Development of Thin-Film Fuel Cell Models for Degradation Studies

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Outline

• Background
  • Fuel cell structure and mechanisms
  • X-Ray Reflectometry
  • Previous Attempts
• Goals, Methods, and Results
• Summary/Conclusion
PEM fuel cells

- Proton Exchange Membranes (PEM) only allow the protons to pass through

- Electrons are conducted across an alternate path to power the load
Nafion
Fuel Cell Interfaces

Three Phase Region
(where the gases, electrode, and PEM come together to allow the electrochemical reaction)

Identifying Contributing Degradation Phenomena in PEM Membrane Electrode Assemblies Via Electron Microscopy
K. L. More, R. Borup, and K. S. Reeves
Fuel Cell Test Structures

- Nafion
- Carbon Black
- Pt Nanoparticle
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X-Ray Reflectometry

Incident Plane Wave

Path length difference

Reflectivity

Critical Angle

\[ \Delta Q_z = \frac{2\pi}{t} \]

Scattering I

Substrate

Depth
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Previous Attempts

Reflectivity

Voltage vs. Ag-AgCl [V]

Current Density [mA/cm²]

Qz[A⁻¹]

Distance from Si [nm]

PtO
Pt
PtO(2)

SiO₂
Nafion
H₂O
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Fundamental Question

• Do different substrate treatment methods affect the structure of the deposited catalyst?

[Diagrams showing the effect of different treatments on substrate structure]
Substrate Treatment

- Reflectivity vs. Depth $z$ [	ext{Å}]
- SLD [	ext{Å}^{-1}]
- $Q_z$ [	ext{Å}^{-1}]

Graphs showing the effect of detergent + acid and detergent only on reflectivity and SLD.
Fundamental Question

- How do varying annealing situations affect catalyst structure?
- Can annealing the test structure before the addition of Nafion promote the growth of unwanted structures?
Effects of Annealing

Reflectivity vs. \( Q_z [\text{Å}^{-1}] \)

SLD vs. Depth \( z [\text{Å}] \)

As Cast
Annealed at 210 °C
Effects of Annealing

- Does the addition of Nafion amplify structural changes under annealing?
Effects of Annealing

Reflectivity vs. \( Q_z \) for different thermal treatments:
- As Deposited
- Annealed at 210 °C
- Annealed at 210 °C with Nafion

SLD vs. Depth \( z \) for the following conditions:
- As Deposited
- Annealed at 210 °C
- Annealed at 210 °C with Nafion
Fundamental Question

• How does electrochemical cycling affect PtSi and Platinum in the test structure?
Effects of Electrochemical Cycling

Reflectivity vs. $Q_z$ [$\text{Å}^{-1}$]

- As Deposited
- Annealed with Nafion
- Electrochemically Cycled

SLD [$\text{Å}^{-1}$] vs. Depth $z$ [$\text{Å}$]

- As Deposited
- Annealed at 210 °C with Nafion
- After Cyclic Voltammetry
Fundamental Question

• Can adding Cr before Pt prevent unwanted structure complexity?
Addition of Cr
Conclusions

- The substrate can be treated with just detergent; more aggressive cleaning methods do not improve roughness.
- Annealing the test structure with Nafion promotes the growth of the PtSi layer.
- Electrochemically cycling the test structure increases PtSi thickness and degrades the Pt layer.
- The addition of Cr before sputtering Pt does prevent the development of a PtSi layer.
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