



## FUCHSIA

# Solid-state Hydrogen Storage for Light Vehicles

## Objectives

Over the next two decades fuel cells will possibly displace internal combustion engines as the power source for many light and medium vehicles. The supply, safety and storage of the hydrogen needed for conversion in fuel cells are currently all limiting issues, with storage being pivotal. Compressed and cryogenic hydrogen are likely to be used as interim storage solutions, but only a solid-state store would satisfy market requirements. The objective of FUCHSIA is to explore novel carbon and metallic materials giving hydrogen storage suitable for a light vehicle. The resulting material will be incorporated into a pilot hydrogen store suitable for powering a fuel cell powered light vehicle with a range of 500km. If the hydrogen used was produced by totally renewable energy sources, a successful store would lead to a zero emission vehicle, thus fulfilling key aspects of Framework 5 Priorities.

### Problems to be solved

The central problem for FUCHSIA is to produce an efficient low pressure, ambient temperature and lightweight storage system appropriate for vehicular use. Compressed and cryogenic hydrogen have been used but there are practical and safety limitations for light vehicle application. The preferred alternative is still to absorb the gas into a solid media.

A successful hydrogen store would have:

- Low cost recyclable/rechargeable vessels
- Near ambient temperature and pressure operation and fast recharge/discharge kinetics
- Impact safety
- Tolerance to trace poisoning

The US Department of Energy (DOE) has set a standard for the comparison of storage media by defining a benchmark for the amount of reversible hydrogen adsorption; a ratio of stored H<sub>2</sub> weight to system weight of 6.5 wt% H<sub>2</sub> and a volumetric density of 63 kgH<sub>2</sub>/m<sup>3</sup>. These are now regarded as the FUCHSIA materials parameters.

Well known hydrides, such as LaNi<sub>5</sub> or TiFe can store no more than 2 wt% hydrogen, well below the target capacity. Figure 2 shows that the materials available for light vehicle hydrogen storage are very limited.

The central themes of FUCHSIA have been to:

- Prepare and characterize materials with a hydrogen capacity commensurate with the DOE criteria.
- Establish preparation routes for the most promising materials compatible with volume production.

Carbon nano-tubes and fibres, enhanced carbons, magnesium (Mg) alloys and complex hydrides, such as, alanates or borohydrides, have formed the core of the FUCHSIA work programme.

### Project structure

The FUCHSIA Project Consortium has been active since February 2001 and consists of five partners: University of Birmingham (UK, Coordinators), Johnson – Matthey PLC (UK), University of Reading (UK), IFW Dresden (D) and University of Fribourg (CH). The exploitation for the final material will be via the industrial partner, Johnson – Matthey, one of the EC's major fuel cell component fabricators and suppliers. An R&D Cluster has been formed with the other Framework 5 Hydrogen Storage Projects; HYSTORY and HYMOSESSES, which are addressing different application areas for hydrogen storage (Stationary power generation and marine applications). Contacts are maintained with other relevant Framework 5 projects such as HYPNET, PROFUEL and FUERO.

### Expected impact

Light vehicles are still seen as providing the biggest market for fuel cells. It has been estimated that by 2020, up to 20% (16 million) of new vehicles could be fuel cell powered. Nearer term, adoption of hydrogen as a fuel will be driven by considerations of energy security and urban pollution.

*A breakthrough in solid-state storage is still seen as the major factor in accelerating the introduction of hydrogen as a fuel and would radically advance the market penetration of fuel cell powered vehicles, in the EC and the rest of the world. Only by using stored hydrogen can the double benefit of zero CO<sub>2</sub> emission and energy conservation be achieved. The availability of a commercially viable hydrogen storage system for a fuel cell powered vehicle would address broad aspects of Key Actions 5 and 6 of the Energy sub-programme of Framework 5.*

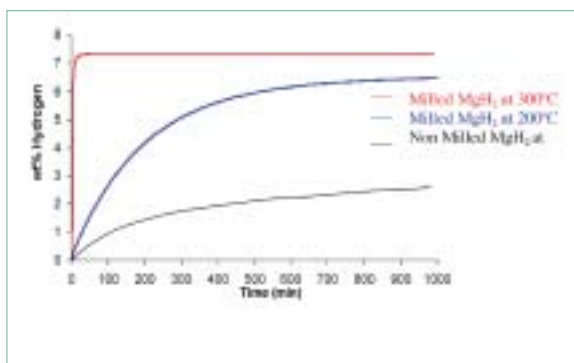


Figure 1: Hydrogen absorption kinetics of  $MgH_2$  before and after milling for 80 hours.

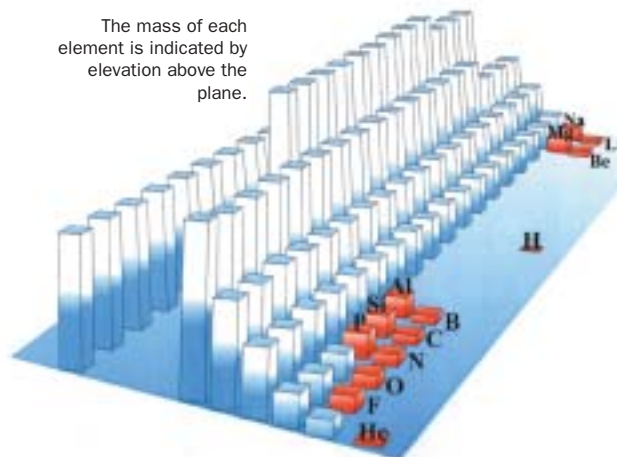


Figure 2: Any Hydrogen-Storage material, targeted at ~ 10wt% must originate from materials derived from those identified elements of the periodic table.

## Progress to date

A number of promising hydrogen storage materials have been explored to identify the one most suitable for subsequent production scale – up and store fabrication. The programme was refined in Year 2 by discontinuing work on Carbon Based materials. Worldwide opinion in 2002 has endorsed our view and swung away from carbon nano – material as commercial hydrogen stores. The FUCHSIA programme was redirected towards more promising candidate store materials notably; Mg alloys and light metal hydrogen compounds. Sodium alanates and lithium borohydride, have attracted attention worldwide as they show potentially practical levels of catalysed hydrogen release (7.4wt% and 18wt%, respectively) at moderate temperatures. For sodium alanates, the regeneration rates, even at high pressures (100bar and moderate temperatures (140°C), have been found too slow for practical vehicle stores. Desorption of hydrogen from Lithium Borohydride can be catalytically enhanced, but to date it has not been possible to attain reversibility. The most promising materials have been Mg and Mg-based alloys, high velocity milled (HVM) under hydrogen in the presence of transition-metal catalysts. This processing route appears to address the two deficiencies of Mg and Mg-based alloys as potential hydrogen stores i.e. the high temperatures (>250°C) and slow rate of release of stored hydrogen (see Figure 2 for FUCHSIA results). HVM  $Mg_2Ni$  alloys, with transition metal catalysts, have shown hydrogen storage capacities of 3.6wt% and desorption of hydrogen beginning at temperatures as low as 100°C. Catalysts, milling conditions and the elimination of surface oxidation have profound effects on the performance of Mg alloys as hydrogen stores. Recent work on Mg-Li

alloys has shown them to offer equivalent storage performance to Mg-Ni alloys but at lower cost and density. Current work is focussed on reducing absorption/desorption temperatures as low as possible. The best Mg alloy material will be incorporated into a prototype store. We propose to collaborate with other Framework 5 hydrogen storage projects (HYSTORY and HYMOSES) in the fabrication of the prototype.

Modelling work on the use of Mg alloys as a viable hydrogen store has shown that higher temperature desorption materials can lead to significant loss (up to 25%) of effective vehicular range for a given volume of store. The higher the temperature the larger the excess store material needed to generate the heat to assist desorption. Alternative, lower cost and quicker processing routes to milling will be explored. A modest amount of effort will be devoted to novel high weight % hydrogen storage media.

## INFORMATION

References: ENK6-CT-2000-00318

Programme:  
**FP5** - Energy, Environment and Sustainable Development

Title:  
 Solid-state Hydrogen Storage for Light Vehicles (FUCHSIA)

Duration: 36 months

Partners:  
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