Membrane Reactor Synthesis of Ammonia at Moderate Conditions
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Project Vision
We are developing an alternative to Haber-Bosch for ammonia synthesis based on membrane reactor technology that decouples H₂ and N₂ dissociation.

Membrane Reactor

The goal is to create a low CapEx manufacturing process that is both scalable and dispatchable for distributed ammonia production.
Innovation and Objectives

Innovation
Use of dense, high permeable BCC metal membranes coupled to two independently optimized catalysts for H₂ dissociation and N₂ dissociation/NH₃ formation, respectively.
Analogous to proton conducting ceramics but no wires!

Task outline, technical objectives
• Install/employ custom sputter tool
• Optimize BCC/catalyst system for NH₃ synthesis
• Investigate alternate NH₃ synthesis catalysts
• Develop cost model

Tech-to-Market strategy
• Develop benchtop prototype membrane reactor for NH₃ synthesis
• Identify industrial partners
• Obtain follow-on funding for pilot scale membrane reactor
Proof of Concept Demonstration

Membrane Synthesis
• Acquired/Installed Sputter Tool
• Sputter Clean
• Catalyst 1 Application
• Sputter Clean
• Catalyst 2 Application

Lab Scale: VCR Cell

Scale-up: Tubular Membranes

Cross-section
Innovation and Objectives

Project history
• Developed composite BCC membranes for H₂ separations
• Demonstrated permeability >Pd and good stability
• Observed reduction of MgO to Mg by permeating atomic H
• Proposed to capture chemical potential of H for hydrogenation rxns

Proposed targets

<table>
<thead>
<tr>
<th>Metric</th>
<th>State of the Art</th>
<th>Proposed</th>
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<tbody>
<tr>
<td>Pressure</td>
<td>~200 bar</td>
<td>&lt; 10 bar</td>
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<tr>
<td>NH₃ Flux</td>
<td>~10⁻⁵ mol/m²*s</td>
<td>~10⁻³ mol/m²*s at T&lt; 500 ºC</td>
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<tr>
<td>Temperature</td>
<td>T= 500 ºC</td>
<td></td>
</tr>
<tr>
<td>Capital Cost</td>
<td>$200/ton NH₃</td>
<td>$150/ton NH₃</td>
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Anticipated Challenges
• Limited by N₂ dissociation catalyst
• Catalyst stability with BCC metals

Pathways Forward
• Transition metal carbide / nitrides
• Use of structured / high surface area catalysts to overcome reactivity

Desirable partnerships
• Couple to low cost H₂ synthesis
• Expertise in catalyst development
• Tech to market partners