**Polymer Electrolyte Membrane Fuel Cells**

**Introduction:**
- Polymer electrolyte membrane fuel cells (PEMFC) efficiently convert the reaction energy of hydrogen and oxygen to electricity and heat.
- Oxygen reduction occurs in a catalyst layer (CL) formed by platinum nanoparticles supported on a network of carbon support particle agglomerates.

**Objectives:**
- Measure and model the diffusivity of CL and GDL.
- Select a suitable substrate and appropriate coating procedures.

**Methods:**
- The diffusivity of gas diffusion layers (GDL) is measured with a dry diffusivity test bed (DDT).
- CL is coated on 70 µm thick hydrophobic porous polymer substrates.
- CL thicknesses are measured by SEM.
- The diffusivity of the substrate and CL/substrate are measured using DDT.
- CL-diffusivity values are determined for different Pt loadings.
- To model the CL, its structure is represented by unit cells based on porosimetry and analysis of SEM images.

**Diffusivity Model for Catalyst Layer**

**Unit cell approach to modeling diffusivity**
- CL is represented by a network of unit cells to model its transport properties.
- The unit cell for primary pores consists of a single primary particle in an FCC arrangement with pore space around it.
- The unit cell for agglomerates consists of overlapped porous spheres with void space around them.

The model considers the following:
- Pore size distribution (through introducing different unit cell sizes)
- Knudsen and classical diffusion mechanisms
- The ionomer, carbon, and Pt particles are non-diffusive solids

The model has been validated for dry conditions.

Future work includes considering the effects of humidity, compression, and the diffusivity of ionomer.

The modeled effective diffusivity for porosity ~0.4 is underestimated the experimental value of Shen study by ~5%. According to the modeled-value diffusivity is highly function of porosity for the same PCD and to be able to accurately compare the results, porosity should be evaluated precisely. In Shen study porosity is reported about 0.2 – 0.4.

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**Dry Diffusivity Testbed (DDT)**

**Fick’s first law of diffusion:**

\[ J = -D \frac{\partial C}{\partial y} \]

**Equation of effective length for DDT:**

\[ l_{eff} = \frac{D}{\text{Diffusivity}} \]

**The dry diffusivity test bed (DDT) is based on a Wicke–Kallenbach cell with two flow channels separated by a porous sample.**

**The resistance to the mass transfer of gas into the sample is measured and subtracted from the total resistance.**

**Effective length is a representative of diffusivity and can be related to effective diffusivity.**

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**Effective Diffusivity of GDL and CL**

**GDL Diffusivity Measurement**

GDL samples containing MPL (248B and 348C) have diffusivity values about 50% less than the ones without MPL (248A and 348A).

**CL Diffusivity Measurement Procedure**

1. Measure effective length of filter PTFE substrate, \( l_{eff} \).
2. Measure effective length of catalyst coated filter PTFE substrate, \( l_{eff} \).
3. \( l_{eff} = l_{eff} - l_{eff} \).
4. \( l_{eff} \) must be < 50% of \( l_{eff} \).

The effective length (diffusion resistance) of filter PTFEs is consistently about 110 µm.

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**Conclusions**

- Diffusivity of CL for different Pt loadings (different CL thicknesses) is measured and reported to be 0.13 of binary diffusion.
- Diffusivity is measured with a WKC based test bed and uncertainty is evaluated to be less than 12%.
- The through plane effective resistance of the CL is less than the in plane values reported in literature and several orders lower than the reported values for agglomerate diffusivity.
- Effect of operating temperature and humidity, compression and cracks on CL diffusivity should be evaluated.
- Interfacial diffusivity resistance between GDL and CL should be measured.

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