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Composite Materials for Hazard Mitigation of Reactive Metal Hydrides

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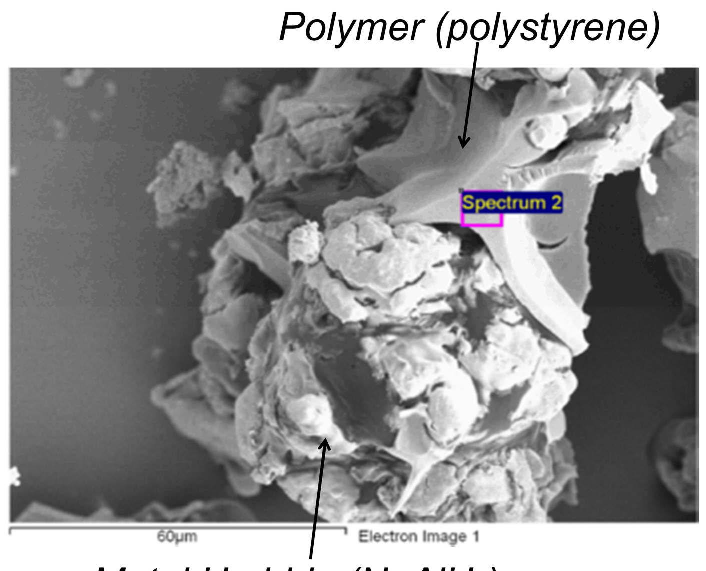
Introduction

- In an accident, reactive metal hydrides may be unintentionally exposed to air or water.
- The resulting exothermic reaction may endanger the safety of those around.
- To enable widespread use of these materials, an intrinsic hazard mitigation strategy could be employed.

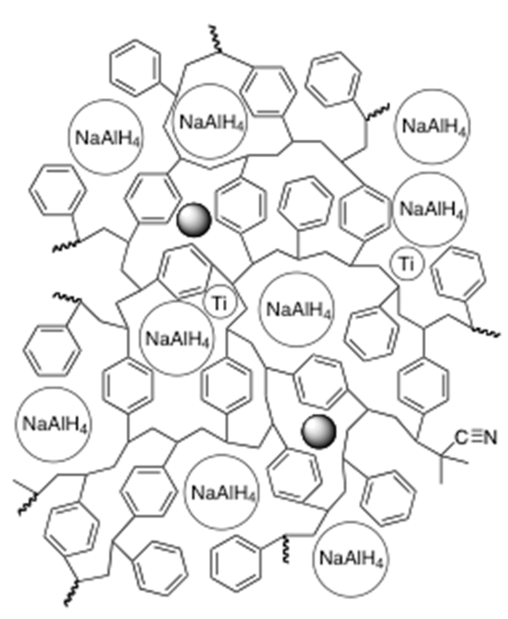
Approach

- A composite mixture of the metal hydride with a polymer should a mitigating feature such as:
  - Slowing the reaction rate.
  - Stopping the penetration of oxygen.
  - Absorbing the heat of reaction.

Polymer (polystyrene)



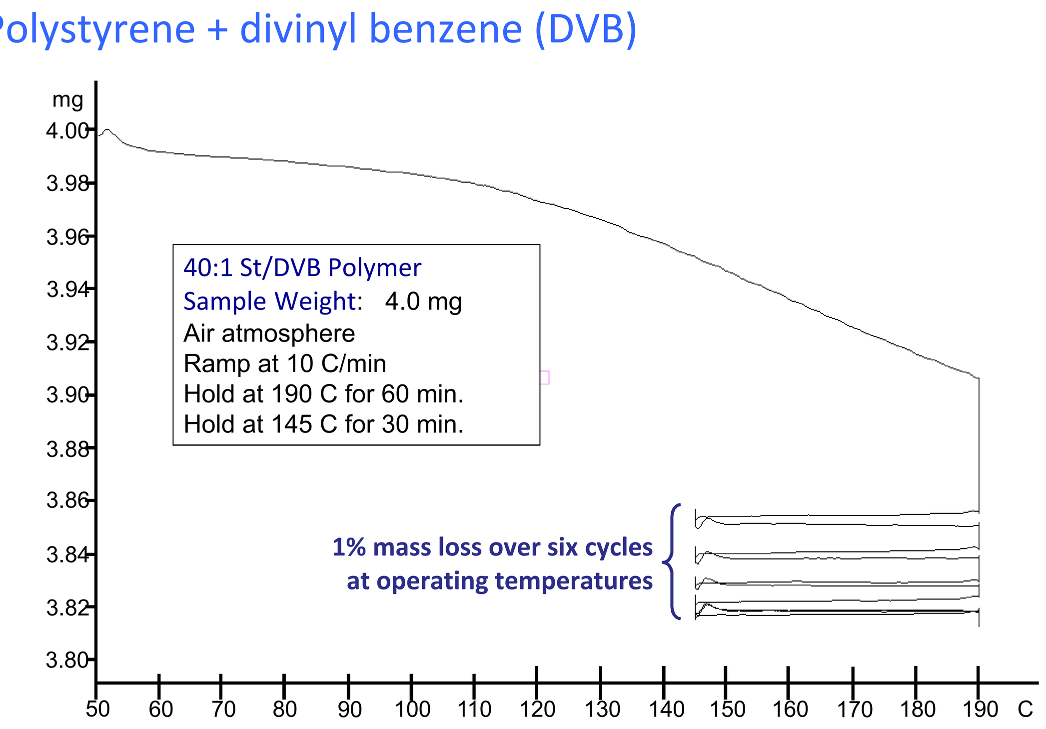
Metal Hydride ($NaAlH_4$)



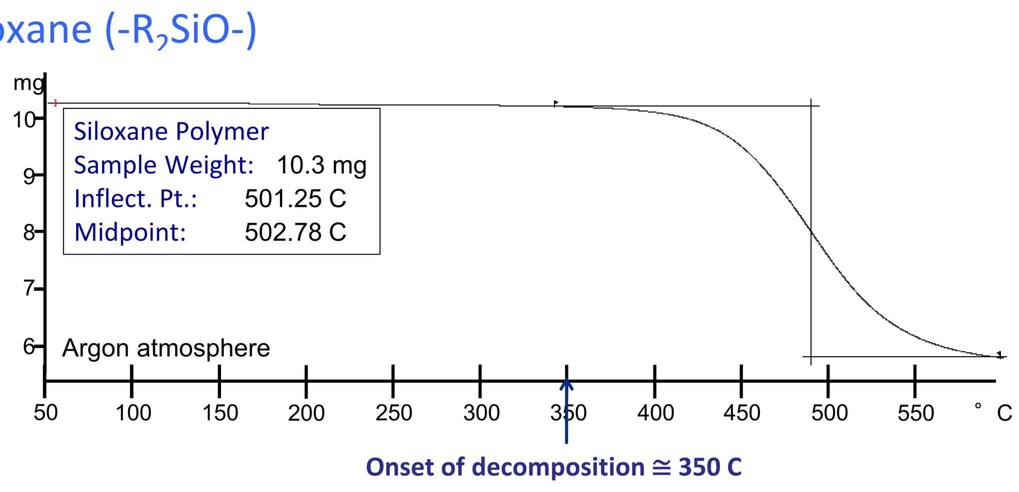
- The ideal polymer would:
  - Form a cross-linked matrix to act as a "scaffold" for the active material.
  - Be able to be polymerized in-situ with the active material.
  - Withstand the operating environment.
  - Have one or more of the mitigating features.
  - Have an insignificant effect on the performance of the metal hydride.

Results

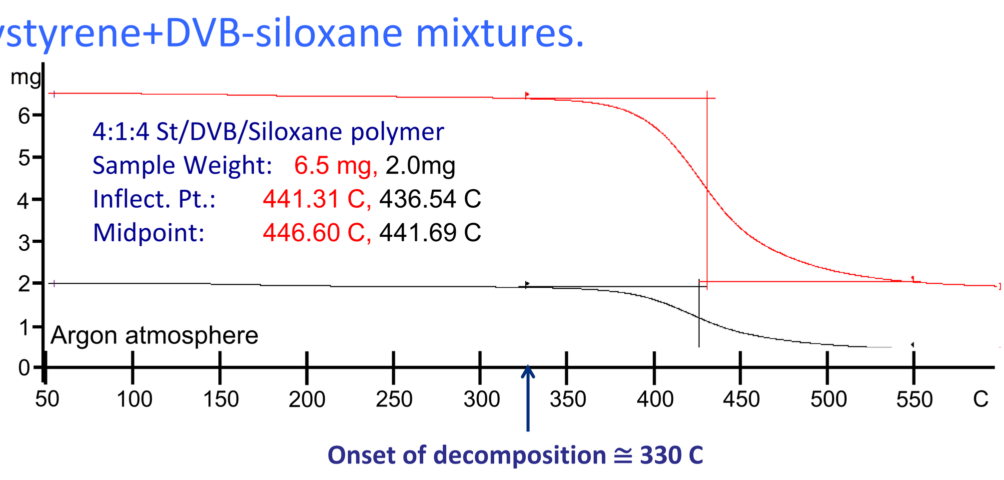
- **Synthesis:** Three polymers were successfully synthesized with sodium alante to composite materials. TGA analysis shows the neat polymers have acceptable performance:
  - Polystyrene + divinyl benzene (DVB)



  - Siloxane (-R_2SiO-)



  - Polystyrene+DVB-siloxane mixtures.



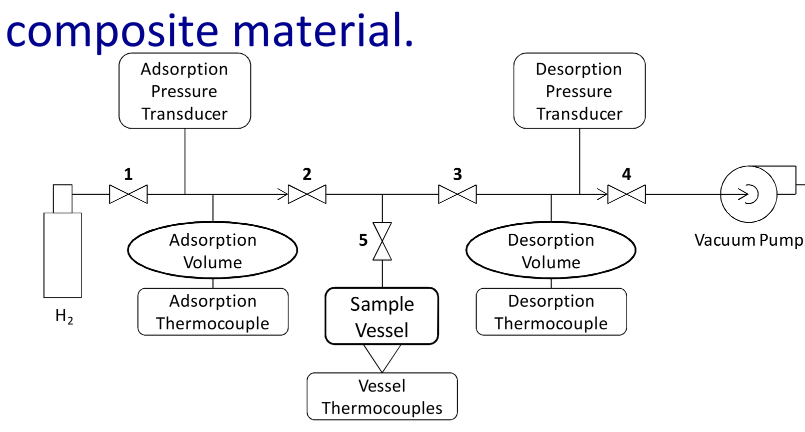
- **Qualitative:** Experiments visually compare mitigated and unmitigated pellets and powder dropped into water.

Unmitigated sodium alanate powder

Composite powder (polystyrene-DVB mixture)

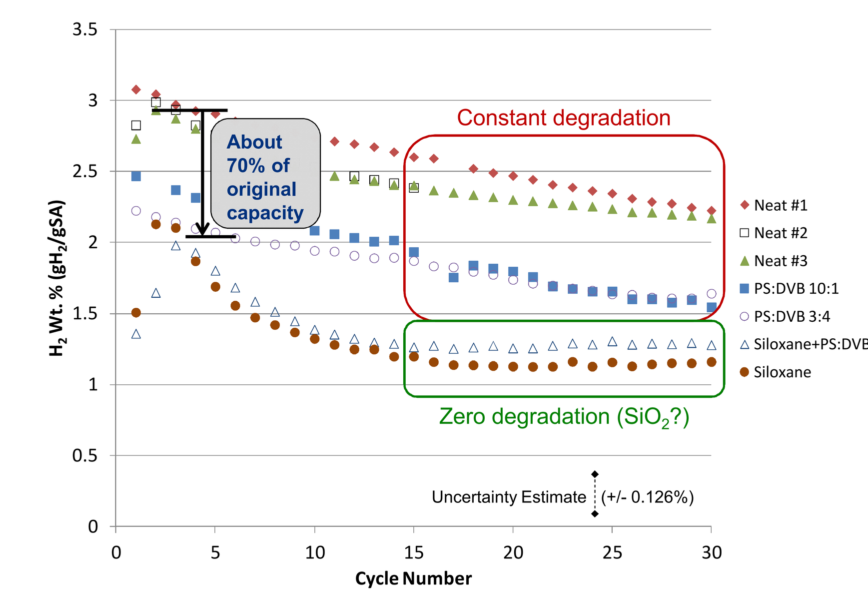
Results

- **Cycling:** Hydrogen adsorption/desorption cycling at normal operating temperatures tests the capacity and durability of the composite material.

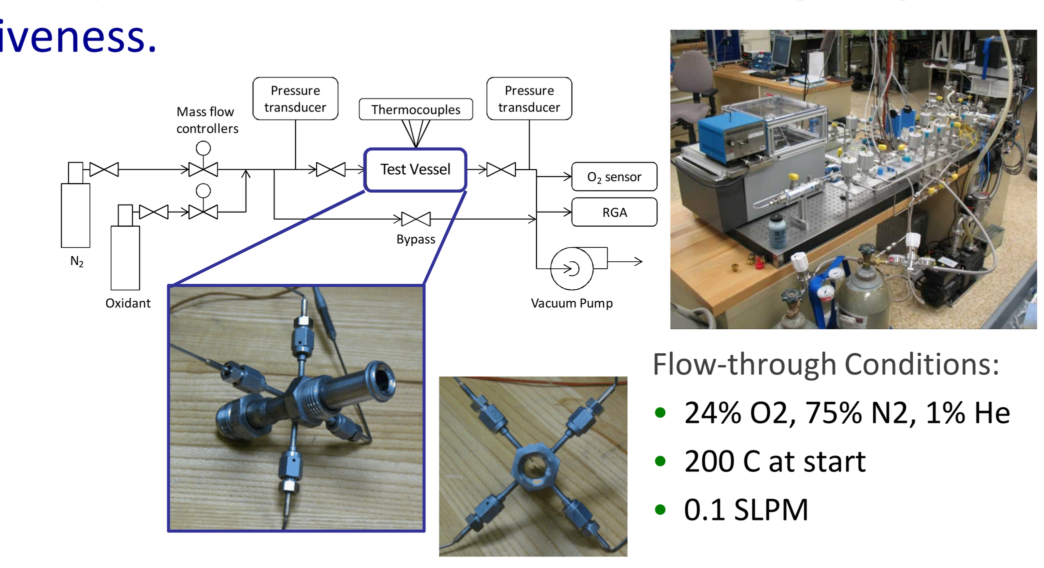


Cycling conditions:
- Adsorption: 30 min at 145 C; 1900 psia (130 bar) supply pressure.
- Desorption: 60 min at 190 C; to vacuum.
- Number of cycles set by user.

  - Addition of the mitigating material decreases the hydrogen capacity of the metal hydride and effects vary with number of cycles:

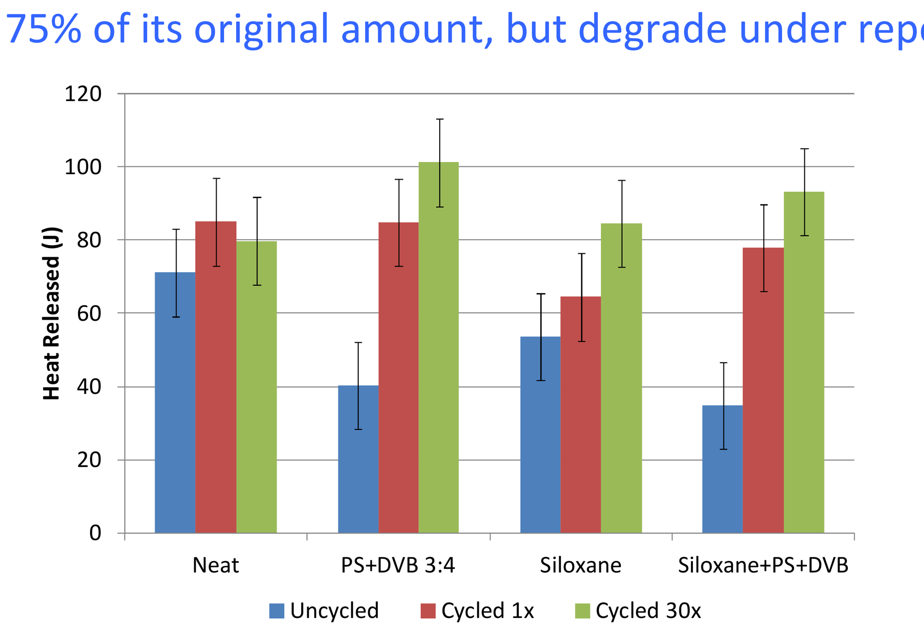


- **Reactivity:** Oxygen is flowed through the sample and the heat released by the reaction determines the mitigating material's effectiveness.



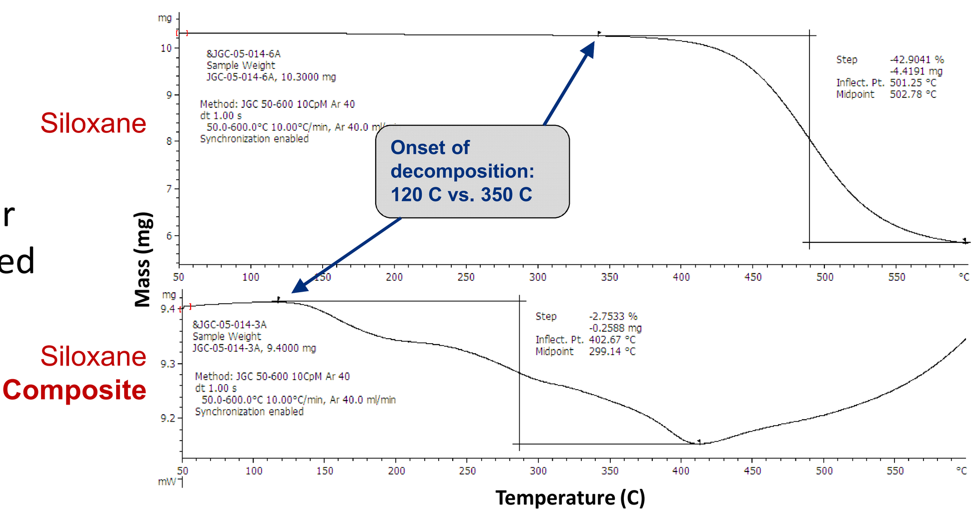
Flow-through Conditions:
- 24% O2, 75% N2, 1% He
- 200 C at start
- 0.1 SLPM

  - The composites mitigate well initially, reducing heat release to between 49% and 75% of its original amount, but degrade under repeated cycling:



- Thermal Stability: The polymers decompose at lower temperatures when mixed with the metal hydride in the composite materials

The other polymer composites exhibited similar behavior.



Conclusions

- Polymer/metal-hydride composites were successfully synthesized.
- The composites started thermal decomposition at lower temperatures than their polymer constituent, but did form a char.
- The addition of the mitigating polymer to the metal hydride decreases the hydrogen capacity more than expected and is postulated to be due to mechanical blocking of sorption sites.
- As-produced, the composites were found to mitigate well, reducing heat release to between 49% and 75% of its original amount.
- Cycling under realistic operating conditions revealed that more work must be done to prevent the polymer matrix from degrading.
- It is suggested that the polymer composite approach to hazard mitigation has merit, and that future work which strives to understand the interaction between the polymer and active material during synthesis as well as cycling may enable better engineering of the polymers to avoid destruction of it mitigating property upon use.

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