- understanding material-process-performance relationships
- understanding effects of process variations
- increasing throughput
- increasing width

FCEV Cost Reduction Pathways

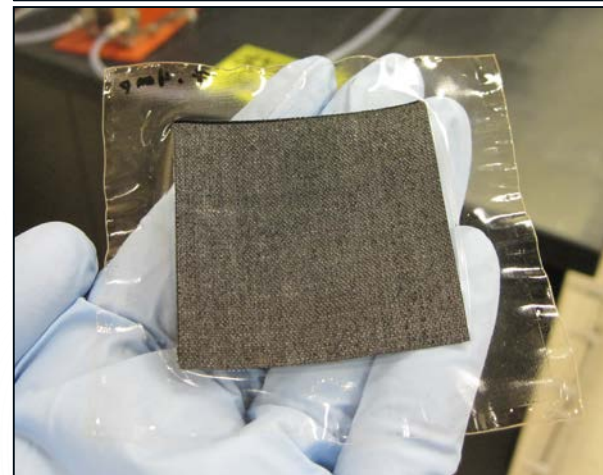
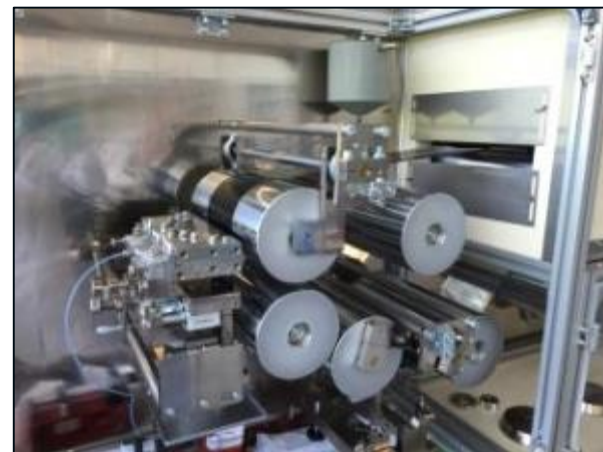


Fuel Cells core lab project: background

- Gas diffusion electrodes (GDE) are recently becoming of more interest in the industry as an alternate or possibly combined fabrication pathway for MEAs
 - GDEs entail a different set of variables that may provide improved performance and lifetime in some cases
- Fabrication of MEAs based on GDEs can require different material structures than CCMs, and, for scaling of GDE-based MEAs, this means potentially different process techniques and conditions
 - An additional layer of ionomer is often required between the GDE electrode and membrane
- These material and process parameters need to be understood and optimized for scalable processes to support increased throughput, increased quality, and reduced cost for high volume production of MEAs

FC Core Lab Project – All Tasks

1. [NREL] Explore phase-separation and other single-coating-layer methodologies to achieve an ionomer-rich surface on the GDE electrode using slot and/or micro-gravure coating
2. [ORNL] Explore dual-slot coating of electrode/ionomer to achieve a similar structure
3. [LBNL] Develop and provide flow visualization and process modeling under conditions relevant to the processes being explored by NREL and ORNL of single and bi-layer electrode ink structures, with a focus on particle-ionomer interactions
4. [ANL] Provide USAXS characterizations of inks under different ultrasonic and shear mixing conditions
5. [ANL] Provide high-throughput exploration of ink synthesis parameter space, as necessary, based on initial formulation studies at NREL and ORNL
6. [ANL] Provide nano- and/or micro- x-ray tomography of coated electrodes
7. [ORNL] Provide high-resolution microscopy of coated electrodes
8. [NREL] Make MEAs from the GDE sheets (made in tasks 1 and 2) using standard methods
9. [ORNL] Explore roll lamination of GDE sheets (made in tasks 1 and 2) and membranes using the calender
- 10.[NREL, ANL] Test hot-pressed and calendered MEAs for performance



Development Assistance Opportunity for Roll-to-Roll (R2R) Advanced Energy Materials Manufacturing – FedBizOpps.gov Solicitation Number: ORNL-R2RAMM-2017-02-02

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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

Notice Details Packages

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Complete View

- Original Synopsis: 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:

GENERAL INFORMATION

Notice Type: Special Notice

Original Posted Date: February 2, 2017

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Roll-to-Roll Advanced Materials Manufacturing DOE Laboratory Consortium

Consortium Background

A DOE laboratory consortium comprised of Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), National Renewable Energy Laboratory (NREL), and Lawrence Berkeley National Laboratory (LBNL), working with industry partners, was formed to address enhancing battery electrode performance and roll-to-roll (R2R) manufacturing deficiencies using an advanced materials manufacturing (AMM) approach. A FY 2016 seed project developed a materials genome synthesis process amenable to R2R manufacturing and provided modeling, simulation, manufacturing and process controls that demonstrate the feasibility of process controls and scale-up potential for an enhanced battery electrode. The FY 2017 program takes a similar approach for the following technology areas:

- Polymer electrolyte fuel cells (PEFCs) and membrane electrolyzers
- Advanced battery materials
- Flexible electronics and displays
- Energy efficient window films
- Energy efficient photovoltaic (PV) cells
- Water separation and purification membranes

Laboratory Capabilities

The R2R AMM DOE Consortium Laboratories possess the following infrastructure, testing, operations, characterization, and analysis capabilities:

- Precision coating equipment
- Pilot-scale R2R operations support
- Device assembly assistance
- Electrochemical and cell performance evaluation
- State-of-the-art microscopy and tomography
- Surface characterization
- X-ray and neutron characterization facilities
- Computational science
- Process modeling and characterization capabilities
- World-class data analysis
- In-line quality control

Current Efforts

In addition to a core program of manufacturing technology and process development for the various technology areas, FY 2017 plans also include the release of 12 to 18 joint Cooperative Research and Development Agreements (CRADAs) between ORNL, ANL, LBNL, NREL, and industrial partners requiring industry to provide at least a 50% cost share, which can be monetary funds or in-kind contribution (e.g., facilities, services, and staff time).

Closing the Commercialization Gap

The Consortium works with industry to develop solutions to difficult R2R manufacturing problems that will allow rapid transfer of manufacturing and processing technologies resulting in cost-effective and energy efficient products to the market place. This requires a process "ecosystem" approach with a materials to prototyping vision.

Mission

The mission of the Consortium is to address the manufacturing "gap" that is developing in R2R between U.S. manufacturers and the rest of the world. The consortium will enable U.S. manufacturers of energy-efficient storage devices and water purification conversion technologies that reduce pollutants/waste to better compete in the world market. The Consortium Laboratories have unique capabilities that complement each other for the research, development, testing and evaluation of energy saving technologies.

Objective

The objective of the Consortium is to partner with material, component, device, and system manufacturers in order to investigate, improve, and scale R2R process methodology that will increase manufacturing levels to internationally significant quantities. Creation and preservation of domestic manufacturing jobs is a primary goal.

Process Ecosystem

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    graph TD
        MANUFACTURE --> TEST
        TEST --> ANALYZE
        ANALYZE --> THINK & MODIFY
        THINK & MODIFY --> PROTOTYPE
        PROTOTYPE --> MANUFACTURE
    
```

For more information, contact: p2RAMM@ornl.gov

transport properties based on structural data from multiple experimental techniques. In addition, ANL has developed techniques for in situ visualization of processing (e.g., X-ray radiography/tomography during drying) and linking process conditions to performance characteristics using mathematical models.

National Renewable Energy Laboratory (NREL)

NREL advances the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies. NREL has capabilities in high-throughput combinatorial synthesis and high-throughput ex situ characterization and mapping, including small-scale ink processing including formulation, mixing, viscosity, spray coating using ultrasonic spin, knife, and rod coating, spray coating using slot aerosol jet, ink jet, electro-spray/spray, R2R coating using slot die, micro-gravure, and atomic layer deposition, and on-line inspection using real-time optical and infrared imaging for detection. Current Consortium efforts are to develop and validate in-line diagnostics, including optical, thermal, and x-ray techniques and relevant modeling for real-time evaluation of material properties such as porosity and phase-loading, conduct a study of novel multi-layer and phase-separated PEFC gas diffusion electrode structures and understand structure-process-performance relations; develop and prototype novel structures and processing of multi-layer, multi-functional R2R water filtration elements, and explore process feedback control and algorithms to understand key needs for R2R manufacturing.

Lawrence Berkeley National Laboratory (LBNL)

LBNL fosters groundbreaking fundamental science that enables transformational solutions for energy and environment challenges, using interdisciplinary teams and by creating advanced new tools for scientific discovery. Current Consortium efforts are to develop a large-scale database of synthesis for battery materials, develop an in situ visualization technique for mixing and drying to mimic the R2R process and understand colloidal interactions, relate colloidal models to rheological properties and fluid dynamic properties (viscosity, thixotropic properties, etc.), provide a detailed drying model to predict the data with various process conditions, model particles in the different layers formed by angle pass, dual pass and slot die processes, model electrical conductivity of battery electrodes during calendaring, and collaborate with industry on manufacturing problems requiring modeling.

For more information, contact: p2RAMM@ornl.gov

Summary

- **Relevance:**

- Develop roll to roll manufacturing techniques to reduce the cost of automotive fuel cell stacks at high volume (500,000 units/year) from the 2008 value of \$38/kW to \$20/kW by 2020.
- Integrate roll to roll with fabrication and assembly processes to produce compressed hydrogen pressure vessels to enable a total onboard storage system cost of \$10/kWh for widespread commercialization of hydrogen fuel cell vehicles across most light-duty platforms by 2020, with an ultimate target of \$8/kWh.

- **Approach:**

- Assist with lower tier research and development for technical barriers proposed by industry through a competitive CRADA process

- **Collaborations:**

- ORNL, ANL, LBNL, NREL, Eastman Business Park, industry

- **Accomplishments:**

- Common CRADA terms and conditions negotiated between DOE and four laboratories
- CRADA call posted on FedBizOpps.gov – Solicitation ORNL-R2RAMM-2017-02-02

- **Future Work:**

- Industry submission of technical proposals
- Selection of CRADA projects
- Negotiation of SOW and start of projects