Spring 4-11-2016

Electrochemical carbon dioxide reduction as an alternative source of fuels and chemicals

Kendra Kuhl
Opus 12, kendra@opus-12.com

Etosha Cave
Opus 12

George Leonard
Opus 12

Daniel Diaz
Opus 12

Nicholas Flanders
Opus 12

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Electrochemical carbon dioxide reduction as an alternative source of fuels and chemicals

Kendra Kuhl
Opus 12
kendra@opus-12.com
4/11/2016
Team: uniquely positioned to bring this product to market

Team: 20 years of ECO2R research, previous startups

Nicholas Flanders, CEO
MBA/MS E-IPER, Stanford
*Work Experience*: COO/CFO Levo ($20M+), McKinsey CleanTech practice

Dr. Kendra Kuhl, CTO
PhD in Chemistry, Stanford, Post doc, SLAC
*Research*: Transition metal catalyzed CO₂ electroreduction.

Dr. Etosha Cave, CSO
PhD in Mechanical Eng, Stanford
*Research*: Nanostructured gold catalysts for CO₂ electroreduction.
Recycle CO$_2$ into cost-competitive fuels and chemicals
Conservation of Energy

Carbon-based compounds are good fuels because they are high in energy.

Burning hydrocarbons releases energy and carbon dioxide.

Inefficiencies reduce the amount of energy harvested from the theoretical value & increase the amount of energy that must be added back in.

To convert carbon dioxide into chemicals and fuels, must add energy back into the system.
ECO2R can also be thought of as “reverse combustion”

**Overall Reaction:**

\[
\text{CO}_2 + \text{H}_2\text{O} + \text{Energy} \rightarrow \text{C}_x\text{H}_y\text{O}_z + \text{O}_2
\]

**Split into electrochemical half reactions:**

<table>
<thead>
<tr>
<th>Water Oxidation (Anode)</th>
<th>( E^0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4(\text{H}^+ + \text{e}^-) )</td>
<td>1.23 V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CO(_2) Reduction (Cathode)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{CO}_2 + m(\text{H}^+ + \text{e}^-) \rightarrow \text{C}_x\text{H}_y\text{O}_z + n\text{H}_2\text{O} )</td>
<td>(~0) V</td>
</tr>
</tbody>
</table>

Determines minimum energy required for ECO2R to various products
Electrocatalytic process

Our $\text{CO}_2$ conversion performance: like 64 football fields of dense forest...

...37,000 trees... in a suitcase-sized reactor
Our efforts are focused on improving four key technical performance metrics that impact overall system economics.

<table>
<thead>
<tr>
<th>The metrics that matter for cost-effective ECO2R:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Product selectivity</strong></td>
</tr>
<tr>
<td>The percent of the electrical current through the system that goes to producing the desired product.</td>
</tr>
<tr>
<td>2. <strong>Voltage efficiency</strong></td>
</tr>
<tr>
<td>The thermodynamic minimum voltage divided by the actual voltage.</td>
</tr>
<tr>
<td>3. <strong>Current density</strong></td>
</tr>
<tr>
<td>The amount of current (proportional to the amount of product made) per electrode area</td>
</tr>
<tr>
<td>4. <strong>Lifetime</strong></td>
</tr>
<tr>
<td>How long the electrochemical reactor runs without a loss in energy efficiency or current density.</td>
</tr>
</tbody>
</table>
Electrochemical CO$_2$ Conversion

- A promising approach to recycle emissions
- Alternative source of carbon-based compounds
- Cost competitive in many situations
Thank you for your attention