**Electrochemical Reduction of CO₂ to Formic Acid Using Gas Diffusion Electrode Technology**

**Authors:** Brian T Skinn¹, Sujat Sen², Timothy D Hall¹, Fikile R Brushett², E. Jennings Taylor¹

¹ Faraday Technology, Inc., Englewood, OH ² Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA

*Principal Investigator: BrianSkinn@FaradayTechnology.com, (937) 836-7749*

**Funding:** Department of Energy STTR Contract No. DE-SC0015173, TPOC: John Litynski (John.Litynski@hq.doe.gov)

---

**Problem**

- New technologies are needed to provide solutions for conversion of captured CO₂ as part of a multifaceted approach for mitigation and maintenance of greenhouse gas production.

**Technical Approach**

- Gas diffusion electrode (GDE) based electroreactor for CO₂ conversion to formic acid (FA)
- Tin cathodic catalyst deposited by FARADAYIC® ElectroDeposition (ED)
- Commercial mixed-oxide anodic catalyst
- Exploit scalable, low-cost ED fabrication methods and MIT expertise in electrochemical analysis and reactor fabrication

**High-Utilization Tin Catalyst via FARADAYIC® ElectroDeposition**

- Conventional methods use catalyst dispersed in ionomer suspension
  - Significant fraction of catalyst isolated from electrical contact and/or far from gas phase
- FARADAYIC® ElectroDeposition intrinsically produces electrically active catalyst = “High Utilization”
  - Smaller mass of applied catalyst, but with significantly enhanced per-mass catalytic efficiency
  - Waveform tuning also enables control over catalyst particle size, microstructure, active surface area, etc.

**Catalyzed GDE Preparation**

- Ionomer Application
  - Sigracet 39BC gas diffusion layer (GDL) with applied microporous layer (MPL)
- Float 40mm × 40mm GDL square MPL-side down on ionomer dispersion in isopropanol
- Sn ElectroDeposition – FARADAYIC® ElectroCell

**Electrochemical Testing**

- Perform electrolysis at constant half-cell potential and measure:
  - Total response current
  - Formic acid production
  - UV absorbance at 202 nm
- Apparatus Configuration
  - CO₂ flush gas behind GDE
  - Na₂CO₃ + Na₂SO₄ electrolyte (pH ~ 10)
  - H₂/Pt GDE counter electrode used to reduce total cell potential
- Desired reaction:
  \[ \text{CO}_2 + 2\text{H}^+ + 2e^- \rightarrow \text{HCOOH} \]

**Preliminary Results**

- Preliminary FARADAYIC® ElectroDeposition (ED) samples show significantly increased total and FA-efficient current densities relative to conventional spray-coating method and literature data
  - \( i_{\text{cell}} \geq 2.75 \text{ mA cm}^{-2} \)
  - %FA > 70%
- Favorable short-term catalyst durability
- Ongoing optimization
  - Ionomer loading
  - Sn electrocatalyst loading
  - Sn electrocatalyst ED parameters
  - GDE (GDL/MPL) parameters

**Alpha-Scale Electroreactor**

- Electroreactor design previously developed by MIT for CO₂ → CO conversion studies
- COMSOL modeling facilitates rapid design optimization to:
  - Increase energy efficiency
  - Minimize pressure drop
  - Maximize conversion

**Economic / Scale-Up Analysis**

**Life Cycle Analysis**

- Standard methodologies
  - EPA, DOE/NETL, etc.

**Scale-Up Analysis**

- Technology evaluation
- Market-entry / pre-commercial analysis