An Innovative Technology for Hydrogen Storage in Portable and Mobile Systems

D. Eliezer, K. Holtappels, M. Beckmann-Kluge

This document appeared in

Detlef Stolten, Thomas Grube (Eds.):
18th World Hydrogen Energy Conference 2010 - WHEC 2010
Parallel Sessions Book 4: Storage Systems / Policy Perspectives, Initiatives and Co-operations
Proceedings of the WHEC, May 16.-21. 2010, Essen
Schriften des Forschungszentrums Jülich / Energy & Environment, Vol. 78-4
Institute of Energy Research - Fuel Cells (IEF-3)
Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2010
ISBN: 978-3-89336-654-5

An Innovative Technology for Hydrogen Storage in Portable and Mobile Systems

Dan Eliezer, C.En Ltd., Sonnhaldenstrasse 3, 8032, Zurich, Switzerland
Kai Holtappels, Martin Beckmann-Kluge, BAM Federal Institute for Materials Research and Testing, Division II.1 "Gases, Gas Plants", Unter Den Eichen 87, 12205, Berlin, Germany

Central to the realization of the profound potential of the hydrogen economy is the resolution of obstacles related to hydrogen technologies- the primary obstacle being the development of an effective and applicable hydrogen storage method. Conventional storage methods are unable to reach necessary targets relating to: weight, volume, safety, cost, durability, as well as charging and permeation rates. This in turn limits the *applicability* of hydrogen and fuel-cell power technologies, curbing the development of the hydrogen economy.

The presentation will outline a novel method for the safe storage of highly pressurized hydrogen in arrays of thin sealed glass capillaries.

The C.En developed system ensures the **safe infusion, storage, and controlled release of hydrogen gas**, under storage pressures of over 1200 bar. These findings have been achieved in experiments conducted on individual and multiple (array) capillaries at the German Federal Institute for Materials Research and Testing (BAM), and demonstrate the unique properties of glass capillary arrays.

Testing at the BAM Federal Institute has lead to the determination of the pressure resistances of individual and multiple (array) capillaries. These were determined in relation to capillary glass materials (quartz, borosilicate, alumosilicate and soda-lime glasses), capillary dimensions, wall thickness, endurance capacities etc. These tests were conducted in order to ascertain the optimal parameters and materials for the utilization of the glass capillaries for a variety of applications. Results demonstrated that borosilicate capillaries were able to withstand pressures over 1000 bar. Endurance testing further established that borosilicate capillaries consistently performed higher than other glass materials through thousands of refill cycles, having the highest average value (1002 bar) and the highest burst pressure rates (1242 bar) (See Figure 1 adjacent). A central determinant of the pressure resistance of glass capillaries relate to defects in the glass structures, such as bubbles, grooves or crack flaws (shingles). These strongly increase stress peaks and therefore decrease pressure resistance. At the same rate, no ignitions were observed when capillaries where burst at different pressures.

The significant advantage of glass capillaries is that they are stronger than steel and are simultaneously of a lower density. In comparison to steel vessels, only a thin wall thickness is needed to achieve an equal pressure resistance. A polymer overwrap acts as a protective shell against mechanical damages and allows for a flexible design of the storage unit. Furthermore, a large number of capillary arrays can be stacked together in a solid tank made of lightweight materials (e.g. plastics). This means that less material is needed and a strong and **lightweight** storage system is achieved. This is especially true as the apparatus of the system does not require additional bulky or heavy equipment, such as pressure reducers, to ensure its safe and efficient use (see details below).

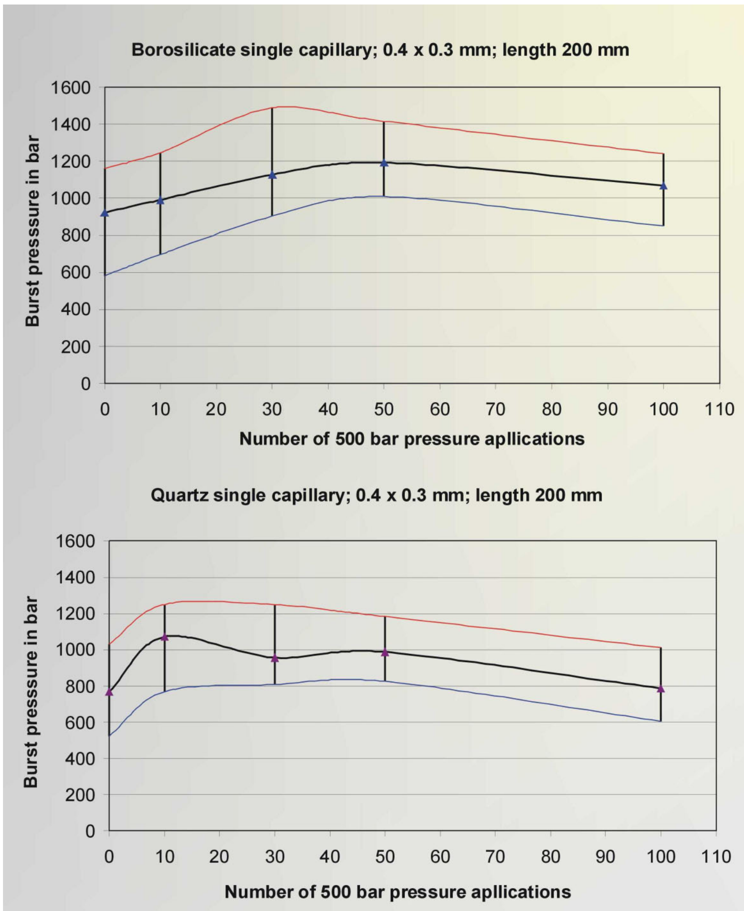


Figure 1: Burst pressure dependence on number of endurance tests.

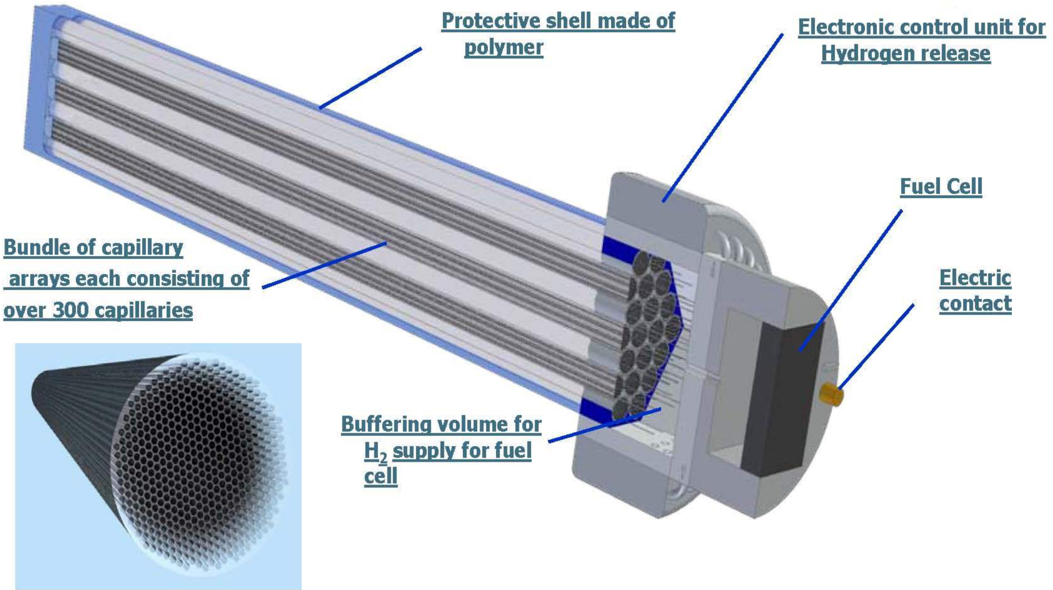
The **safety** of hydrogen supply and storage is paramount. If a rupture occurs in a one-vessel hydrogen storage system the amount of hydrogen released would be very dangerous, likely creating an explosive atmosphere. The advantage of C.En's technology is in the bundling of many single capillaries. Acting as its own pressure resistant vessel, each capillary supports and strengthens the resistance of its adjacent capillaries. In the event that one "vessel" (capillary) is damaged the amount of hydrogen released would be too small to create an explosive atmosphere.

The major barriers to using hydrogen as a replacement for fossil fuels in cars and trucks have been the size and weight of the tank, as well as safety issues related to the infusion, transfer and release of the hydrogen. C.En Ltd. has developed an innovative technology based on capillary arrays that ensures the safe infusion, storage and controlled release of hydrogen gas. The hydrogen storage targets of the U.S. Department of Energy (DOE) are used as a standard to compare various on-board hydrogen storage technologies. In September 2009 the DOE lowered its 2010 gravimetric storage targets from 6% wt to 4.5

wt% and its 2015 gravimetric storage targets from 9 to 5.5% wt (% wt -net useful energy/ max system mass). Similarly the DOE's 2010 volumetric storage targets were lowered from 45 g/L to 28 g/L, and its 2015 targets were lowered from 81 g/L to 40 g/L (g/L - net useful energy/ max system volume). Storage targets were lowered due to the failure of DOE-sponsored hydrogen storage systems to approach original targets.

Storage tests conducted at a specially built state-of-the-art laboratory at the BAM Institute demonstrate that C.En's technology has a gravimetric storage capacity of **33 %wt** and a volumetric storage capacity of **45 g/L**, easily surpassing the U.S. Department of Energy (DOE) recently modified hydrogen storage goals for 2010 and 2015. Test results significantly exceed the published storage capacities of other storage systems, clearly demonstrating that the technology enables the storage of a significantly greater amount of hydrogen than other approaches

The presentation will delineate upon the various methods of: a) refilling capillaries with compressed hydrogen b) permeation through the walls of primarily sealed capillaries at elevated temperatures c) the sealing of capillaries. The theoretical analysis of the resistance of capillary arrays to hydrogen pressure, and the experimental matters of the charging and release of hydrogen will further be presented in detail



Applications:

- Electronic device
- Completely variable construction
- Diameter, length and number of capillary arrays can be varied
- The cartridge can be combined with a fuel cell providing direct current voltage like a "clean" battery
- Without a fuel cell the design can be used as a storage system

Figure 2: Hydrogen storage cartridge prototype.

The technology is founded upon established scientific principles, yet its employable structure is of a malleable nature. The structure of the storage system of arrays depends upon the specific requirements of the end-user applications, and therefore allows for the optimally designed storage system. The cartridge system prototype itself demonstrates the flexibility of the technology allowing for: the open scaling of arrays- in size, length and number; easy linkage to a variety of fuel cells and for the simple shaping of the device using a moldable polymer overwrap.

Testing of these advances prototypes at the BAM Institute have further clearly proven that the technology can be modified to suit the specific requirements of various end-user applications and can in turn enhance the applications by ensuring an efficient, light weight, safe and compact source of clean energy.

Experiments conducted at the BAM Institute have conclusively demonstrated the various uses of our system for a variety of applications, including those of the:

- **Transport industries** -automotive, aircraft/aerospace, ships, maritime vessels, submarines, trucks, rails
- **Electronic industries -**communications, defense industry, electric and power applications – mobiles, computers, laptops etc.)
- **Manufacturing Industries** fiber materials, containers)
- **Infrastructural projects** (large and bulk storage, stations).

The relationship between the properties of the storage system and potential end- user applications will be discussed in detail.