Fuel cell electrodes: Plagued by transport losses

• Porous electrode is very thin
• Still, at high current, transport can be an issue

Ionic potential gradients can be high

Winding transport pathways
H⁺ consumption by reaction
Conductivity of ionomer?
Fuel cell electrodes: Plagued by transport losses

- Porous electrode is very thin
- Still, at high current, transport can be an issue

Ionic potential gradients can be high

Oxygen gradients can be high

Macro- vs. micro-scale resistances

O₂ consumption by reaction

Water blocking pores?
Fuel cell electrodes: Plagued by transport losses

• Porous electrode is very thin
• Still, at high current, transport can be an issue

Ionic potential gradients can be high

Oxygen gradients can be high

We measure these gradients to understand transport resistance
Microstructured Electrode Scaffold (MES) Diagnostics

Structure consists of two electrodes separated by a PEM just as in a typical fuel cell

Quasi 1-D column of working electrode

Hess et al., Anal Chem 83 pg. 9492 (2011)
Microstructured Electrode Scaffold (MES) Diagnostics

Use to measure spatio-temporal distributions of:
• Potentials (electric/ionic)
• Conductivities
• Currents
• Local reaction rates
• EDL charging/discharging

Advantages:
• Through-plane measurements
• Uninterrupted, representative electrode structure
• Applicable to many porous electrode technologies

Hess et al., Anal Chem 83 pg. 9492 (2011)
Ionic Potential Sensing MES

Mesures ionic potential through electrode’s thickness

MES surrounding a 170 μm diameter column of catalyst on the cathode side

Hess et al., Anal Chem 83 pg. 9492 (2011)
Ionic Potential Sensing MES

Measures ionic potential through electrode’s thickness

Apply voltage or current to fuel cell

Measure potential at reference electrodes

Hess et al., Anal Chem 83 pg. 9492 (2011)
Results from Ionic MES

Distributions measured by MES

MES performance as fuel cell?

Comparable to regular fuel cell

Hess et al., Anal Chem 83 pg. 9492 (2011)
Results from Ionic MES

- Flooded condition (high humidity)
  - Linear distribution profiles
  - Suggests mass transport limitations even at low currents
- Dry condition (less humid)
  - Good match with analytical solution for uniform reaction (solid lines)
  - More linear at highest currents
    - mass transport limitations (expected)

Hess et al., Anal Chem 83 pg. 9492 (2011)
Capability of MES

Various operating conditions
- gas flow rate
- temperature
- humidity
- pressure

Various physical properties of catalyst layer
- structures
- material properties
- material contents

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Measurement/data

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Measurement/data

Potentials (electric/ionic)
Conductivities
Oxygen concentration
Currents
Local reaction rates

Understanding the relation of physical properties of catalyst layer, operating conditions, and fuel cell performance

Hess et al., Anal Chem 83 pg. 9492 (2011)