Hybrid Electrical/Thermal Hydrogen Production Process Integrated with a Molten Salt Reactor Nuclear Power Plant

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PROJECT OVERVIEW

TIMELINE:
Start: July 1, 2018
End: Sept. 30, 2020

TOTAL CENTER FUNDING:
DOE Share: $600K
Cost Share: $823K
DOE Share Expended: $511K

BARRIERS:
A. Hydrogen Levelized Cost
B. System Energy Efficiency
C. Total Capital Investment

PARTNERS:

HyS CHEMISTRY

- Hybrid Sulfur (HyS) is a two-step thermo-chemical cycle based on sulfur oxidation/reduction.
- Key Reaction Step is electro-chemical water splitting using an SO2 depolarized electrolyzer (SDE).
- All fluid processing minimizes entropic losses due to phase changes
- HyS is “hybrid” cycle requiring both electrical and thermal energy input
- Optimization of the system requires trade-offs between the various components

HyS Process
H2SO4 + H2O ↔ H2 + 1/2 O2
Net Reaction
Electrochemical: 0.37 V
Thermochemical: 600-800°C
H2O ↔ H2 + 1/2 O2 (Low Temp)
vs. Low Temperature Electrochemical
H2O ↔ H2 + 1/2 O2 (Electrochemical: 1.23 V)

INTEGRATION WITH MOLTEN SALTS REACTOR

Hydrogen Generation by the Hybrid Sulfur Process

MEMBRANE ELECTRODE ASSEMBLY (MEA)

- New high temperature membranes having minimal SO2 permeability and durability in SO2/ SO3 environment required
- New catalysts and supports resulting in 600mV potential at 500mA/cm2 required
- Membrane electrode Assembly (MEA) required having >10% degradation in potential after 700 hrs. operation.

EX-SITU CATALYST TESTING

- Cyclic voltammetry studies on SDS show trends in activity:
  - Au>>Pt at high potential (kinetic region)
  - Au>>Pt at low potential (activation region)
- Consistent with linear sweep voltammetry results

TECHNOECONOMIC ANALYSIS

- Given projected performance of IMSR® and HyS process, production cost estimated to be 2.55 $/kg H2.
- 650°C upper limit major hurdle
- Path to $1.93 $/kg H2 identified
- Requires 25% reduction in heat, power cost
- Conceptual plant design based on s-PBI MEA SDE
- Being updated for SDAPP MEA
- Rotating disk electrode with Na2SO3 dissolved in sulfuric acid to evaluate the catalyst performance
- Scanning droplet system (SDS) probe for irreversible redox reactions

PROPOSED FUTURE WORK

- Evaluate electrolyzer performance at process relevant conditions
- Incorporate Au based catalyst into catalyst layer
- Conducting studies of PtAlum (M = transition metal) via combinatorial sputter deposition
- Identify combinations of cell potential, current density, and acid concentration that will achieve specific production cost targets

SUMMARY

The HyS process could add value to nuclear generation and serve as an energy storage mechanism for concentrating solar.
- Thermal energy can be used most effectively through hybrid thermo-chemical/electro-chemical process.
- House process utilizes 78% thermal energy and 22% electrical energy to store SO2 or H2SO4 indefinitely as required.
- Electro-chemical step key to efficient SO2 oxidation.