A Novel Hollow Fiber Membrane Reactor For High Purity H₂ Generation From Thermal Catalytic NH₃ Decomposition

Miao Yu (PI), Rensselaer Polytechnic Institute
Shiguang Li (co-PI), Gas Technology Institute
Jochen Lauterbach (co-PI), University of South Carolina

Project Vision
We are solving the challenge of high purity H₂ production from NH₃ decomposition by designing a novel, self-sustained hollow fiber membrane reactor running at <450 °C.

Project Impact
The technology, if successful, is expected to solve H₂ transportation and storage problems by using NH₃ as an effective H₂ carrier for PEM fuel cell application, and may open potential markets utilizing H₂ as a fuel.
Innovation and Objectives

**Innovation**

Novel membrane reactor:
- Lower cost and active Ru-based catalysts
- Highly selective H₂ membranes
- High packing-density hollow fibers.

**Task outline, technical objectives**

Component Development and proof-of-concept:
- Ru-based catalyst development (USC and GTI; Q1-Q6)
- H₂ selective membrane (RPI and GTI; Q1-Q6)
- Equilibrium reaction shifting (RPI; Q5-Q6)
- Mini membrane reactor: (GTI; Q3-Q7)

**Tech-to-Market strategy**

- Develop technology from TRL-2 to TRL-5
- Fabricate modular system, and minimize manufacturing and scalability risks
- Secure IP, and identify next phase funding
- Solicit industrial partners assisting in the future development and value creation
- Anticipated first markets: 2024
Innovation and Objectives

**Project history**
- Prior collaboration between YU (PI) and LI (co-PI) on three DOE (ARPA-E or NETL) projects
- Ru-based catalyst developed in Lauterbach’s group
- H₂ selective membranes developed by YU (PI)
- Experience/expertise on high-temperature membrane reactors of LI (co-PI)

**Anticipated challenges**
- Membrane permeance and selectivity: ultrathin molecular layer deposition (MLD) coatings will be used
- NH₃ <100 ppb level in product: a H⁺ form ion exchange resin or commercial adsorbent may be used

**Proposed targets**

<table>
<thead>
<tr>
<th>Metric</th>
<th>State of the Art</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>7.5 L H₂/min</td>
<td>10 L H₂/min</td>
</tr>
<tr>
<td>Temperature</td>
<td>480-660 °C</td>
<td>350-450 °C</td>
</tr>
<tr>
<td>H₂ generation rate, g H₂/h/cm³</td>
<td>0.126</td>
<td>&gt;0.15</td>
</tr>
<tr>
<td>H₂ purity</td>
<td>~25%</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>Cost of H₂ delivered at 30 bar</td>
<td>N/A</td>
<td>&lt;$4.5/kg</td>
</tr>
</tbody>
</table>

**Desirable partnerships**
- **Demonstration phase** (10/2020-10/2023): MPT and Engineering Companies (e.g. EPIC System)