MEA Defects for QC in PEM Fuel Cell Manufacturing (NRC Internal Project)

Project Introduction and Key Defects Identification

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Project Overview

Title: "MEA Defects for QC in PEM Fuel Cell Manufacturing"

Objectives: To define the key defects during MEA manufacturing and understand the effects of defects on PEM fuel cell performance and durability

Duration: January 2021 to December 2022 (Two years)

Scopes:

1. Identifying key defects for MEA and its sub-components
2. Defining methodologies to introduce designed defects
3. Conducting ex-situ characterizations and in-situ performance/durability testing
4. Discussing defects QC guideline with MEA component suppliers and fuel cell manufacturers

This project initiates research activities and build a foundation to leverage and collaborate with Canadian fuel cell companies and international organizations.

Project Team

Project manager: Dr. Ken Shi

Task 1. Membrane and catalyst layers (CLs), Dr. Nana Zhao, EME-Van

Task 2. Gas diffusion layer (GDL), Dr. Riny Yuan, EME-Van

Task 3. Catalyst ink, Dr. Régis Chenitz, AST-Boucherville

Primary collaborators:

- Prof. Erik Kjeang group at Simon Fraser University
- Ballard Power System

15+ Consultants for prioritizing defects,

- Fuel Cell Developers
- Component Suppliers
- Research Organizations

Identifying Key Defects

1. **Listing all possible defects**

   Membrane: 21
   Ink: 32
   Catalyst layer: 26
   GDL: 38

2. **Sending the lists of defects to the external consultants**

3. **Summary of feedback and narrow-down lists of defects**

4. **Discussing with USA and Germany partners in NREL QC workshop** ⇦ May 5th

5. **Key defects identified at NRC (8-10 defects in total)**

Identifying Key Defects

1. Listing all possible defects, for each component

Major category	Defects and explanations				In house (H) or from manufacturer (M)	Property and Characterization		References	Priority (1-5)	Comments
	Source of defects	#	Name of defects	Explanations		Related properties	Characterizations			

Identifying Key Defects

2. Sending the lists of defects to the external consultants

Major category	Defects and explanations				Priority (1-5)	Comments
	Source of defects	#	Name of defects	Explanations		

3. Summary of feedback and narrow-down lists of defects

- Three fuel cell developers
- Five component suppliers
- Four research organizations

Identifying Key Defects: Membrane

Catalogue	#	Name of defects	Explanations
Irregularity	1	**Pin holes**	Pin holes (size, depth, location, distribution etc.)
	2	**Air bubbles**	Air bubbles formed during solvent evaporation
	3	**Uneven thickness**	Uneven membrane thickness
	4	**Gel formation**	Gels from ionomer dispersion
Contamination	5	**Dust**	Dust particles, human hair, skin scraps
	6	**Metals/ions**	Metal ions, especially Fe^{2+} (ppm) , metals debris and halogen impurities (ppm)
Processing conditions	7	**Mechanical weakness**	Weak mechanical performance results from higher/lower annealing temperature
	8	**Uneven reinforced layer**	Uneven thickness, nonuniform pores and size, on membrane surface, and folding of reinforcement material
	9	**Stretching in different directions**	Different swelling and tensile strength in X and Y directions due to tensile forces variation in Roll-to-roll processing
Others	10	**Delamination damage**	Backing sheet removal results in curling, scratches and tears of the membrane

Yellow highlighted are key defects identified

Identifying Key Defects: Ink

Category	#	Name of defects	Explanations
Catalyst	1	**Active metal loading (Pt, …)**	Out-of-Specification regarding Metal loading(s)
	2	**Nanoparticle agglomeration**	Out-of-Specification regarding size dispersion and agglomeration
Ionomer	3	**Inapropriate wt.% of ionomer in solution**	Variability between batches will influence final amount in CL
	4	**Polymer agglomerates**	Fish eyes can be formed in polymer dispersion
	5	**Decomposition**	Shelf Life
Solvent	6	**Impurities in solvent**	Out of range for solvent specification (incl, water) from handling or storage environment, shelf Life of solvent
Slurry formulation	7	**Variation in dispersion viscosity**	Offset in weight of ionomer and solvents (precision)
Slurry processing	8	**Material settling**	Settling time is usually a parameter dictated by formulation governed itself by FC performances and not necessary by coating process or storage time
	9	**Fast drying**	During coating, fraction of slurry may be too dry or wasted => Redispertion Feasibility or dilution of dried or highly viscous slurry (process waste)
	10	**Metal contamination**	Dust particles, Impurity ions from tools or solvent(s), environmental influence
	11	**Nanoparticle or carbon support damage**	Chemical reaction or mechanical forces (high shear mixing, ultrasounds, over-mixing, etc…) can change nanoparticles or carbon support

Identifying Key Defects: CL

Category	#	Name of defects	Explanations
Handling	1	**Scratches**	Scratches on catalyst layer
	2	**Missing Catalyst Layer**	Missing/empty catalyst layer, especially on cathode
	3	**Catalyst Layer Delamination**	Catalyst layer delamination resulted from inappropriate roll core diameter during R2R processing or from inappropriate drying. E.g. excessive temperature
	4	**Ions (metal) Impurity Contamination**	Catalyst layer contamination with ions
	5	**Uneven Catalyst Layer Surface**	Alteration of catalyst layer surface by surface shear forces (R2R or manual handling)
Coating	6	**Uneven Catalyst Layer Thickness**	Uneven catalyst layer thickness from coating process
	7	**Defects Caused by Uncontrolled Coating Environment**	Mechanical stress and strain resulted from uncontrolled relative humidity/temperature
	8	**Substrate Folding**	Folding of substrate before or during coating
Drying	9	**Undesirable Pore Holes**	Undesirable pore holes formation from inappropriate drying. E.g. fast solvent vaporization

Identifying Key Defects: GDL

Category	#	Name of defects	Explanations
Substrate	1	**Unevenness/variation of thickness**	These properties can be measured simultaneously using the 3-in-1 device
	2	**Unevenness/variation of conductivity**	
	3	**Unevenness/variation of permeability**	
	4	**High/low diffusivity**	An optimal range needs to be defined
	5	**Surface holes/breaks/streaks/globs**	Web holes/breaks/streaks/globs from manufacturing
	6	**Surface scratches/cracks/fractures**	Surface scratches/cracks/fractures from handling
	7	**Out of range roughness**	Surface roughness is out of range and the range needs to be defined.
MPL	8	**Uneven thickness**	Variation in thickness
	9	**Missing MPL**	Missing MPL sections
	10	**Scratches**	Manually made scratches (square from 0.04-2 cm^2)
	11	**Out of range roughness**	Surface roughness is out of range and the range needs to be defined.
Substrate + MPL	12	**Uneven thickness**	Change in thickness, resistivity and IP permeability over time or over several compression cycles, they can be measured simultaneously.
	13	**Uneven conductivity**	
	14	**Uneven permeability**	
	15	**Holes**	Manually made holes with different sizes, depths and densities
	16	**Surface cuts**	Surface cuts from 5-20 mm long of different oritations (0°, 45°, 90°)
	17	**Diffusivity variation**	An optimal range needs to be defined
	18	**Cracks/fractures**	Cracks/fractures from handling
	19	**Edge defects**	Edge defects caused by cutting tools (e.g., die cut etc.).

Identifying Key Defects

4. Discussing with USA and Germany partners in NREL QC workshop

Component	Number of defects	Narrow-down defects	Key defects	Project
Membrane	21	10	6	**2-3**
Ink	32	9	6	**2-3**
CL	26	10	5	**2-3**
GDL	38	19	7	**2-3**

Feedback on the lists highly appreciated.
It would help the project to defined key investigating defects!

5. **Key defects identified at NRC (8-10 defects in total)**

Thank you!

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