FueL Additives for Solid Hydrogen (FLASH) Carriers for Electric Aviation

Noemi Leick (P.I.)
National Renewable Energy Laboratory

DOE Hydrogen Program, Award # TCF-21-24761
2023 Annual Merit Review and Peer Evaluation Meeting – June 6th, 2023

AMR Project ID# ST243

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Photo from iStock-627281636

Project Goal

Technology Commercialization Fund
U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

- Develop FLASH formulation that can deliver 6g H_2/100g fuel (lead: NREL)
- Design, build and test fuel cell cartridge compatible with FLASH (lead: Honeywell Aerospace)
- Test FLASH with 600W fuel cell system and quantify cartridge and system specific energy (lead: Honeywell Aerospace)

Optimization of fuel formulation for H_2-powered unmanned aerial vehicles (UAVs).

www.aerospace.honeywell.com

Overview

Technology Commercialization Fund
U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

Timeline and Budget

For Competitively Selected Projects awarded through FOAs and fully funded at project start:

- Project Start Date:
  - NREL: 11/01/2022
  - Honeywell: 03/15/2023
- Project End Date: 03/14/2024
- Total Project Budget: $250k
  - Total DOE Share: $250k
  - Total Cost Share: $250k
  - Total DOE Funds Spent*: $52k
  - Total Cost Share Funds Spent*: $18k

* As of 04/14/2023

Barriers and Targets

Technical barriers addressed by the project	Project's key technical targets
Cost of borohydride fuel too high.	Max. $150/kg of fuel
Lacking assessment matrix for fuels is preventing efficient material screening.	Min. 6 wt% H_2 from total fuel
Impurities in H_2 stream: detrimental to fuel cells and toxic to living organisms.	Power a 600 W fuel cell system

Partners

- N. Leick (PI, NREL)
- F. Harrington, R. Moen (Honeywell)
- N. Strange (consultant, SLAC)
- T. Gennett (advisor, NREL & Colorado School of Mines)

Potential Impact

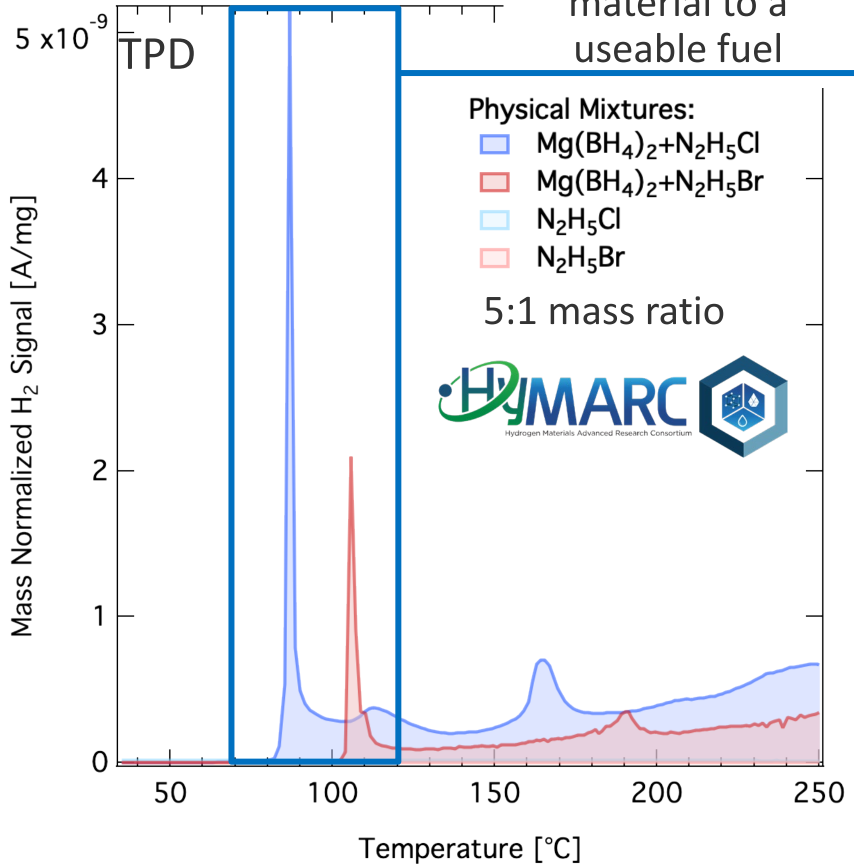
Technology Commercialization Fund
U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

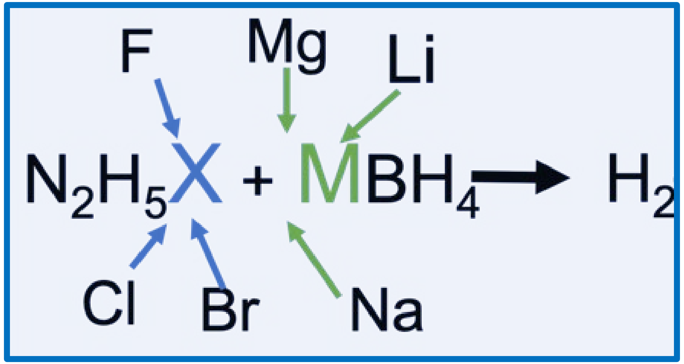
Technical barriers	Impacts of this project
Cost of borohydride fuel too high.	Mixtures of borohydride and salts can overcome current borohydride challenges (e.g., high dehydrogenation temperature, mass transport) and thereby allowing $NaBH_4$-based fuels that could meet the target of $150/kg.
Lacking assessment matrix for fuels is preventing efficient screening.	Understanding the key parameters that H_2-fuels for drone applications will enable a more efficient selection of fuels.
Impurities in H_2 stream: detrimental to fuel cells and toxic to living organisms.	Quantification of impurities and understanding their impact in different environments (fuel cells, atmosphere, biosphere) is crucial for the advancement of green technologies.

Approach

6-8 wt%
pure H_2 released

From a HyMARC material to a useable fuel





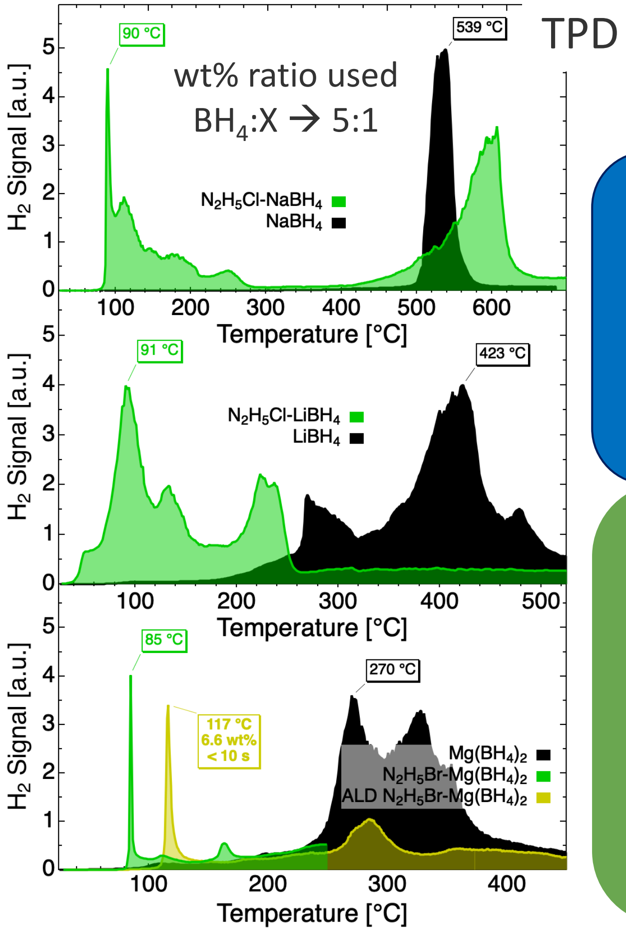
Develop formulations of fuels from borohydride/hydrazinium salt mixtures to meet the fuel assessment criteria:

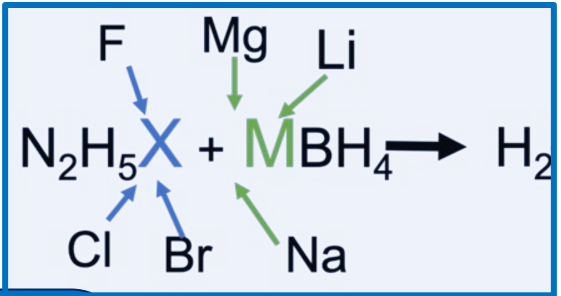
- **Which X and M?**
- **Which ratios?**

Technology Commercialization Fund

U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

Accomplishments and Progress





What *X* is best?

→ -F will likely lead to the formation of HF

→ -Br has a higher T_{desorb}, has a higher molar mass and is currently discontinued from the supply chain.

→ -Cl leads to lower T_{desorb}, and clean H_2

What *M* is best?

→ Li: releases H_2 at low temps, but safe handling and potential increase in price might be an issue

→ Mg: more expensive, but rapid release and good understanding

→ Na: very cheap, rapid release, mass transport can be an issue

Down select:
$Mg(BH_4)_2$+ N_2H_5Cl
$NaBH_4$+N_2H_5Cl

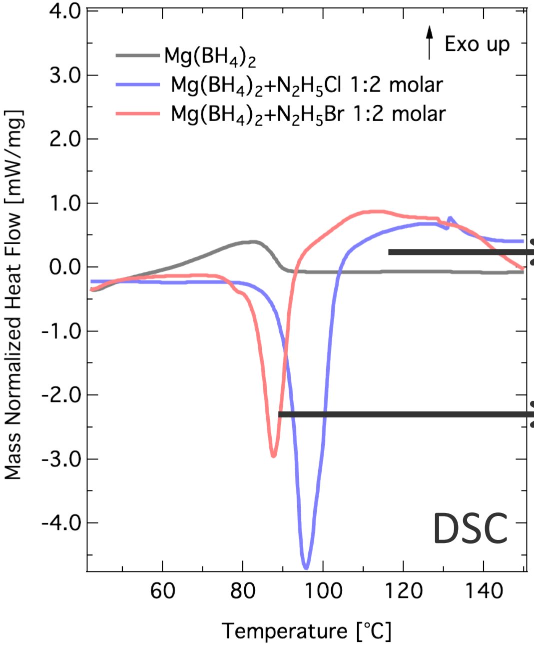
Accomplishments and Progress

Technology Commercialization Fund
U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

Established thermolysis mechanism for $Mg(BH_4)_2 + N_2H_5Br$

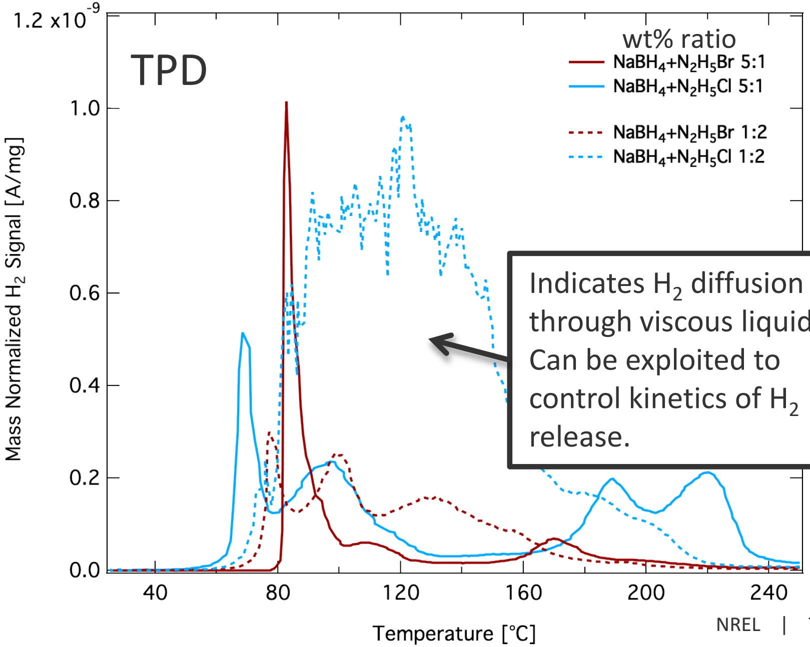
$$Mg(BH_4)_2 \cdot 2\,N_2H_5Br \xrightarrow{\Delta} MgBr_2 + 2\,N_2H_4BH_3 + 2\,H_2$$

Best molar ratio:
$[Mg(BH_4)_2] : [N_2H_5Cl]$
[1] : [2]



Hypothesis:
Exothermic reaction initiating $N_2H_4BH_3$ decomposition

Endotherms are due to the melting points of the N_2H_5Br and N_2H_5Cl salts.



Indicates H_2 diffusion through viscous liquid. Can be exploited to control kinetics of H_2 release.

Collaboration and Coordination

FLASH formulations

Partner	Role
NREL	P.I., project coordination, leads FLASH formulations, material characterization and optimization
SLAC	Expert in borohydride chemistry, consultant on reaction mechanism
Colorado School of Mines	Advises on technical aspects related to material handling, characterization, scale up.

Fuel cell development

Partner	Role
Honeywell	Establishes fuel assessment matrix, design/build/test fuel cartridge, and test 600 W fuel cell with developed FLASH formulation

Proposed Future Work in FY23 based on Remaining Challenges & Barriers

Technology Commercialization Fund

U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

Any proposed future work is subject to change based on funding levels

- challenge (C): supply chain issues
  → Impact on project (I): slows down confirmation of reaction mechanism, and scale up
  ❖ Solution/Future Work (S/FW): prioritize reactions/formulations to test, e.g. focus on $NaBH_4$
- C: Reliable technique to quantify H_2, kinetics and impurities
  → I: inhibits assessment of fuels and design of fuel cell cartridge
  ❖ S/FW: PCT system is being adapted for the quantification of H_2 and kinetics; and a transfer system is being developed to quantify impurities using GC-MS
- C: scaling up characterization of material
  → I: characterization of mg quantities is not representative of a g-scale fuels
  ❖ S/FW: PCT system will enable 100 mg, 500 mg and finally 1 g to be characterized.

Summary

Technology Commercialization Fund
U.S. DEPARTMENT OF ENERGY | OFFICE OF Technology Transitions

- Develop formulations of fuels from borohydride/hydrazinium salt mixtures for H_2-powered unmanned aerial vehicles (UAVs).
- Reaction mechanism for $Mg(BH_4)_2+N_2H_5Cl$ has been hypothesized and validation is underway
- Material down select: $Mg(BH_4)_2$, $NaBH_4$ mixtures with N_2H_5Cl
- SDS development for the down-selected materials is in development
- Strategies for testing larger scales (100-500 mg) of fuel are being implemented

Technical Back-up Slides and Additional Information

Tech Transfer activities

- Successful completion of sub-contract with Honeywell, enabling this research.
- Patent on new class of fuels under consideration.

www.nrel.gov

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Hydrogen and Fuel Cell Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL Transforming ENERGY