**Introduction & Motivation**

Electrochemical systems are widely used for being efficient and environmental friendly, but...

**System:** Electrochemical cell with gas evolving electrodes

- Gas and liquid flow fields
- Bubble-liquid interactions

**Focus on:**
- Bubble departure from the surface
- Mass transfer
- Bubble coalescence

**Increase efficiency**

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**Multiscale Modeling**

1-D models → Simple, informative, capable of capturing averaged efficiency parameters

- Detailed flow field prediction → Navier-Stokes equations (PDE)
- Toolkit: CFD

**PDE's → Requires BC's to solve**

- Electron balance: Faraday’s law
- Mass of gas injected

Can we use sub-models to better represent the physical phenomena near the electrode?

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**Experimental System & Techniques**

Electrochemical system with gas evolving electrode

- Phase hold-up
- Bubble size
- Qualitative description

**System:**
- Anode: RuO$_2$/TiO$_2$ dimensional stable anode (DSA$^*$)
- Cathode: Titanium

**Suitable for**
- Chlorate production
  \[ \text{NaClO}_3 + 3 \text{H}_2\text{O} \rightarrow \text{NaCl} + \text{H}_2\text{O}_2 \]
- Water splitting
  \[ 2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \]

**Optical Probe**

**High speed Camera**

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**Planned Experiments**

**Aim:** Systematically investigate the effect of different bubble sizes on the flow characteristic. This will be done in three phases:

1. **Testing the limits of the experimental apparatus**
   - Externally inject bubble the system through distributor at the bottom (Controlled conditions)
   - Test the limits of the pressure fluctuation method for different flow regimes
   - Outline the pressure signature for different flow regimes
   - Use the camera to qualitatively map the flow field
   - Use pressure transducer due to calibrate the pressure transducers

2. **Analyzing the system under controlled conditions**
   - Create artificial gas evolving wall by injecting gas a porous membrane
   - Use the camera to qualitatively map the flow field
   - Map pressure signal with respect to bubble size

3. **Analyzing system with gas evolving electrode**
   - Run the electrochemical system under different operating conditions
   - Use the map on step 2 to characterize the flow the electro chemical system with gas evolving electrode

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**Modeling**

**Bubble Growth on the Surface**

- Cyclic generation and departure of bubbles
- The inflation of bubble introduces additional resistance
- Lower reaction rate

**Wait Period**

- Wait Period
  - Departure of bubble
  - Convective transfer of species to the wall

**Inflation Period**

- Inflation
  - Transfer of reactants to the wall
  - Reaction on the wall
  - Transfer of products to the nucleation site
  - Change bubble volume (Inflation)

**Island model** will be used to calculate the rate of bubble inflation hence the temporal change in bubble coverage.

**How does the surface coverage affect the reaction?**

- An time estimate relationship will be introduced (similar to nucleate pool boiling)$^3$

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**Summary**

- For a given current density the surface coverage is a distribution

\[ \theta(t) = \frac{A_{l(x)}}{A_{l(x)}} \]

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**References**

1. For different aspects of the work, please refer to Annual CREL report (Page 54) or contact me directly at moral@wustl.edu