High-Efficiency Ammonia Production from Water and Nitrogen

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Mary Biddy, National Renewable Energy Laboratory (NREL)

Project Vision

The proposed project aims to design and implement advanced components (e.g. catalyst and membrane) to transform the efficiency of electrochemical synthesis of ammonia (ESA) using air, water and renewable energy.

Project Impact

The proposed project is anticipated to significantly increase the efficiency of ESA at an appreciable current density; it may ultimately lead to the reduction of ammonia production cost by 30% compared to conventional Haber-Bosch process.

Fed. funding: $1.5M
Length 24 mo.
Innovation and Objectives

Innovation

- High-performance selective catalysts to boost ammonia synthesis while inhibiting hydrogen evolution
- Durable high-temperature alkaline membranes (>100 °C) to promote the ammonia production reaction
- State-of-the-art electrolyzer cell design to maximize the ammonia production efficiency

Task outline, technical objectives

<table>
<thead>
<tr>
<th>Institute</th>
<th>Tasks</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUNY</td>
<td>N₂ Reduction Catalyst</td>
<td>Q1-Q6</td>
</tr>
<tr>
<td>UD</td>
<td>Alkaline Membranes</td>
<td>Q1-Q6</td>
</tr>
<tr>
<td>NREL</td>
<td>Cost Analysis</td>
<td>Q1-Q8</td>
</tr>
<tr>
<td>GINER</td>
<td>MEA Design and Test</td>
<td>Q3-Q8</td>
</tr>
</tbody>
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Tech-to-Market strategy

- Long-term focus: automotive sector as liquid hydrogen carrier
- 1st market: Wind power; 2nd market: Liquid fertilizers
- Licensing / partnership with renewable farms and distributed fertilizer plants
Innovation and Objectives

Catalysts

- Undoped nitrides
- Doped nitrides

DFT

- FeN RDE Data

Membranes

- poly(aryl piperidinium) (PAP)-AEM

Molten Hydroxides in Porous Ceramics
Innovation and Objectives

Project history
• Giner initiated electrochemical NH₃ synthesis under USDA SBIR funding;
• Giner worked with SUNY on catalysts for reversible fuel cell under EERE funding
• Giner worked with UD on alkaline membranes under ARPA-E IONICS
• Giner worked with NREL on multiple projects for renewable energy utilization

Proposed targets

<table>
<thead>
<tr>
<th>Metric</th>
<th>State of the Art</th>
<th>Proposed</th>
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<tbody>
<tr>
<td>Ammonia production rate (mol/h-cm²)</td>
<td>10⁻⁵</td>
<td>10⁻⁴</td>
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<tr>
<td>Faradaic efficiency</td>
<td>30%</td>
<td>50%</td>
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<tr>
<td>Current Density (mA/cm²)</td>
<td>25</td>
<td>150</td>
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Anticipated challenges
• Challenge 1: hydrogen evolution reaction becomes dominant
  **Strategy:** selective catalyst inhibiting hydrogen evolution will be developed
• Polymer membranes unstable at elevated temperatures (>120 °C)
  **Strategy:** alternative ceramic alkaline membranes will be employed.

Desirable partnerships
Future partnerships are expected in 2019-2020; partners to test initial applications (renewable energy storage and distributed fertilizer plants)