Fed. funding:	$3.1M
Length	36 mo.

Protonic Ceramics for Energy Storage and Electricity Generation with Ammonia

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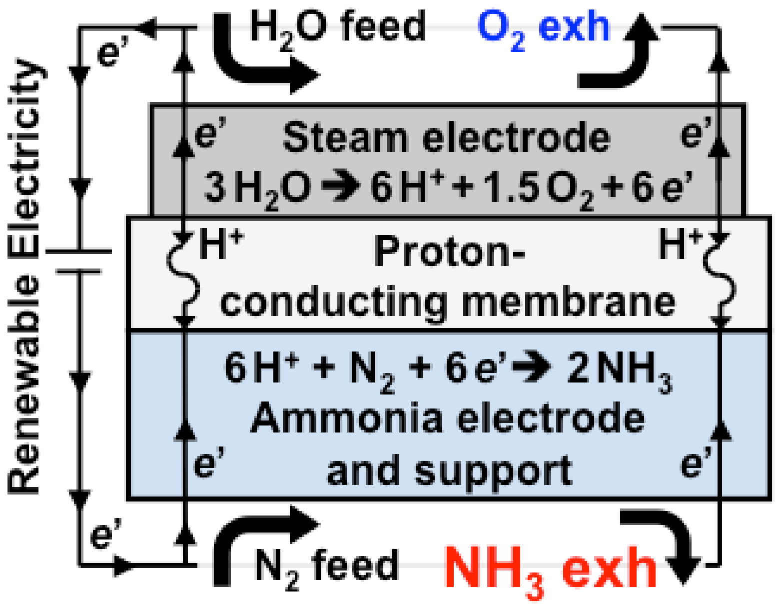
Project Vision

We are developing regenerative protonic ceramic fuel cell technology for synthesis of carbon neutral ammonia and its subsequent use for electric power generation



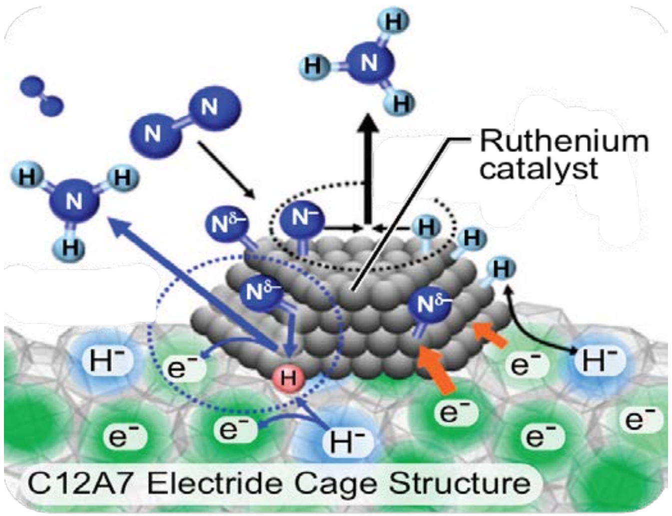
Project Impact

This project will result in a scalable low-cost efficient technology for utilizing renewable energy in production of ammonia and its further use as a fuel source for making electricity

Innovation and Objectives

Innovation

- Proton-conducting electrochemical cell for hydrogen generation from H_2O
- Optimized Ruthenium ammonia-synthesis catalyst supported on an electride
- Integration of the catalyst into the electrochemical cell for increasing NH_3 production rate



Ammonia-formation process

Task outline, technical objectives

- Develop reversible proton-conducting ceramic cells (CSM and FCE)
- Develop and integrate advanced electride catalysts to increase ammonia-production rates by two orders of magnitude (CSM)
- Develop and demonstrate performance and durability of a prototype stack manufactured using commercially relevant processes (FCE)

Tech-to-Market strategy

- Dual market strategies:
  - – Scalable ammonia production
  - – Electric power generation
- Renewable energy storage potential initial market entry
- Established SOFC manufacturing base

Innovation and Objectives

Project history

- FCE has established pilot scale manufacturing for advanced reversible SOFC power plants, electrolysis and storage applications
- CSM has been developing state-of-the-art protonic ceramic fuel cells (ARPA-E Rebels)
- CSM has verified feasibility of NH_3 production from N_2 and H_2O using protonic ceramic fuel cell (PCFC)

Proposed targets

Metric	State of the Art	Proposed
Ammonia synthesis rate	Highest published solid-state ammonia synthesis rate = 1×10^{-8} mol/ (cm^2 s)	Target NH3 synthesis rate ≥ 5×10^{-8} mol/ (cm^2 s)
Proton-Conducting Fuel Cell Performance	Laboratory scale button cell with ammonia fuel at 500 mA/cm^2 and 0.75 V	50 W NH_3 fueled stack PCFC with: ≤0.3%/khrs degradation, at ≥500 mA/cm^2, 0.75V, T≤650^oC, ≤20 bar.

Anticipated challenges

- Increased activity of the ammonia-synthesis catalyst
- Integration of ammonia-synthesis catalyst into the electrochemical cells
- High-performance steam electrode for efficient water splitting
- Cell and stack fabrication and scale-up

Desirable partnerships

- FCE and CSM team has the sufficient capabilities to proceed with the conduct of the project research and development activities
- The project team is open to the long-term partners involved in the commercial aspects of ammonia production, distribution and use

Technical Details

Ru-C12:A7 catalyst increases ammonia-production by 10x

- C12:A7 catalyst support has unique "cage-like" structure
- Transfers electrons through the cages to react with N_2
- Electrons weaken N_2 triple bond
- 10x improvement in NH_3 formation compared to Haber-Bosch catalyst

Proton-conducting ceramic cells further increase NH_3 production

- Highly reactive protons, rather than gas-phase H_2, are hydrogen source
- Electric potential drives membrane
- Two effects can increase ammonia formation by ten-fold

Ammonia Fueled Protonic Ceramic Fuel Cell (PCFC)

- Focus on cell and stack manufacturing and scale up using well-established ceramic processing techniques
- Develop cost-effective systems for ammonia production and use to generate electricity