Hydrogen storage in porous metal hydride - polymer hybrid materials

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Abstract

Hydrogen is an irreplaceable energy vector of a carbon-neutral future, and high-performance storage must be available to allow its proper usage. Although metal hydrides hold the promise to be the superior storage option, many hurdles, including complex **activation** treatments, slow kinetics, and insufficient chemical and mechanical stability, need to be surmounted.

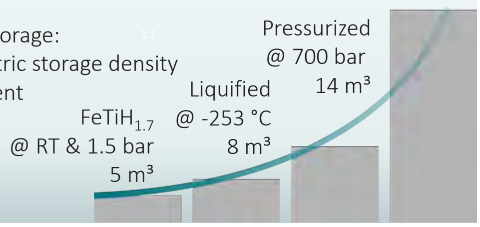
This investigation aims to solve these problems by prototyping a porous metal hydride-polymer composite.

H_2 - Storage

Volume required to store H_2 equivalent to the annual natural gas consumption per household. [1]

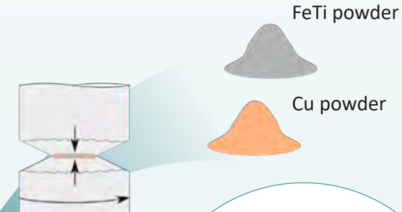
Advantages of metal hydride storage:

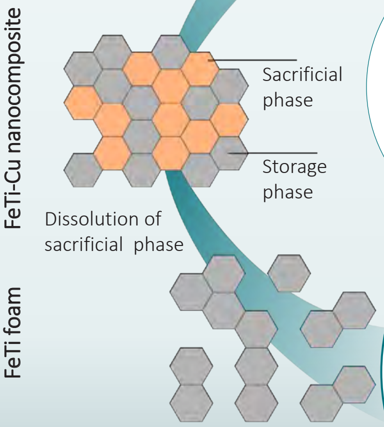
- High volumetric storage density
- Energy efficient
- Low losses
- Save



Processing

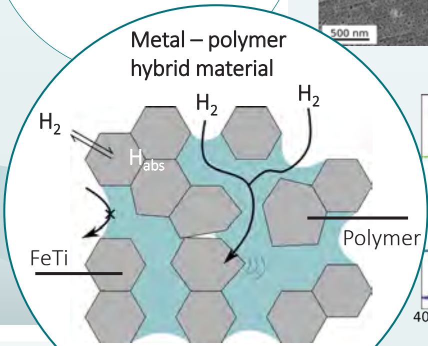
- Severe plastic deformation
- Temperature up to 600 °C
- Pressures up to 10 GPa





Important parameters:

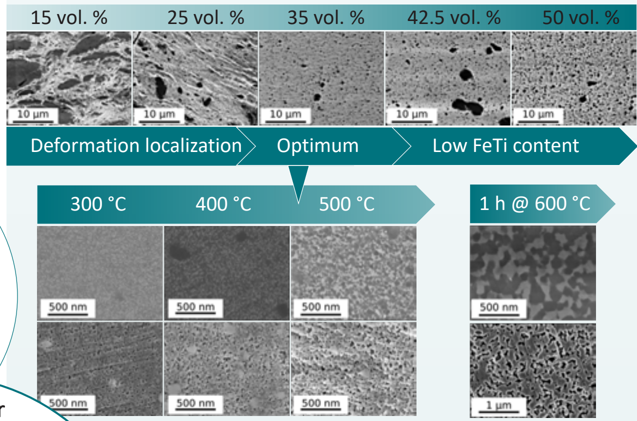
- *Pre-milling step*
- *Volume fraction Cu*
- *Deformation T*



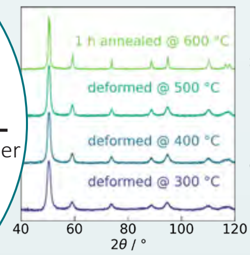
Structure

Micro- & Nanostructure

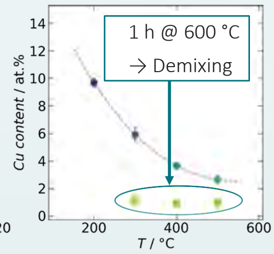
Variation of Cu-content – deformation at 400 °C - 50 revolutions



Phases & chemistry



Two-phase composite under all conditions

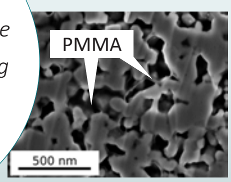


EDX analysis of FeTi foam

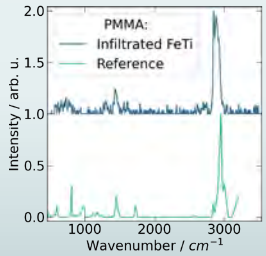
Polymer infiltration

Tunable structure:

- *Grain size adjustable*
- *Controllable alloying*
- *Polymer infiltration possible*



Infiltration using PMMA-Aceton solution

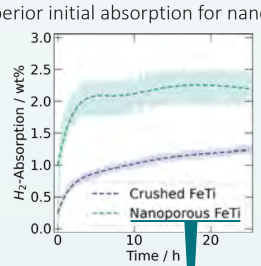


Polymer identification with Raman spectroscopy

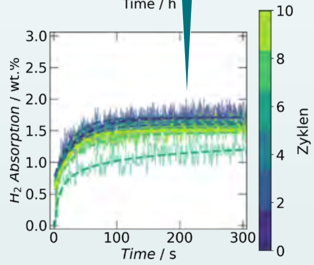
Properties & Performance

Initial absorption

Simplified activation - 30 min @ 450 °C
Superior initial absorption for nanoporous FeTi



Stable cycling



No significant capacity loss
Higher cycle numbers planned

Hydrogen sorption:

- *Absorption without activation treatment*
- *Stable capacity*
- *Rapid absorption*
- *Improved mechanical stability*

Bulk sample remains intact after 10 cycles - no catastrophic pulverization

Conclusion

- We can prepare **FeTi-Cu nanocomposites and nanoporous FeTi foams** with tailorable structure.
- FeTi foams **absorb hydrogen without complex activation treatment** and can be **cycled without catastrophic pulverization**.
- Filling **ultra-fine-porous FeTi foams with PMMA** for additional stability is possible. This hybrid material could be an interesting model system for detailed characterization.

1. Schlapbach, L. & Züttel, A. Hydrogen-storage materials for mobile applications. Nature 414, 353–358 (2001).

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SCoRe A+ Strategic Core Research Area Hydrogen and Carbon

Polymer-based hydrogen carriers for mobile application

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Introduction:

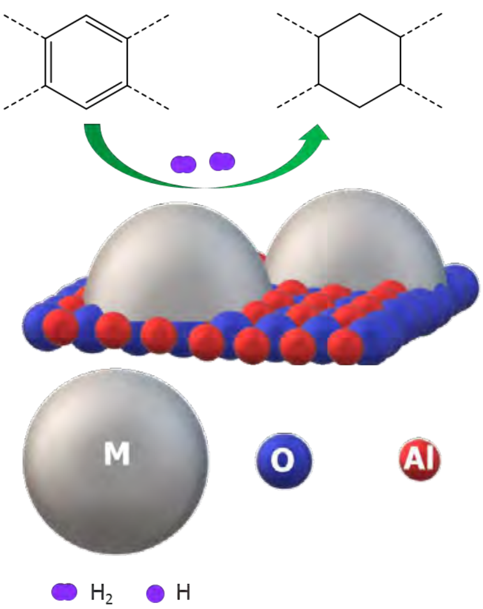
The high safety risks associated with hydrogen gas leakage have led to the development of solid-state hydrogen carriers as alternative storage systems. Hydrogenated organic compounds have been investigated for their ability to securely store hydrogen through chemical bonding. Recently, novel polymers have been designed with specific pendant groups that can readily absorb hydrogen through covalent bonds. By subjecting the polymer to hydrogen in the presence of a catalyst and elevated temperatures, these bonds are formed. The objective of this research is to create a safe and efficient polymer-based hydrogen carrier with high capacity, suitable for various applications such as vehicles fuel. These innovative polymers offer a sustainable and cost-effective solution, contributing to a greener and more sustainable future.[1]

Experiment:

Here, polymers with aromatic pendant groups are employed as solid-state hydrogen carriers, storing hydrogen through chemical bonding. The polymer solution is hydrogenated using a high-pressure autoclave under different conditions, leading to form stable covalent bonds.

Results:

The FTIR and HNMR results of hydrogenated and dehydrogenate polymer represents the possibility to reversibly transform from hydrogen poor to hydrogen rich polymers. By comparing the aromatic picks (red box) and aliphatic peaks (green box) the transformation can be approved.



Scheme: The structure of hydrogenation reaction in presence of metal based catalyst

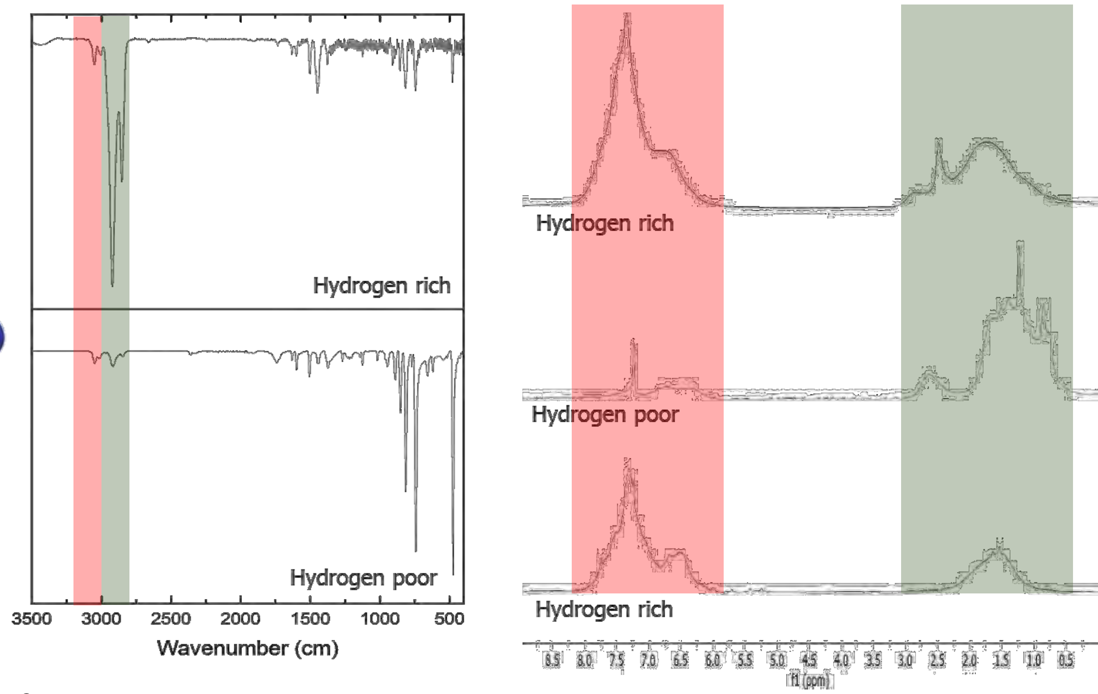


Figure: The FTIR (left) and the ^{1}HNMR (right) spectrum of hydrogen rich and hydrogen poor polymers.

Conclusion:

The approval of using polymers with aromatic pendent groups for mobile applications has provided promising results for the solid-state hydrogen carrier. These polymers have demonstrated the potential to offer the high hydrogen capacity required according to the DOE standard.

Reference:

M. Sharifian, W. Kern, and G. Riess, Polymers 2022, 14, 4512, doi: 10.3390/polym14214512.

This research activity has received funding from Montanuniversität Leoben and is part of the Strategic Core Research Area SCoRe A+ Hydrogen and Carbon

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