Fuel Cell vs. Low Temperature Electrolysis Materials

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QC Workshop
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Outline

- Approach of Sensitivity Assessment and Tolerance Determination
- Example: Effect of Processing on MEA Integrity
- Fuel Cell vs. Electrolysis Cell - Comparison of Material
- Future Electrolysis Systems
- Discussion: How can we port existing QC work over to LTE?
    - What is similar, what is new?

Approach of Sensitivity Assessment and Tolerance Determination

Approach

An “Inhomogeneity” can be classified as a ”Defect” when one of the three following criteria applies:

1. **An initial detrimental performance effect is observed.**
2. **The lifetime is reduced.**
3. **The performance over time suffers.**

NREL conducts sensitivity studies varying size and/or other defining criteria of inhomogeity:

Performance experiments

- **With single cell & segm. cell**

Accelerated stress tests

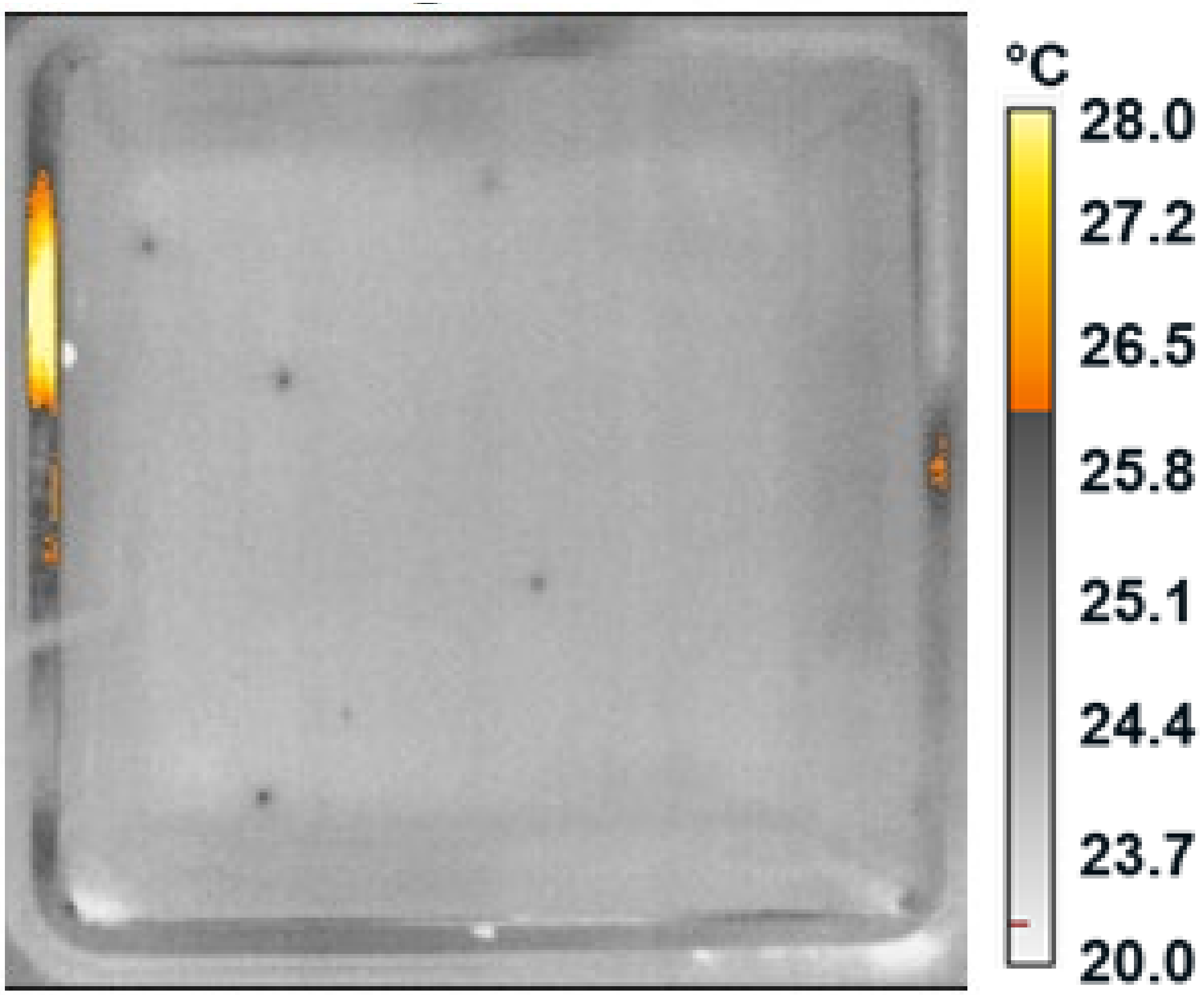
- **With custom IR hardware**

Drive cycle operation

Any QC equipment needs to be able to identify variations at or below the ”Inhomogeneity” to “Defect” threshold.

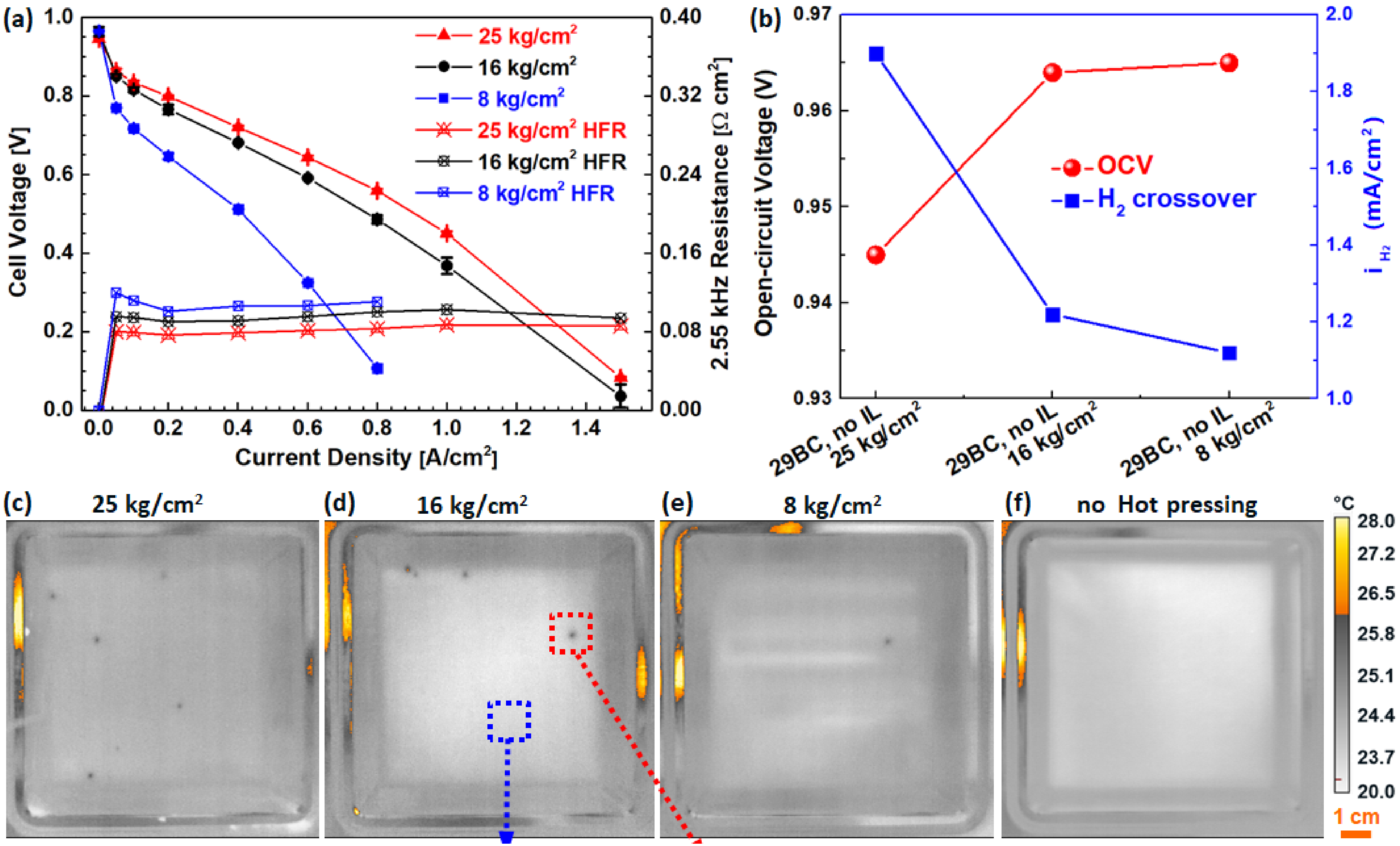
Example:
Effect of Processing on MEA Integrity

Process Induced Morphology Changes



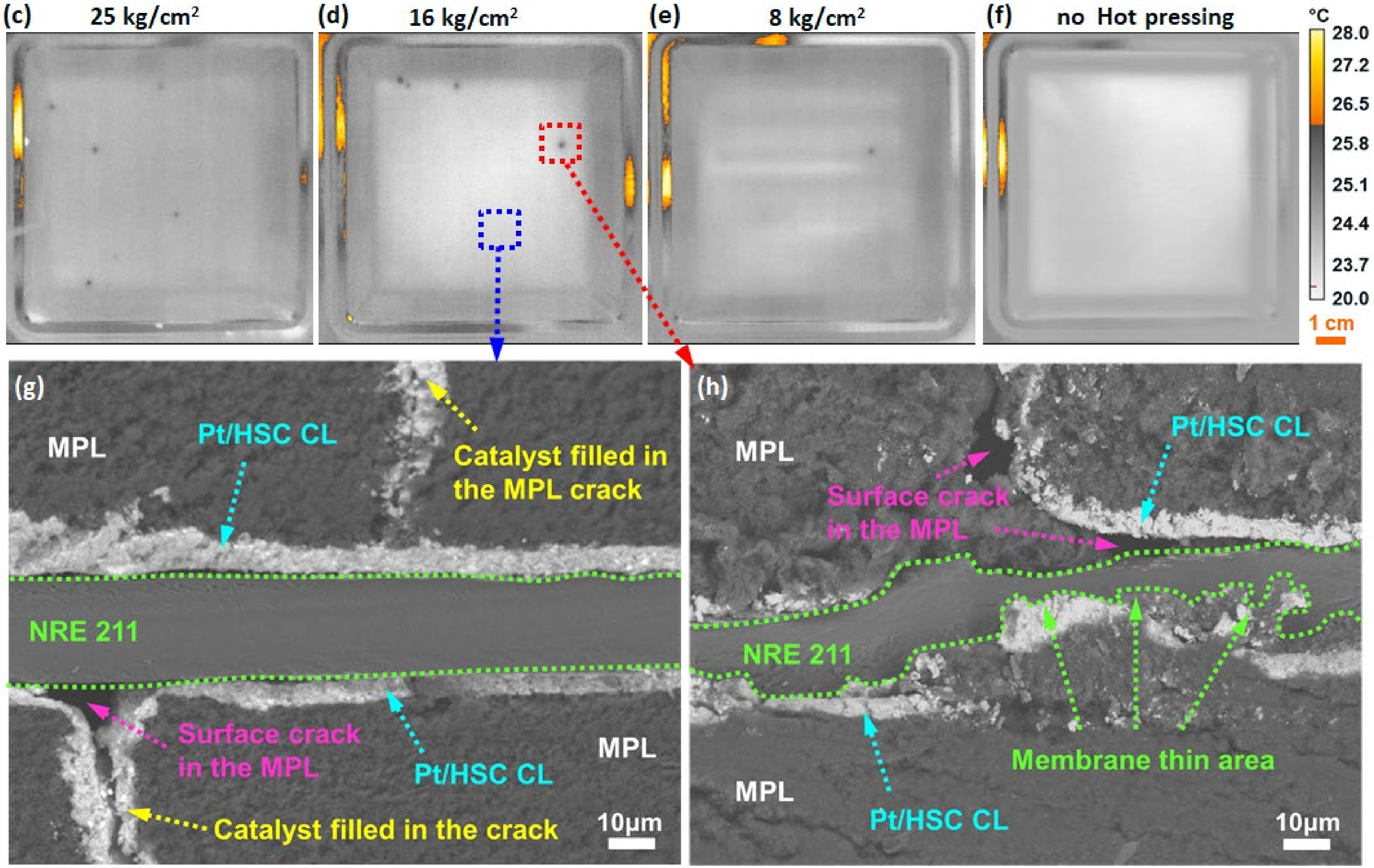
- Beginning of Life (BOL) high resolution hydrogen crossover (H2Xover) measurement using IR camera
- Dark spots indicate localized areas of increased H2Xover
- Such areas were repeatedly detected with two different gas diffusion electrodes

Process Induced Morphology Changes



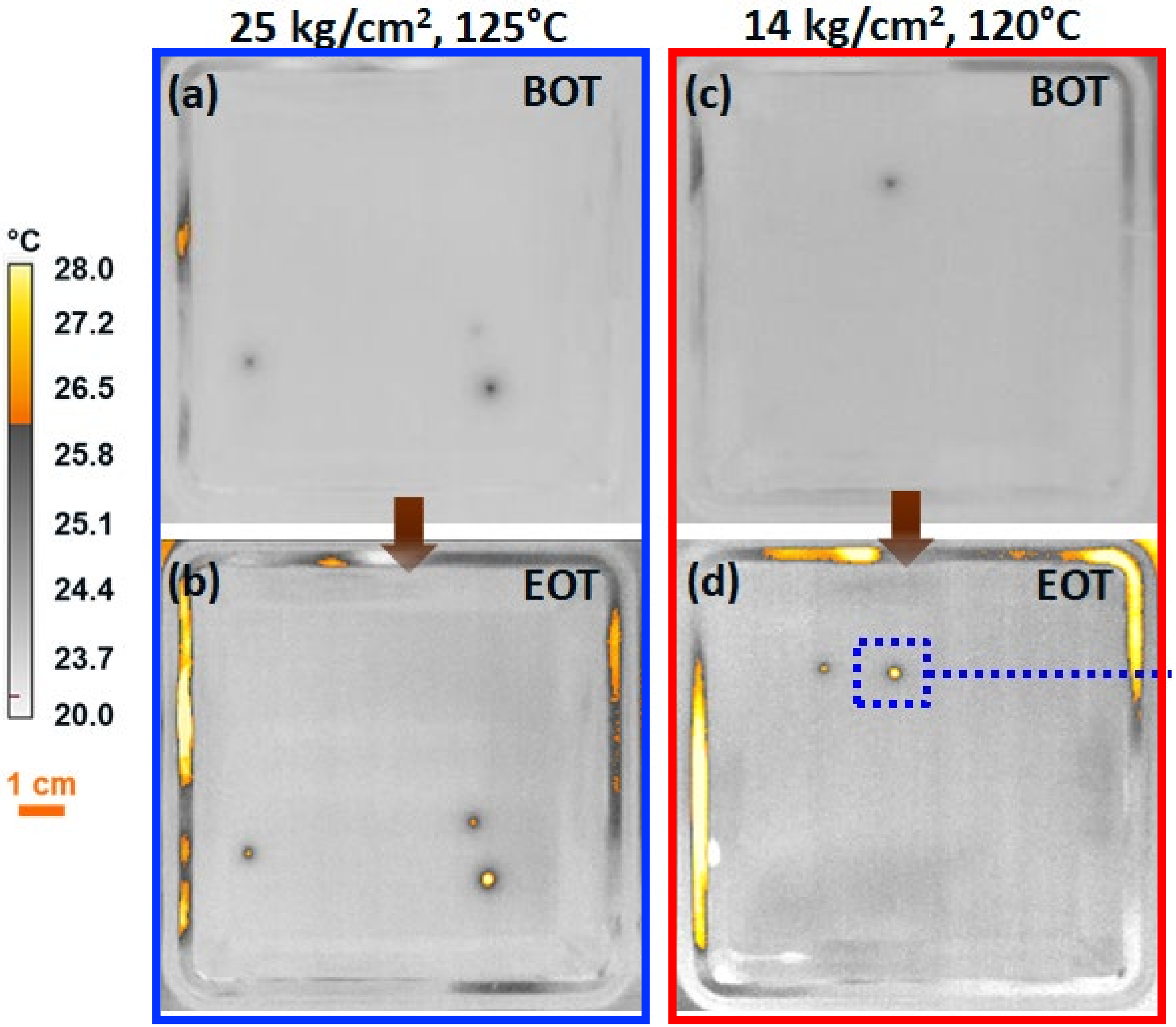
- Phenomena was dependent on fabrication conditions, i.e. applied hot pressing force & temperature
- Fabrication conditions impact performance

Process Induced Membrane Irregularities (PIMs)



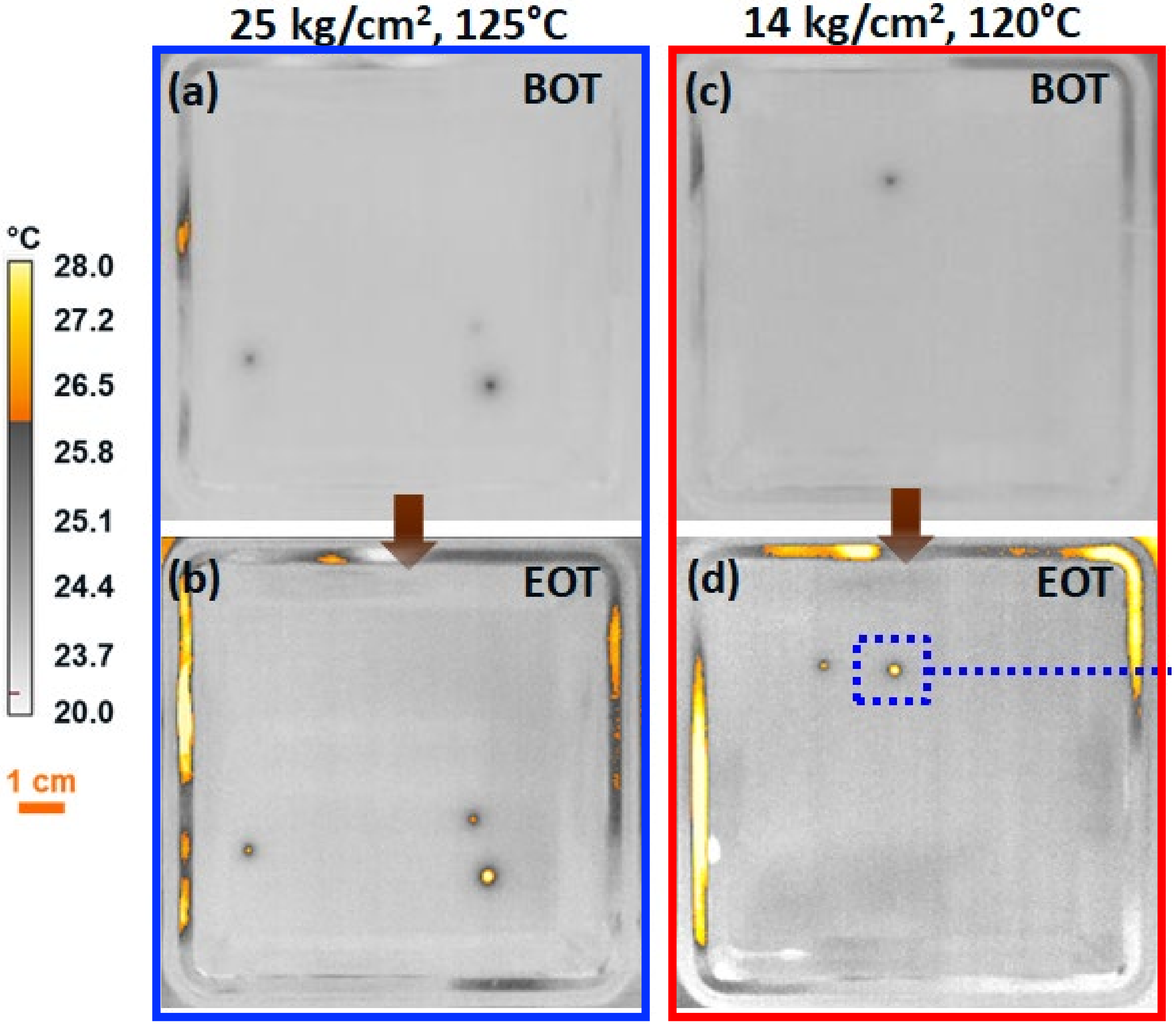
- **Closer investigation found that morphology of membrane was impacted by combination of local GDE features and process parameters**

Process Induced Morphology Changes

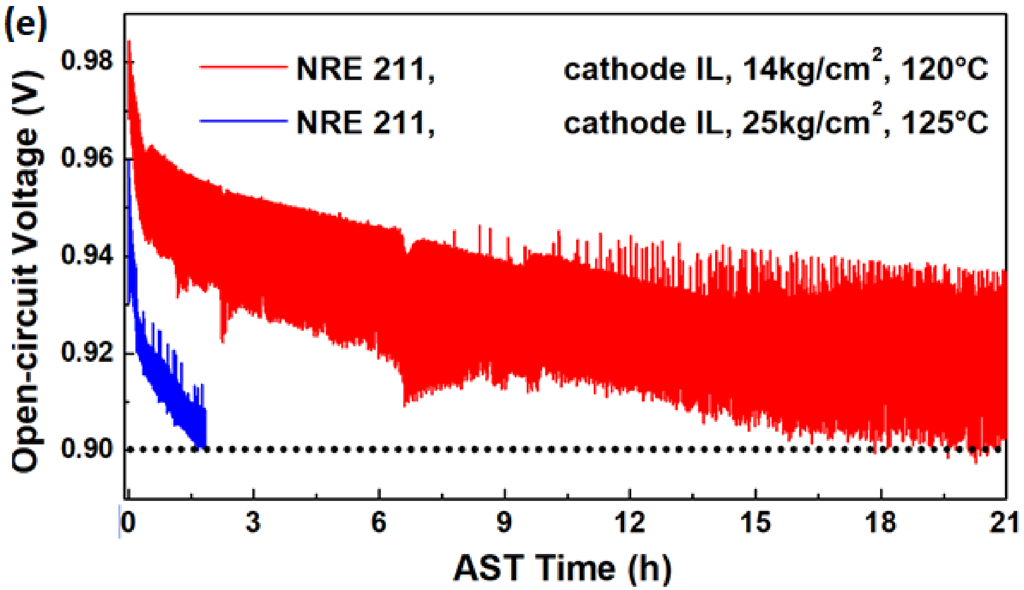


- **No significant initial performance impact, but…**
- **…the PIMs developed into failure locations and reduced MEA lifetime**

Process Induced Morphology Changes



- **No significant initial performance impact, but…**
- **…but the PIMs developed into failure locations and reduced MEA lifetime**
- **Processing conditions were able to mitigate PIM development**



Other Inhomogeneities

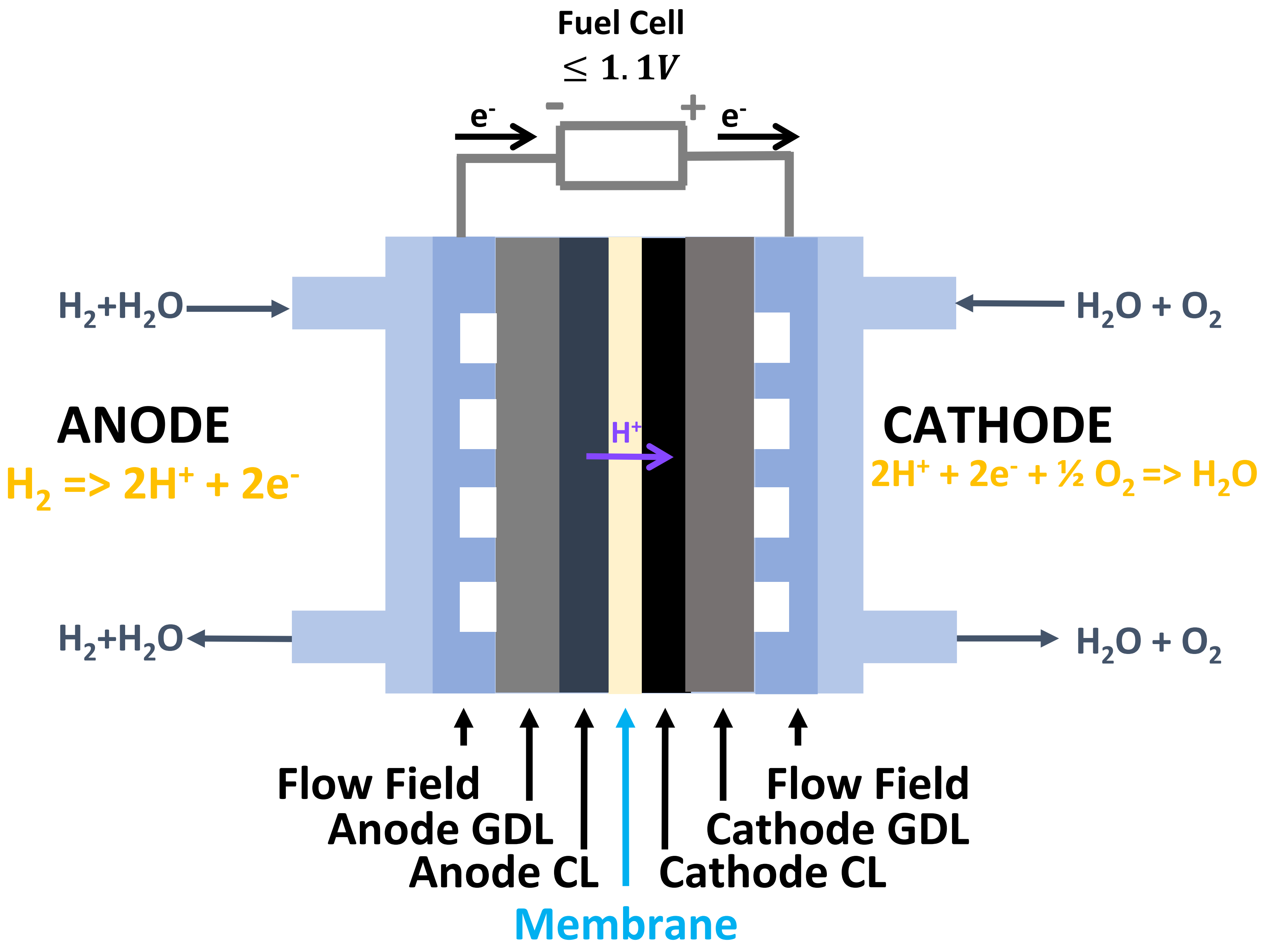
Similar work was conducted at NREL on:

- **Coating drops/blobs**
- **Catalyst layer**
  - **Voids**
  - **Thin spots**
  - **Thick spots**
- **Pinholes**
- **Trapped bubbles in membranes**

Fuel Cell vs. Electrolysis Cell
Comparison of Material

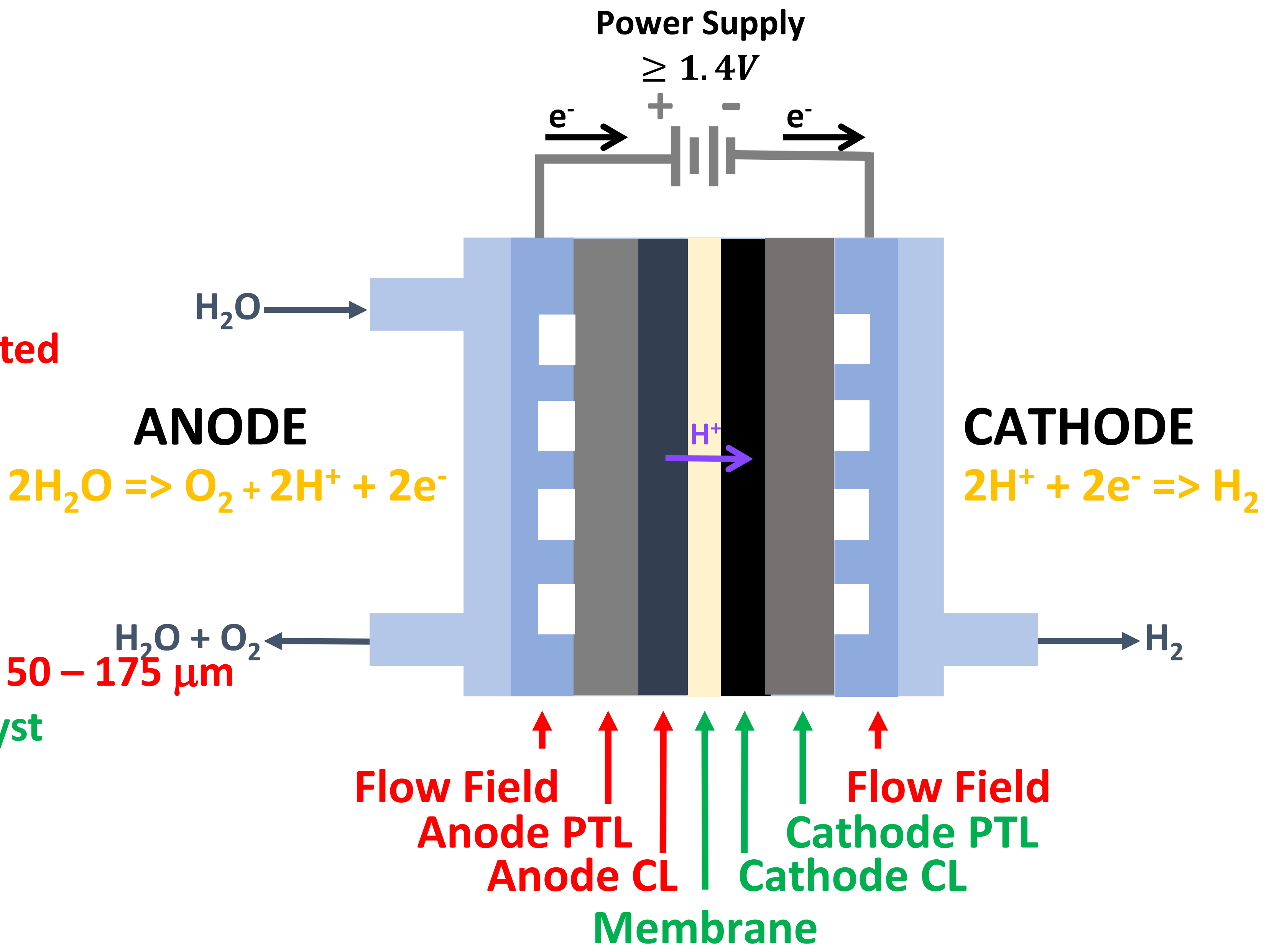
Fuel Cell

- Gas to electrical power generating ≤ 1.1 V
- Graphite or coated metal flow-fields
- Carbon based porous gas diffusion media with microporous layers
- Carbon supported Pt catalyst layers
- Thin proton conductive membrane ≤ 25 μm



Electrolysis Cell

- Electric Power to Gas at Potentials $\geq$ 1.4 V
- Titanium anode flow-field coated with PGM
- Sintered porous titanium material coated with PGM
- Unsupported IrO_2 anode catalyst layer
- Proton conductive membrane 50 – 175 µm
- Supported Pt/C cathode catalyst layer
- Untreated carbon paper
- Titanium or other bipolar cathode flow-field (based on anode material)

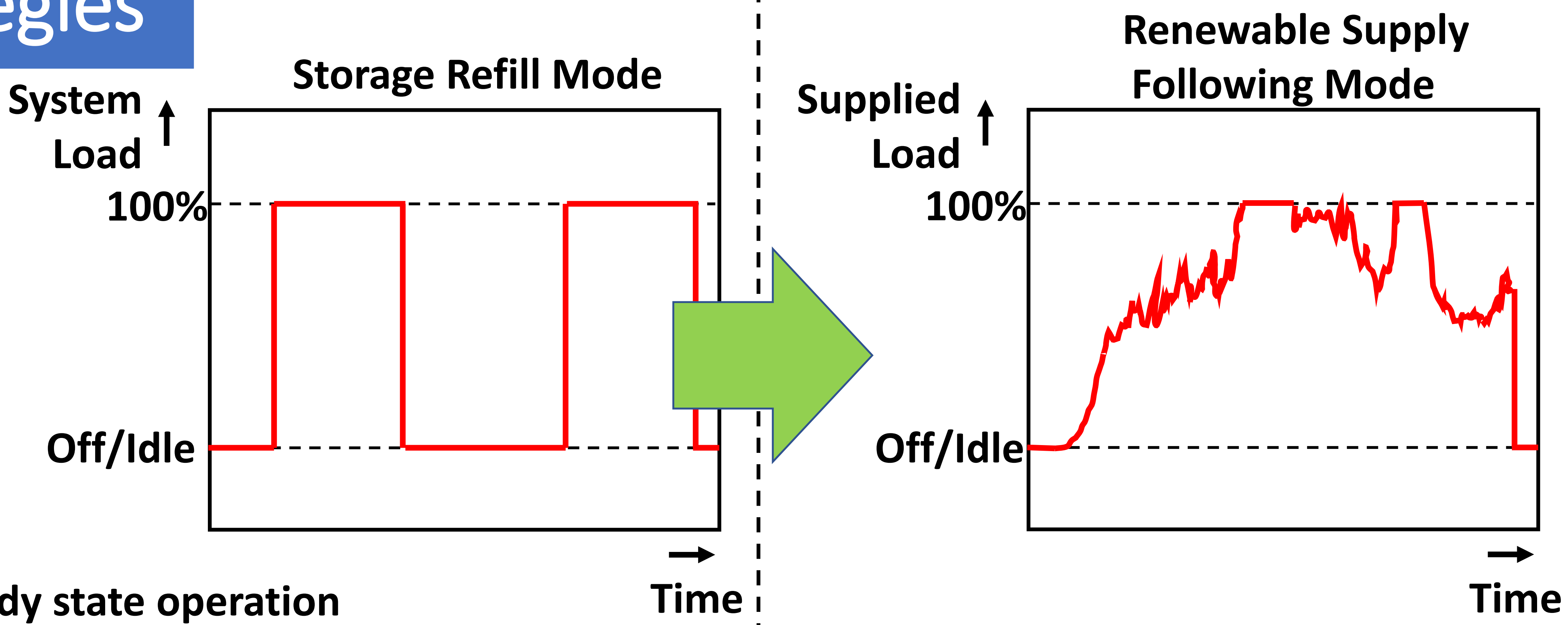


Future Electrolysis Systems

Operating Strategies

Existing Systems

Future Systems



- Steady state operation
- Turn system on at certain vessel pressure
- Refill system at 100% system power
- Switch system to off or idle

- Follow renewable energy supply
- Maybe cap high and low performance to minimize degradation

State-of-the-Art

Existing Systems

- **2V @ 2A/cm^2**
- **2-3 mg/cm^2 PGM catalyst loading on anode & cathode**
- **60k – 80k hours in commercial units**
- **Niche applications**
  - Life support
  - Industrial H_2
  - Power plants for cooling
- **$3.7/kg H_2 production***

Future Systems

- **2V @ $\geq$ 2A/cm^2**
- **Thinner membranes**
- **Lower loadings**
- **$\geq$ 80k hours**
- **Supply following**
- **Renewable & Net integrated applications**
  - Wind
  - Solar
  - Nuclear
- **$2/kg H_2 production***

*High volume projection of hydrogen production for electrolysis:
https://www.energy.gov/sites/prod/files/2017/10/f37/fcto-progress-fact-sheet-august-2017.pdf

** K.Ayers, AMR Presentation PD094, 06/2014

Discussion:

How can we port existing QC work over to LTE?

What is similar, what is new?

Electrolysis Cell

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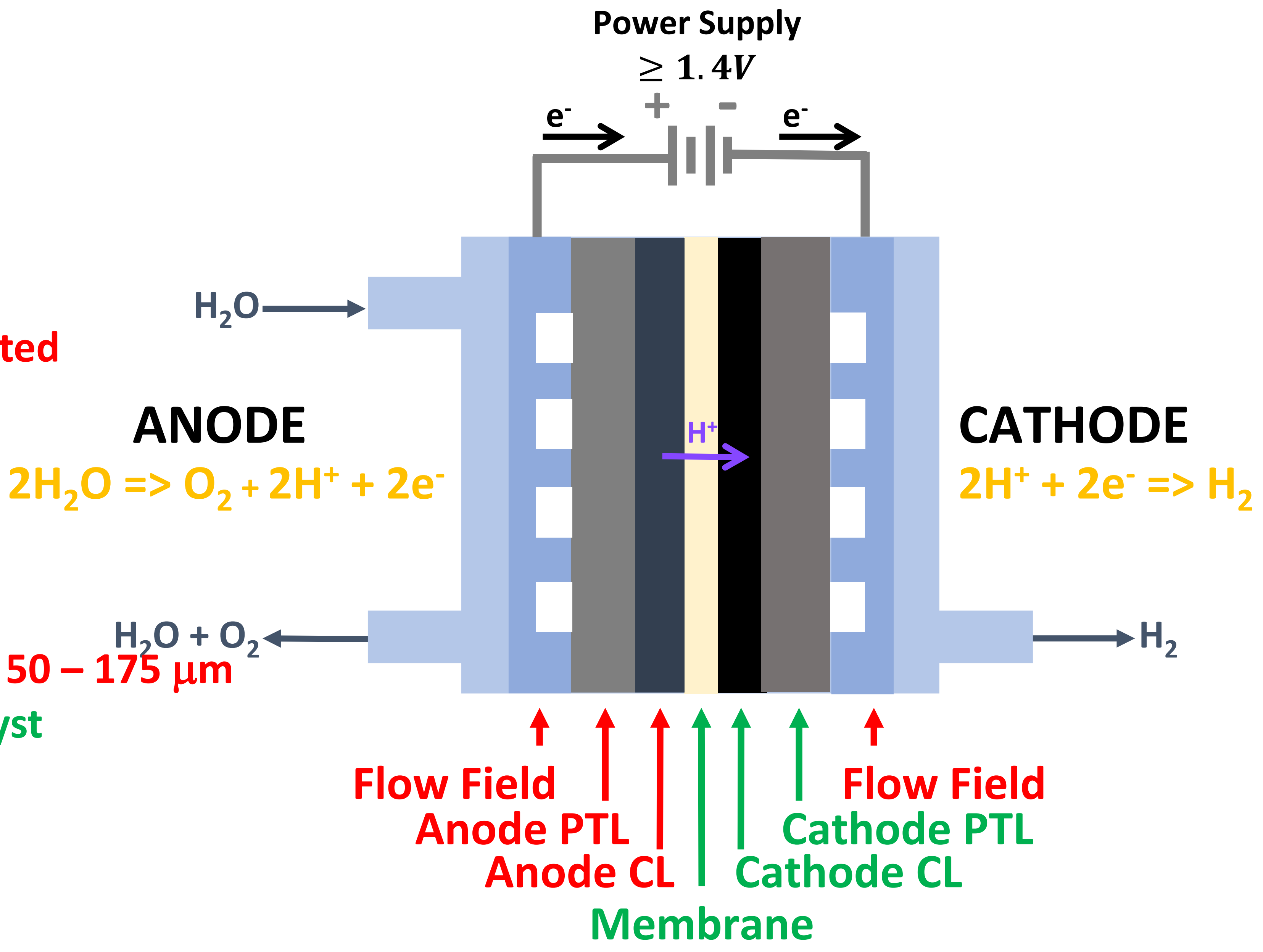

Electrolysis Cell

- **Electric Power to Gas at Potentials ≥ 1.4 V**
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High potential requires materials with high corrosion resistance

- **Titanium => TiOx passivation**

⇒ **Thickness of oxide layer prior to coating or to install**

  ⇒ **Contact resistance measurement?**

- **Titanium requires coatings**

⇒ Improve interface

⇒ Protect functionality by preventing TiOx growth

⇒ **Loading of coating**

⇒ **Coating continuity**

  ⇒ **Thickness**

  ⇒ **Voids**

  ⇒ **Lamination**

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High potential requires materials with high corrosion resistance

- **Very different catalyst material**

⇒ **Metal to oxide ratio**

⇒ not very reproducible standard material

⇒ **Catalyst Utilization**

⇒ no reliable ECSA measurement

⇒ **Catalyst Loading**

⇒ XRF

⇒ **In-plane resistance of electrode layer**

⇒ depends on fabrication method & ink formulation

- **Catalyst layer thickness or voids can impact PTL coating durability**
  - Exposure of PTL coating to very low pH

⇒ Pt dissolution

⇒ Loss of PTL functionality

⇒ **Local catalyst loading**

⇒ XRF mapping, optical 2D mapping methods

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- **Thicker membranes**
- **Operation may include high differential pressures**
  - Δ30 bar or higher

⇒ **Creep through assembly or compression**
⇒ **Hydrogen crossover**
⇒ **Membrane reinforcement**
⇒ **Membranes may include Gas Recombination Layers (GRC)**
⇒ **Loading & Distribution**
  ⇒ **XRF mapping**

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Electrolysis Cell

Stack Assembly Considerations

- **PTL**
  - Total thickness
  - Thickness variation within sheet
  - Sharp edges
- **Gasket thickness variations**
- **Membrane / Gasket creep due to high compression**
- **Particles / Debris inclusion**
- **Membrane swelling resulting in deformation / shearing**

Questions?

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