

### Hotter fuel cells necessary for efficient use of hydrogen from metal hydrides

For sustainable development, the resources of the earth need to be maintained and carbon dioxide emissions should be avoided. In particular, we need to find an alternative for the use of fossil fuels in vehicles. Since long, hydrogen has been recognised as the fuel of the future because it exhausts only water when used in fuel cells and hardly any pollutants when used in conventional internal combustion engines. However, the storage of hydrogen onboard vehicles is a major concern. Recently, I defended my thesis entitled *Towards a hydrogen-driven society?* This work has been performed within the department FAME of R<sup>3</sup> (former IRI) financed by the Delft Institute of Sustainable Energy.

Hydrogen is a very light and volatile gas. Extremely low temperatures or very high pressures are needed to store a practical amount for vehicular use. Since these options are regarded to be expensive and unsafe, a material is sought that is capable of storing hydrogen in a reasonable amount under close-to-ambient conditions. Two options for hydrogen storage in materials were considered: 1) high surface area materials such as single walled carbon nanotubes (SWNT) and 2) hydride-forming metals such as magnesium.

Due to their specific tubular morphology, SWNTs were thought to show high hydrogen storage capacities. Our neutron scattering experiments provide evidence that hydrogen is not able to enter the SWNT bundles, explaining the relatively low hydrogen storage capacities. They conclude that hydrogen storage on single walled carbon nanotubes is very much similar to hydrogen storage in ordinary activated charcoals (the latter being much cheaper). From a fundamental point of view, however, there are some distinct differences due to the curved surfaces of the nanotubes. All high surface area materials, such as SWNT, activated charcoal, Metal Organic Frameworks (MOFs) and zeolites possess a relatively low interaction, meaning that low temperatures (as low as 77 K) and/or high pressures are needed. Another problem with these materials is that virtually all other gases exhibit a higher adsorption strength than hydrogen. Trace amounts of e.g. water vapour therefore slowly poison these materials.

Regarding hydrogen storage in magnesium metal it was shown that structural changes such as defects and dislocations in magnesium due to a ball milling treatment are not of decisive importance for the resulting increase in hydrogen sorption speed. The ball milling treatment reduces the particles to about 40 nm, which is thought to be a main reason of the increase in hydrogen sorption speed. By *in-situ* neutron diffraction, a new phase was found in Nb catalysed magnesium that might play an important role in the increase of the sorption speed. This crystal phase is most likely a Nb-Mg perovskite. It may be formed when during the ball milling treatment the MgO layer of the particles mix with the Nb catalyst particles. It was also found that NbH is the active phase for the catalysis and that the nano particles are initially loaded with lower than the maximum amounts of H, which surprisingly deviates from the results on large particles.

Heat effects are very important: since hydrogen storage compounds all possess a relatively high absorption energy, a large amount of heat (up to 30 percent of the energy content of hydrogen when used in e.g. fuel cells) is released. This means that a high-capacity cooling system is needed. We therefore think that in the future the whole storage tank will be exchanged, which can then be reloaded in a factory.

This high amount of heat needs to be supplied to the tank again when the hydrogen needs to be released from the tank. Since this costs energy, we propose to use the waste heat of the fuel cell for this purpose. Because practical storage materials function at elevated temperatures, this means that the operating temperature of the fuel cell should match those of the storage material. However, the operating temperature of fuel cells that are suited for this need to be in the range 200 - 250 degrees Celsius, which is high compared to usual operating temperature of 80 degrees Celsius of present-day PEM fuel cells.

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