Novelty on the energy storage and hydrogen storage markets: McPhy hydrogen solid-state storage systems

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Energy storage is facing an impressive growth mainly coming from renewable energy sources. Sun and wind do not always provide electricity when it is needed the most (peak periods). Electricity has then to wait for its consumption. Transforming the excess of electricity into hydrogen makes electricity easy to store for both long and short term period. McPhy has decided to focus on this opportunity and comes up on the market with a highly innovative energy storage system. On the other hand, hydrogen consumers need safe hydrogen storage, 300 bar pressure vessels and liquid hydrogen are in most cases issues. Metal hydrides allow low-pressure storage and are a solution for industries, which require safety hydrogen storage. While coupling hydrogen produce with water electrolysis from renewable energy and McPhy storage system, it brings today on the market breakthrough "green" hydrogen. Thus CO_2 emissions from hydrogen production can be heavily lowered.

Key words: Hydrogen, solid state, Magnesium hydride, phase change material, nanostructure, adsorption, desorption, adiabatic, energy storage, safe hydrogen storage

Introduction

McPhy's storage systems are enabling a real breakthrough in merchant hydrogen distribution and create a viable answer to the rising demand for energy storage. McPhy's mission is to industrialize and commercialize an innovative solid-state hydrogen storage technology that offers unique advantages compared to other hydrogen storage solutions.

• **Safety**: McPhy's solid-state hydrogen tanks present an unprecedented limitation of risks compared to liquid or compressed hydrogen.

• **No compression**: McPhy's systems store hydrogen at a pressure of 10 bars, which is typically the outlet pressure of an electrolyser, therefore removing the need for a costly and difficult to operate hydrogen compressor.

• **Simplicity of use**: McPhy's storage units are easy to install and transport. They do not require the presence of operators or particular maintenance.

• **Clean technology**: with a 97% efficiency rate, McPhy's products require less energy than liquid or compressed hydrogen technologies which use up to 33% of the hydrogen energy content for storage. Furthermore the company's products do not generate any hazardous waste at the end of their life cycle.

• **Performance**: McPhy has strongly improved the kinetics of solid-state storage and has been able to reach load/unload times of a few minutes. The magnesium hydrides also offer a very high density and reduced footprint versus existing technologies.

McPhy owns exclusive rights on a portfolio of unique patents, which results from over 8 years of research at the CNRS and CEA, in partnership with Joseph Fourier University. McPhy is led by an experienced management team combining unique R&D competencies with strong business expertise of the industrial gas market.

Market opportunity

McPhy has targeted the following two markets that both have strong needs in hydrogen storage.

The merchant hydrogen market

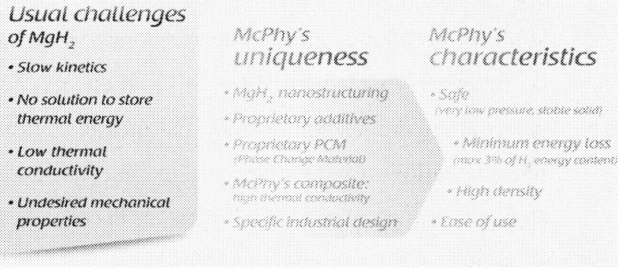
McPhy's management has a strong experience in this already mature market. The company's targeted customers are "medium" industrial consumers who do not consume enough hydrogen for gas providers to install on-site production units next to their factory, and who are hence provided with their needs through compressed hydrogen tank. The logistics implied by this procurement method requires frequent refueling brought by trucks which is complex to handle, increases the carbon footprint of the company and indirectly induces higher hydrogen costs. To help these clients to replace this logistics scheme, McPhy has chosen to partner with big gas providers who will package H_2 tanks in standard small and integrated on-site production units.

The renewable energy production plants' market

McPhy provides storage systems for green hydrogen production: concentrated solar power plants and wind farms that use part or total of the electricity they generate to produce hydrogen. Energy storage is a clear answer to the issues raised by the development of renewable energy: short term storage allows curve leveling of the production and long term massive storage allows reducing the unpredictability of the renewable energies production due to climate conditions. Storage also allows the decoupling of production and distribution: it is possible to have more control of the quality of power released on the network as storage units can answer more quickly to load changes than the power stations themselves.

The McPhy technology

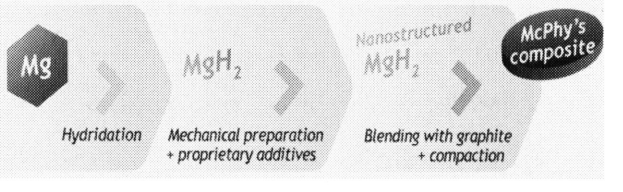
McPhy has developed unique techniques that solve the traditional limits of solid-state hydrogen.



McPhy's technology value chain

McPhy's composites production line

MgH_2 production capacity at McPhy's current manufacturing site:100 kg/day, Expandable to: 400 kg/day



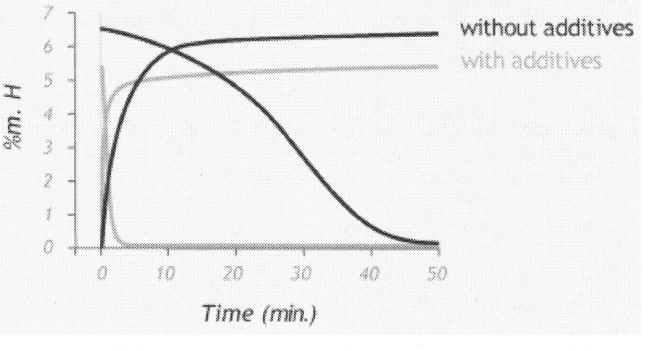


Fig1 Additives' catalyst property.

The additives and the nano-structuration of the MgH_2 help speeding up the process of hydrogenating and dehydrogenating of the magnesium during the absorption/desorption cycles.

Thermal energy storage: McPhy's stationary adiabatic tank

A patented Phase Change Material (PCM) brought into thermal contact though the metal walls with the McPhy composite allows to store heat energy during loading and to return it during unloading.

Fig. 2 A 4kg MCP storage.

• Minimum loss of energy (performance > 97%)

These technological advances already make McPhy's products a viable new alternative for hydrogen storage. The company profits from the inherent advantages of the use of magnesium hydrides for hydrogen storage while solving a number of problems, making its solution very attractive.

Products

High-capacity storage in ISO containers

MCP series

Fully autonomous

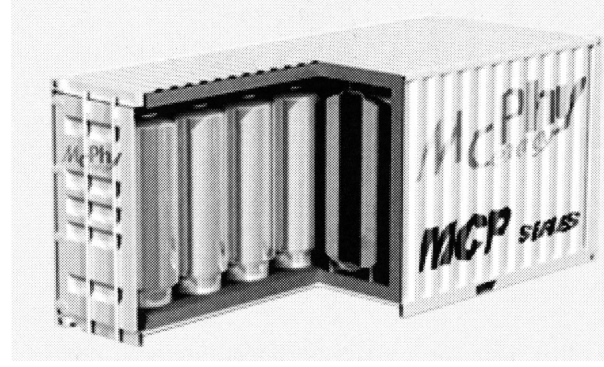


Fig. 3 Stationary adiabatic storage tank, 70 kg H_2 – 2.3 MWh.

Most applications for McPhy's hydrogen storage solution will require the heat from hydrogenation to be stored so it can be used to spark the dehydrogenation reaction: to this end MCP units are constructed. The cartridges containing the McPhy composite and surrounded by a Phase Change Material are put together in containers. The size of these containers can be chosen according to the storage need of the customer. However, using standard transportation container sizes (10 feet, 20 feet) proves very useful in many cases, as it facilitates transportation of the MCP units.

The inherent advantages of magnesium hydrides and the unique technology implemented by McPhy, as well as the choice of form and dimensions for the containers make McPhy's hydrogen storage solution safe, energy neutral, cheap, easily transportable and quickly chargeable and dischargeable. No other current means of hydrogen storage can list all of these advantages.

MGH series

External Heat Exchange

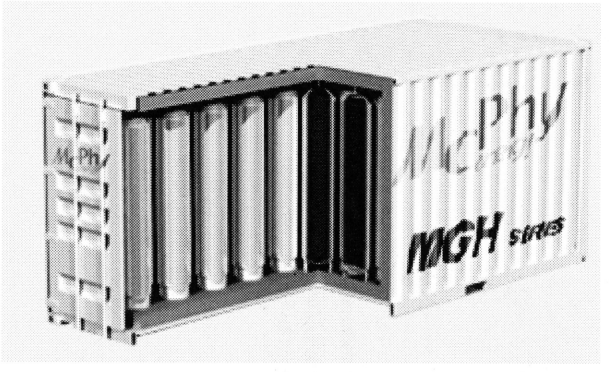


Fig.4 Stationary storage tank for integration in customers' processes, 700 kg H_2 – 23 MWh.

With the modular cartridges alone (no need for additional Phase Change Material use), there is already a substantial market that can be served: energy storage for a CSP (concentrated solar power) plant. Green hydrogen production from such a site does not require the heat from the reaction to be stored, as there is plenty of heat available from the CSP plant itself. Combining heat generated/needed by the storage with upstream/downstream processes procures a drastic improvement of the overall efficiency of the plant.

For this type of solution, the cartridges containing the McPhy composite and surrounded by a heat exchanger are simply put together in a container.

Applications

Industrial gas storage

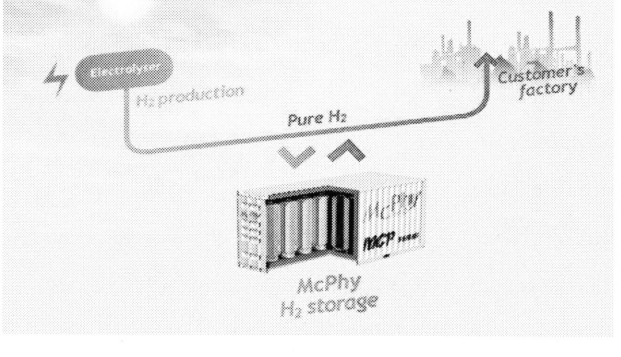


Fig. 5 Example of design for an OSSHY concept (On Site Solid Hydrogen).

This solution specifically appeals to industrial hydrogen consumers. Bottles and tanks of compressed or liquefied H_2 are replaced by on-site H_2 production coupled with McPhy's solid-state H_2 storage containers.

Benefits:

- Reduce industrial risks with safer storage.
- Reduce energy consumption (storing a certain volume of H_2 traditionally requires up to 33% of the energy contained in that volume).
- Reduce CO_2 emissions and environmental footprint.

Renewable energy storage

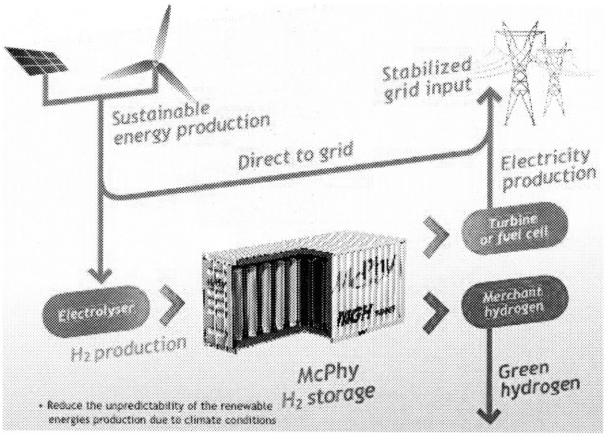


Fig.6 Example of renewable energy storage.

The CSP plant produces heat, and from this heat it produces electricity. This electricity is usually fed directly to the electricity grid. However, due to the variable nature of the electricity generation from a CSP plant, it is difficult to match electricity generation and electricity demand from the grid. At a certain point too much electricity is generated. This can be used to produce hydrogen, which is stored in a McPhy's storage container. The plant can then either convert the hydrogen back to electricity using a fuel cell, feed into a pipeline or transport McPhy's storage container to a hydrogen consumer.

Benefits:

Reduce the unpredictability of the renewable energies production due to climate conditions.

- Solve the time discrepancy issue between the production (offer) and consumption (demand).

The McPhy solution

Metal hydrides

Metal hydrides are chemical compounds formed when hydrogen gas reacts with certain metals.

McPhy has selected magnesium hydrides (MgH_2) for mass storage because they offer a large range of benefits.

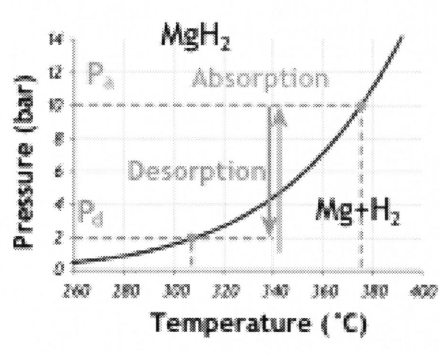


Fig. 7 McPhy's technology operating mode.

Totally reversible storage: $Mg + H_2 = MgH_2$

Loading at typical electrolyser outlet pressure (10 bar)

Min. time for complete loading: 8h

Unloading at fuel cell/H_2 gas turbine inlet pressure (2 bar)

Min. time for complete unloading: 8h

No compression (energy, cost and maintenance savings)

High cycling stability

For a given temperature, if the pressure is above a certain level (the equilibrium pressure), the metal absorbs hydrogen to form a metal hydride. If the pressure is below the equilibrium pressure, hydrogen is desorbed, and the metal returns to its original state. The equilibrium pressure varies directly with temperature.

Efficiency

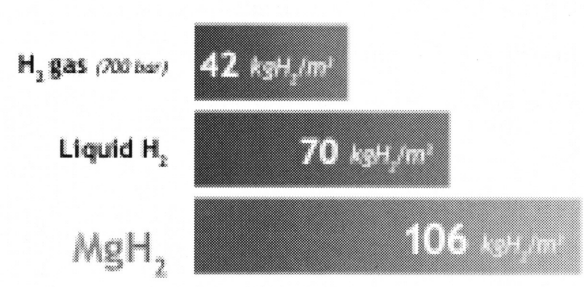


Fig. 8 H_2 volumetric density comparison.

Metal hydrides provide a much higher volume density than compressed or liquid gas.

No compression is required during the loading/unloading process. With a 97% efficiency rate, McPhy's products allow significant energy, cost and maintenance savings compared to existing gas storage solutions for which 10 to 25% of gas energy content is used for compression.

Safety

Hydrogen is an extremely light and inflammable gas and safety requirements implemented by countries have been strong. Pressurized and liquefied hydrogen storage infrastructures are less and less welcome in urban environment, which further pushes in favor of alternative storage technologies.

In the case of large quantities, pressurization and liquefaction technologies appear as both inefficient and unreasonable from a safety perspective

whereas McPhy's products allow a drastic reduction of risks.

Logistics

Existing storage technologies that need to be delivered suffer from a structural risk related to potential logistical problems such as strikes or accidents. In addition, trucks accessing to industrial areas through cities and villages need to comply with various limitations that make transportation an important issue, and thus McPhy's independent on-site storage is thus a strong advantage.

Ease of use

McPhy's products are 'plug and play' and do not require the presence of operators or expensive maintenance. Thanks to a modular approach in standardized size, they are easy to transport.

Carbon footprint

Thanks to McPhy's patented technology, the heat that is released from the absorption reaction can be recuperated for the desorption reaction. In this case, the energy necessary to store hydrogen is very low compared to direct storage solutions. This reduced energy necessity not only translates in a lower cost, but also in a lower carbon footprint through the lifetime of using McPhy's solid-state hydrogen storage solution.

Other advantages

Magnesium is an abundant and affordable material without any environmental impact. In addition, because of its non-reactivity with other materials, the magnesium hydrides do not have to be stored in containers made from specially treated metals.