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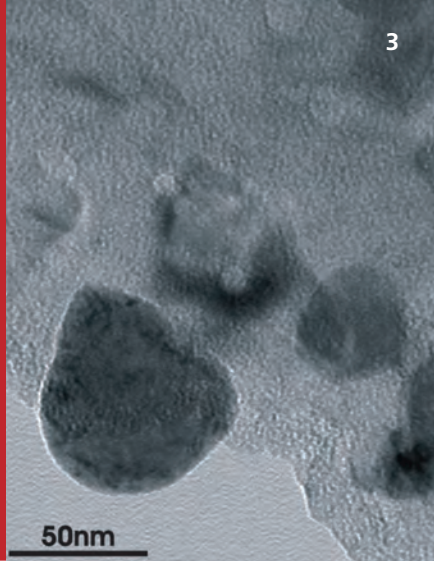
FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY
AND ADVANCED MATERIALS IFAM, BRANCH LAB DRESDEN

HYDROGEN TECHNOLOGY

STORAGE MATERIALS & SYSTEMS



Hydrogen Solid-State Storage

The safe and sustainable energy supply is fundamental for industry and society for stationary and mobile applications. Hydrogen is an environmentally friendly, safe and powerful energy carrier with a broad range of applications for fuel cells, internal combustion engines, turbines etc.
The safe, effcient and reliable storage of hydrogen is an important element in a hydrogen-based energy cycle.
For individual customer needs, Fraunhofer IFAM Dresden produces and develops materials, processing technologies and tank systems for the solid-state storage of hydrogen, which shows clear advantages over high-pressure or cryogenic hydrogen storage.

Metal Hydrides

Various metal alloys and intermetallics can react with gaseous hydrogen forming solid metal hydrides. By controlling temperature and pressure appropriately, the direction of the chemical reaction can be adjusted. Thus, metals can be charged and discharged with hydrogen:

$$\text{Metal} + H_2 \underset{\text{endothermic}}{\overset{\text{exothermic}}{\rightleftharpoons}} \text{Metal Hydride}$$

Metal Hydrides for Hydrogen Storage

Safety: Solid-state hydrogen storage systems present an unprecedented limitation of risks compared to liquid or compressed hydrogen.

Low operation pressure: Fraunhofer IFAM's hydride materials store hydrogen at moderate and relatively easy to handle pressures between 8 and 30 bar, which is typically the outlet pressure of electrolyzers. Therefore, a costly and diffcult to operate hydrogen compressor can be avoided.

No boil-off: In idle mode, Fraunhofer IFAM's hydride-based storage systems do not release hydrogen to the surroundings due to a boil-off of the gas.

Simplicity of use: Hydride storage systems are easy to install and transport. Furthermore, the materials used do not generate any hazardous waste at the end of their life cycle.

Performance: Fraunhofer IFAM has strongly improved the kinetics of solid-state storage materials and has been able to reach charge / discharge times of a few minutes. Furthermore, hydrides also offer highest volumetric storage densities.

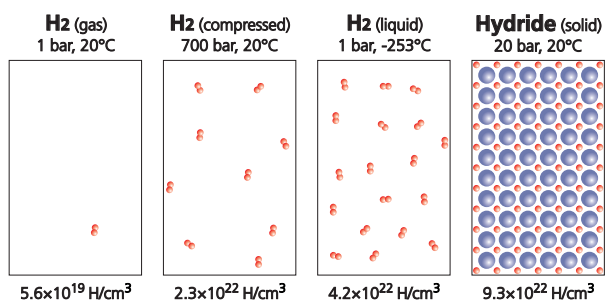


Fig. 1 Comparison of volumetric hydrogen storage densities

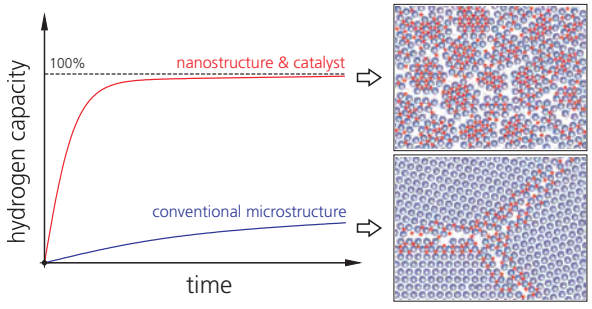
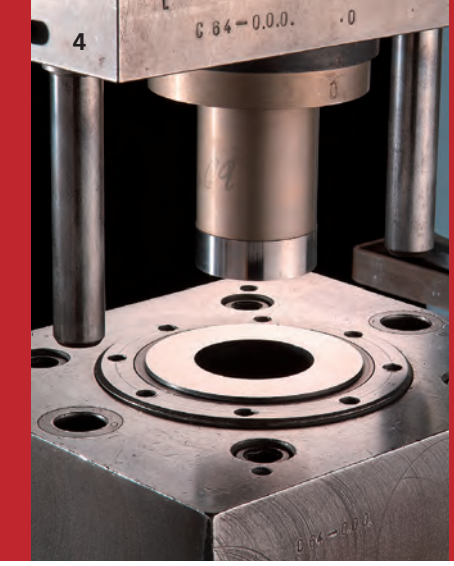
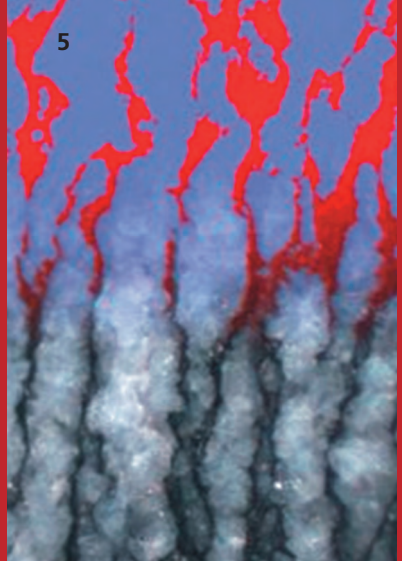


Fig. 2 Schematic hydrogenation of nanocrystalline vs. microcrystalline alloys





Materials, Technologies & Methods

Materials:

- Low-temperature hydrides
  -20°C ... 80°C,
  e.g. Zr-Mn, La-Ni, Ti-Mn, Fe-Ti alloys

- Medium-temperature hydrides
  80°C ... 200°C,
  e.g. $LiAlH_4$, $NaAlH_4$, $LiNH_2$

- High-temperature hydrides
  200°C ... 400°C,
  e.g. various Mg alloys

- Hydride composites with enhanced heat transfer and optimized gas permeability

Technologies & Methods:

- Induction melting
- High-energy ball-milling
- Rapid solidification (melt spinning, melt extraction)
- Powder metallurgical techniques for processing
- Thermal, structural & elemental analysis
- FEM simulations for tank design
- Test rig for tank evaluation

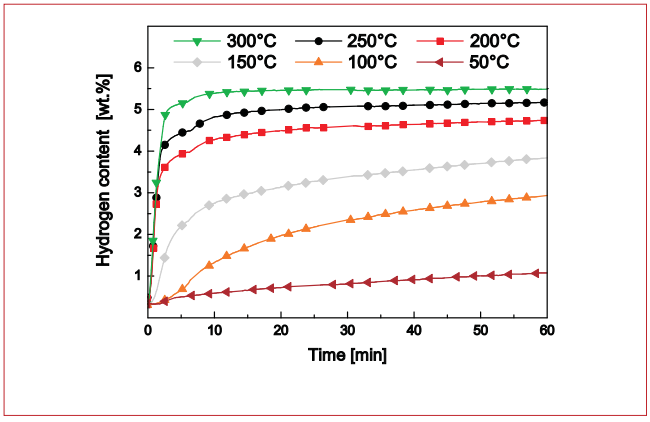
Powder-Metallurgical Processing Chain

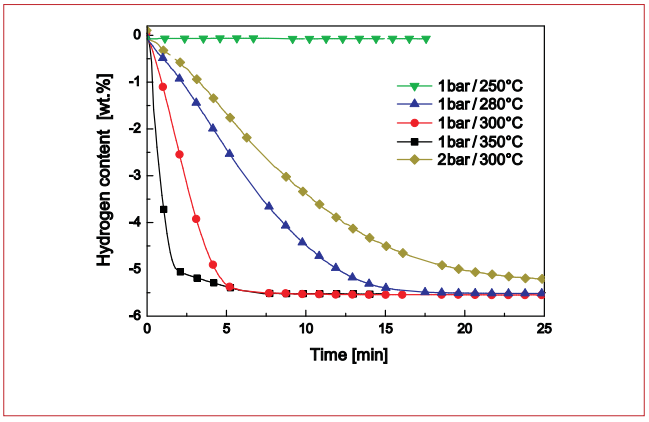
Powder-metallurgical (PM) technologies can be employed to process hydride-forming powders, granules or flakes into pelletized compacts with tailored heat conduction properties and gas permeability.
At Fraunhofer IFAM Dresden, a complete PM processing chain is available:

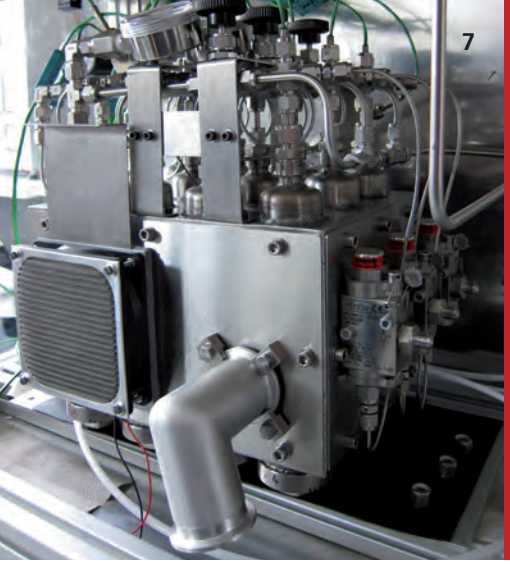
- Synthesis and modification of powders, granules or flakes and mixtures thereof
- Blending with minor phases (e.g. graphite, Al, Cu, metal foams)
- Compaction into manageable and stable pellets

Applications of Metal Hydrides

- Hydrogen storage
- Hydrogen purification (7.0 and better)
- Hydrogen gettering
- Hydrogen separation from gas mixtures (e.g. H_2-CH_4)
- Thermochemical devices:
  - Compressors for H_2
  - Heat pumps for cooling, heating or both
  - Thermoboosters for fast heating
  - Heat storage
- Thermochemico-mechanical actuators







Hydride Storage Tanks & Cartridges

The design of hydride tanks and cartridges according to individual customer needs requires a profound understanding of the physical, chemical and mechanical processes that take place during hydrogen loading and unloading.
FEM simulations are suitable to design storage tank architectures and to determine operation parameters.

Based on COMSOL Multiphysics, a thorough simulation package is available at Fraunhofer IFAM Dresden. It takes various static and dynamic aspects into account, e.g.

- Tank or cartridge geometry (also free forms)
- Gas transport (diffusion, flow)
- Reaction kinetics (absorption, desorption)
- Thermal management
- Pressure gradients in the hydride bed
- Safety aspects (pressure limits, vibrations etc.)

www.h2storage.de
www.ifam-dd.fraunhofer.de

R&D Services

- Materials synthesis and development (storage density, kinetics, thermal conductivity)
- Materials evaluation (degradation, cycle stability, recycling etc.)
- Development of materials processing technologies
- Design and construction of hydride storage tanks
- Testing and evaluation of tanks and cartridges
- System integration with
  - Electrolysers
  - Hydrogen fuel cells
  - Hydrogen internal combustion engines

1 *Melt-spun and chopped Mg-Ni alloy*
2 *Melt spinning device at Fraunhofer IFAM Dresden*
3 *TEM micrograph of a hydrogenated melt-spun Mg-Ni-Y alloy*
4 *Uniaxial press for consolidating hydride-carbon composites*
5 *MgH_2-graphite composite (blue-red) with optimized heat transfer properties*
6 *Pelletized hydride-carbon composites*
7 *Hydride storage tank with active thermal management*
8 *Test rig for hydride tank testing at Fraunhofer IFAM Dresden*
9 *Gas flow and pressure control devices*

CONTACT

Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM), Branch Lab Dresden
Winterbergstrasse 28
01277 Dresden | Germany

Prof. Dr.-Ing. Bernd Kieback (Director of the Branch Lab)
Phone: +49 351 2537 300
Fax: +49 351 2537 399
E-Mail: Bernd.Kieback@ifam-dd.fraunhofer.de

Dr. rer. nat. Lars Röntzsch
Phone: +49 351 2537 411
Fax: +49 351 2537 399
E-Mail: Lars.Roentzsch@ifam-dd.fraunhofer.de

Dr. rer. nat. Marcus Tegel
Phone: +49 351 2537 413
Fax: +49 351 2537 399
E-Mail: Marcus.Tegel@ifam-dd.fraunhofer.de