Breakout Group 3: Water Management

Participants

Name	**Organization**
Tom Benjamin	Argonne National Laboratory
Rod Borup	Los Alamos National Laboratory
James Cross	Nuvera Fuel Cells
Chinbay Fan	Gas Technology Institute
Tom Jarvi	UTC Power
Ken Kacynski	L-3 Combat Propulsion Systems
D. J. Liu	Argonne National Laboratory
Bob Marzke	Arizona State University
Denise McKay	University of Michigan
Julian Norley	GrafTech International
Ugur Pasaogullari	University of Connecticut
Pete Rieke	Pacific Northwest National Laboratory
Jim Waldecker	Ford Motor Company
Heli Wang	National Renewable Energy Laboratory
Adam Weber	Lawrence Berkeley National Laboratory
Shawna McQueen (Facilitator)	Energetics Incorporated
Tom Benjamin (Scribe)	Argonne National Laboratory

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GAPS/BARRIERS

The Water Management gaps and barriers identified by breakout group participants (see bullets below) fall into the following general categories:

1. Lack of initial and long-term materials (chemical, physical, and microstructural) property data to support basic understanding and to develop/validate models
2. Lack of understanding of cell component interactions and interfaces and effects of operating conditions on durability
3. Lack of experimental data on water movement in the cell/stack during operation and transients
4. Lack of test protocols and tools for in-situ observation of water behavior
5. Lack of understanding of effects of freezing and thawing on cell components

- Lack of fundamental understanding
  - impact of microstructure on performance and durability
  - Microstructure of three-phase region (integration) component stability
- Autonomous operation
  - no water feed
  - hydrocarbon fuels
  - maintain efficiency and packaging
- Plate and gas diffusion layer (GDL) materials (and membrane electrode assembly) have not been engineered to work together for purposes of water management
  - Are they working against each other?—polymer electrolyte membrane (PEM) fuel cells, phosphoric acid fuel cells (PAFC), and direct methanol fuel cells (DMFC)
  - Little experimental information is available regarding water migration/profile at catalyst/membrane/GDL under operating conditions
  - Lack of properties for components - PEM, catalyst layers
- Optimal PEM performance requires optimal water management (to minimize cost, maximize power density)
- Active management/control
  - development of toolset
  - influence of sensors/actuators
  - control-oriented modeling/validation
- Water management critical to minimize balance of plant components
- What is the practical state-of-the-art limit to rating current density? What can/should it be?

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GAPS/BARRIERS (Continued)

• Relationship of water/no water to performance and durability; and window of stable operation
• Water removal from ultra-thin electrodes (e.g., nano-structured thin film (NSTF) support structures)
• Fundamentals of water transport at low temperature: For PEM, freeze conditions involve a third phase (solid) for which transport becomes more complicated than nominal
• What is the target for cell uniformity (variance) in stacks?
  - effect on durability
• Range of properties (uniformity) effect on water management (manufacturing)
• In-situ analytical tools for understanding and mapping the “fate” of water (and proton and heat); correlation to computational fluid dynamics
• Measure proton motion in cell during operation
• Correlation of durability to local process condition (membrane electrode assembly (MEA), metal plates, etc.)
• Durability of materials changes water management
  - hydrophobicity changes
  - membrane
  - catalyst layer
  - GDL
• Durability cuts across many DOE program topics
  - need to address with failure mode and effects analysis (FMEA) approach
  - impacts water management, supports, catalyst, membrane, accelerated test development
• Integration of metal plates and GDL with projected behavior durability
• Some customers want hydrophilic; others hydrophobic coatings on plates/GDL
  - challenge for materials manufacturers; long term stability of surfaces? PEM, PAFC, DMFC!
• Non-carbon GDLs with tailored properties needed
• Bipolar plates/MEA interface (material lifetime)
• Hydrophobic/hydrophilic surface energies for flow fields
• Need validated model for GDL intrusion into flow fields

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RD&D NEEDS
(priority votes are shown in parentheses)

MODELING	MATERIALS & DESIGN	ANALYTICAL TOOLS
• Validated models of water transport with temperature dependence and 3-phases (vapor-liquid-ice) **(5)** - demonstrate applicability of models at unit-cell and stack levels - *related idea*: Validated mathematical models ▪ Link macroscopic for optimization and microscopic for understanding link micro - macro models • Low-order, physics-based, experimentally validated models of channel-GDL-ct-mb for active management for different system classes **(2)** • Aging models **(1)**	• Freeze operating strategies (materials/freeze rates) **(4)** - development of fundamental understanding of freeze effects on materials - development of materials that can withstand freeze - how to show range of results over different cell designs - increase understanding of local phenomena • Cost-effective and integrated BP + GDL (matching wettabilities) material issues and surface energetics **(3)** - *Related idea*: surface modification and advanced wettability and surface energetics - impacts on flow • Design of catalyst/diffusion media with porosity and hydrophobicity gradients (Z-plane) **(2)** • Design of segregated water/gas pathways in diffusion media, catalyst layers (X-Y plane) **(2)** • Tailoring of GDM *or* flow field to prove feasibility of stable operation [at ≥ 2.0 A/cm^2] **(2)** - for reduced cost via increased W/cm2 - innovation of cell architecture to prove we're not limited by current density • Robust operation with ultra-thin electrodes (one micron or less) **(1)** • Development of flow field and GDL materials with engineered stable water management characteristic (degree of hydrophobicity) **(1)** • Co-design of flow field and GDL and MEA for water-management	• In-situ measurement of water transport, proton transport, etc., in all directions **(3)** *Related ideas:* - Water imaging, (with that of other cell component substances) - diffusivity measurement **(2)** - Confirmed diagnostics to map water at full-size unit cell in-situ (water management in "1-dimension" with subscale parts is common) **(1)** - inexpensive, rapid in-situ diagnostics (new & better) - Development of experimental techniques to determine local conditions (T, Φ, i, RH, etc.) **(1)** - Developing experimental methods to address fundamental water transport issue across GDL/MEA at relevant spatial resolution (preferably at micron scale) **(1)** - Techniques for characterization of in-situ vapor/liquid water profiles (x, y, z) - Measurement of water velocity in catalyst, diffusion media • Tools/methods for monitoring water distribution against T **(1)**

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DURABILITY & ACCELERATED TESTING	OTHER	MANUFACTURING ISSUES
• Interaction of degradation of other components to the degradation of components responsible for water management, e.g., seal, bipolar plates, membranes, impurities **(3)** • Accelerated durability testing methodology (verified) related to water management **(1)** • Parametric aging studies - Standard cell, protocol - Suite of state of the art components - Detailed *a posteriori* areal mapping of MEA, GDL, BPP aging **(1)** • Data for models: degradation of hydrophobic agents, properties (contact angle, porosity, permeability, cell resistance, etc.) with known automotive cycle stressors (e.g., freeze)	• Development of hydrocarbon fueled APU that meets DOE's technical targets without a water feed line • Passive thermal solutions for portable fuel cell applications to reduce size/improve heat rejection	• Design of flow field plates for high volume manufacturing - Keep in mind that overly complex designs are not suitable for high volume manufacturing • Manufacturing-compatible means of grading properties x, y and z • Manufacturing vs. profit and market - government support for manufacturing is needed