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Membrane Electrode Assembly Manufacturing Automation Technology for the Electrochemical Compression of Hydrogen

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DOE Hydrogen and Fuel Cells Program
2018 Annual Merit Review and Peer Evaluation Meeting

Project ID: h2006

Overview

Timeline and Budget

- Project start date: 05/01/18
- Project end date: 11/01/19
- Total project budget: $371,240
  - Total partner share: $150,000
  - Total federal share: $150,000
  - Total partner in-kind: $71,240
  - Total DOE funds spent*: $0

* As of 4/17/18

Barriers

- Lack of High-Volume MEA Processes
- Low Levels of Quality Control

Partners

- HyET
- NREL
- LBNL (associated project with HyET)

Relevance

- Relevance (H_2@Scale CRADA call)
  - Develop materials, processing techniques, and/or innovative designs for components used in hydrogen equipment and compressors, to enhance durability
  - Design novel manufacturing approaches and technologies for compressors and pipeline fatigue life and durability
- Objectives:
  - Full rheological understanding of optimum ink formulation for roll-to-roll coating method for catalyst layers + electrochemical hydrogen compression (EHC) relevant tests
  - Implementation of real-time optical/areal quality inspection techniques for electrodes, membranes and MEA (sub)assemblies
  - Compare EHC performance of R2R and manually manufactured MEAs
  - Design and specification of an EHC MEA manufacturing line

Approach

- Approach
  - Project will leverage NREL in-line MEA inspection and electrode scaling capabilities and expertise developed for fuel cell and electrolysis materials, and apply to EHC
  - NREL will develop QC techniques and inks/coating process understanding and will transfer knowledge to HyET
  - HyET will perform in situ testing of coated materials in their hardware/system
  - Project outcomes will inform manufacturing line specification

Approach

- Milestones

Deliverable title	Description	Producer	Due date Month (M)
Suitable ink formulation	Standard operating procedure with a specification for mixing method of specified catalyst and solvents	NREL	M6
Coated electrodes	Either gas diffusion electrode (GDE) or Catalyst Coated Membrane (CCM) type electrodes ready for further assembly into MEAs	NREL	M12
Selection report on inline quality control (QC) inspection methods	Description of inline quality inspection methods for the MEA production for EHC application	NREL	M12
EHC test report on manual vs automated MEA production quality	Test report comparing the EHC performance in single cells and stacks of MEAs 1) produced in the current way, manually and 2) produced with the new developed process	HyET	M16
Manufacturing line design spec	Report on a design study for a new EHC MEA manufacturing line including a list of potential US suppliers of manufacturing equipment	HyET	M18

Accomplishments and Progress

- Funding has not yet been received, therefore there are no technical accomplishments to report
- We were able to leverage a visit to Golden, CO by HyET for other research activities to have a project kick-off meeting, with our LBNL collaborator

Accomplishments and Progress: Responses to Previous Year Reviewers' Comments

- This is a newly awarded project, and thus was not previously reviewed

Collaboration and Coordination

- Industry partner: HyET
  - Defines objectives
  - Defines materials and structures
  - Provides information about applicable manufacturing processes and techniques
  - Performs in situ cell testing of NREL-produced cell materials
  - Defines major parameters for MEA manufacturing line
- National lab partner: NREL
  - Explores and develops relevant inspection techniques for MEA materials
  - Formulates and characterizes inks for scalable electrode processing
  - Explores applicable coating processes
  - Provides methods and coated materials to HyET
  - Assists in the specification of MEA manufacturing line
- Additional partner: LBNL
  - LBNL has project with HyET; NREL and LBNL will coordinate on research as applicable

Challenges and Barriers

- Identifying suitable in-line inspection techniques for HyET MEA materials
- Formulating inks for scalable processes
- Identifying scalable process methods and procedures for high-volume electrode production

Proposed Future Work

- See milestone plan

Technology Transfer Activities

- Under the CRADA, applicable technology will be transferred to the industry partner
- NREL will assist HyET in the implementation of project outcomes

Summary

- Project awarded under H_2@Scale CRADA call
  - Industry partner: HyET
  - Lab partner: NREL
- Approach: leverage NREL manufacturing R&D capabilities developed for fuel cells to similar EHC materials and processes
- Relevance: develop materials, processes, techniques and manufacturing approaches for electrochemical hydrogen compression MEAs
- Accomplishments/Future Work: Project just initiated

Acknowledgements

HyET

- Martijn Mulder, Industry Partner PI

NREL

- Peter Rupnowski, QC Development sub-lead
- Scott Mauger, MEA Scaling sub-lead

LBNL

- Gao Liu, Sister-project collaborator

Thank You

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Publication Number

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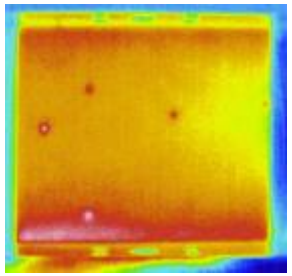
Technical Back-Up Slides

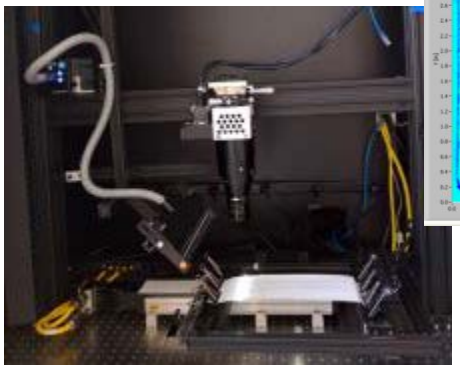
NREL Capabilities: In-line Inspection

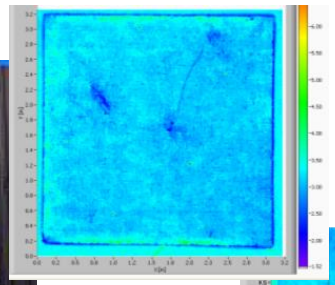
Development of real-time, in-line quality control diagnostics to support the continued scale-up of MEA components for low-cost production

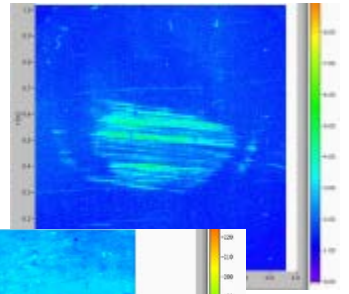
- Material portfolio: Fuel cell, battery, and electrolyzer materials
- Membrane defect imaging and thickness mapping
- Electrode and GDL uniformity
- MEA shorting and gas crossover
- Property measurement, e.g. porosity
- Optical and IR diagnostic platforms
- Non-destructive, 100% inspection

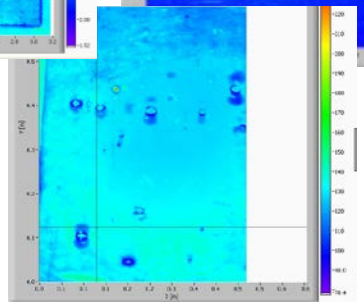


Infrared imaging of electrode and MEA defects







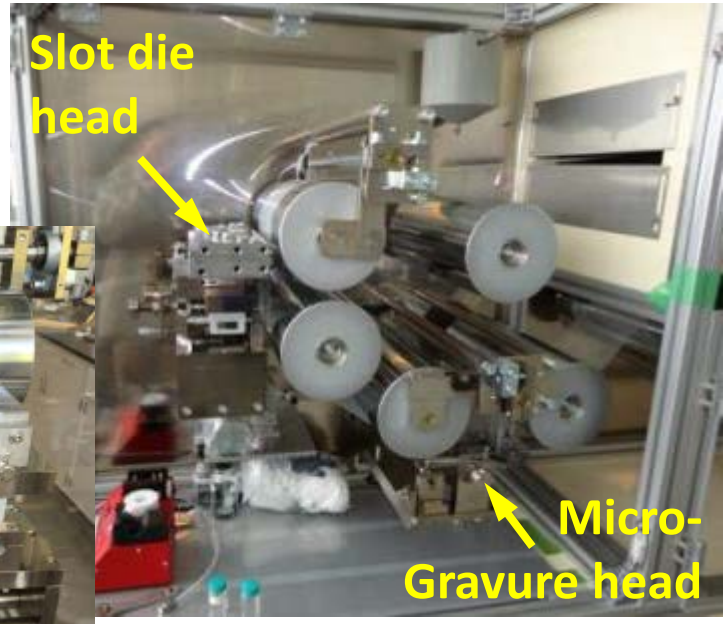


Optical reflectance imaging of membrane and electrode defects

NREL Capabilities: MEA Scaling

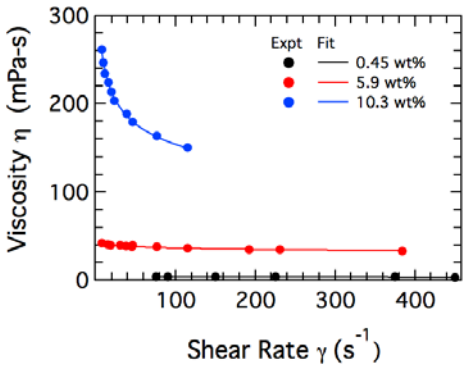
Understanding how parameters of scalable, high-volume processes effect MEA morphology, uniformity, and performance

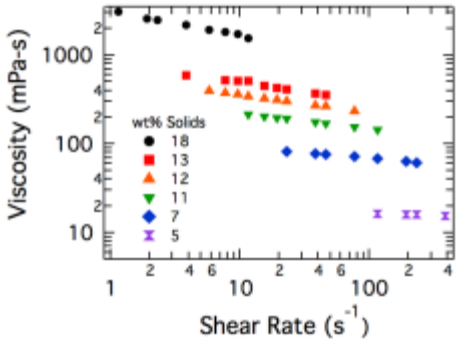
- Roll-to-roll coating station
  - Slot/knife coating head
  - Micro-gravure coating head
  - 50-300 mm coating width
  - 4 independently controllable drying sections
  - Coating speeds from 0.2-10 m/min
- Applicable to various thin-film technology applications
- Formulation, rheology, coating, drying studies



Multi-head coating enclosure

Slot-die coating





Viscometry of electrode inks

Project Task Details

- **Task 1: Inks and Coating Process Development (NREL)**

  NREL will bring to bear ink characterization tools, including rheology, dynamic light scattering, and zeta potential, and electrode fabrication equipment across several scales including a roll-to-roll coating line to evaluate and perform initial optimization of inks and coatings for EHC electrodes. NREL will perform parametric studies to understand the impact of formulation and process variables on the thickness and uniformity of electrode layers. NREL will provide electrode sheet materials to HyET for assembly into cells and in situ testing at HyET's facility.

- **Task 2: Quality Inspection Development (NREL)**

  NREL will bring to bear multiple test-beds for the development of real-time quality inspection techniques for electrodes, membranes, and MEA subassemblies for HyET's EHC MEA materials. NREL's activity focuses on areal inspection techniques, i.e. techniques that utilize optical or infrared imaging to provide the potential for 100% inspection of MEA material webs (rather than point measurements). These techniques enable detection of small discrete defects in MEA materials as well as determination of overall film or layer uniformity. If appropriate, NREL can utilize its industrial-style web-line to validate techniques with sheet or roll materials.

Project Task Details

- **Task 3: EHC testing of R2R vs manual MEA based EHC single cell & stack (HyET)**

  HyET will manufacture the MEAs and perform EHC cell testing which will include standard diagnostics (as used for PEMFC) like shorting tests, IV-curve recording, (Electrochemical Impedance Spectroscopy) EIS and cyclic voltammetry (CV analysis), hydrogen (H2) cross-over testing, H2 pumping at ambient pressure and finally compression testing to maximum pressure. Duration testing to evaluate the performance stability will conclude the membrane evaluation test program. Performance of the manual vs automated manufactured MEAs will be compared.

- **Task 4: Specification of a manufacturing Line (HyET+NREL)**

  Using its experience with R2R equipment and fabrication of MEA materials, and based on its work and results in Tasks 1 and 2, NREL will assist HyET in the design and specification of a manufacturing line for the high volume production of its MEAs. NREL will specifically provide inputs relative to electrode coating and quality inspection devices and integration. US suppliers of required production line equipment will be identified.