International Journal of Research Publication and Reviews, Vol 3, no 10, pp 1884-1888, October 2022

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review of Current Challenges of Hydrogen Storage Technologies for Fuel Cell Vehicles

Tangula Shyam Prasad [1]***, Dr. G. Chandra Shekhar*** [2]

[1]*B. Tech Student, Department of Electrical and Electronics Engineering, GMR Institute of Technology, Vizianagaram District, A.P, India*
[2]*Professor, Department of Electrical and Electronics Engineering, GMR Institute of Technology, Vizianagaram District, A.P, India.*

ABSTRACT

Energy consumption and carbon dioxide emissions can be significantly decreased with the help of fuel cell-powered vehicles. The low density of hydrogen gas, however, places a limit on the volume of hydrogen that may be held in a container. Additionally, this restriction prevents the widespread use of fuel cells. Hydrogen storage is the main piece of technology for the hydrogen society. For testing on the road, liquid hydrogen and high-pressure tanks are currently used, although neither method completely meets the requirements of prospective fuel cell vehicles. This study provides a quick explanation of the current state of traditional technologies, such as high-pressure tank systems and cryogenic storage. Another strategy is hydrogen-absorbing alloy, which has been studied for a long time but faces several obstacles when used in vehicles, such as low-temperature discharge characteristics and quick charge capability because of heat reaction. We used a model metal hydride and high-pressure combination. The gravimetric density will perform better and several issues will be fixed. This study discusses the most recent system and research developments.

Keywords: hydrogen storage, high-pressure tanks, cryogenic storage, Insulation System

INTRODUCTION:

The development of materials for energy storage applications is one of the main problems facing our generation. Energy storage is necessary to reduce carbon emissions and expand the use of renewable energy sources. The production of renewable energy has increased recently on a global scale. Sustainable energy storage options are therefore required. Hydrogen is regarded as the finest energy carrier or energy sector for creating energy because it is easily accessible, clean, and emits nearly no pollutants. It is the periodic table lightest element and the best fuel in terms of the amount of chemical energy it can store. Both gas and liquid forms of hydrogen can be kept. There are some difficulties with storing hydrogen. High-pressure tanks are often needed for hydrogen gas storage. Cryogenic temperatures are required for liquid hydrogen storage (very low temperatures).

1. HYDROGEN GAS STORAGE:

Hydrogen gas is compressed at a high charging pressure and then stored in a high-pressure vessel known as a hydrogen storage tank. With an increase in charging pressure, the high-pressure hydrogen storage tank can hold more hydrogen gas. The amount of hydrogen gas that can be supplied to the fuel cell is therefore increased due to the high charging pressure. As a result, the high-pressure hydrogen storage tank's pressure needs to be raised as much as possible. The improvement in pressure resistance of the container has a limit, therefore it is difficult to raise the charge amount in the high-pressure hydrogen storage tank by further compressing the hydrogen gas. As a result, the charging pressure also has a limit. As the charging pressure is increased, the amount of energy required for charging likewise doubles. Boron hydrides and metal hydrides like LiBH4 and MgH2 both store hydrogen Research are being done on new hydrogen storage materials such as carbon nanostructure and metal chemical or complex hydrides. Nanotechnology is the manipulation and alteration of matter on a size ranging from 1 to 100 nano meters, as well as the use of novel phenomena and features that result from the nano meter length scale. As a result, usable functional materials, gadgets, and systems of any helpful size are produced.

1.1 LiBH4:

Due to its high volumetric (121 kgH2/m3) and gravimetric (18.5 wt.%) hydrogen densities, LiBH4 has been the subject of substantial research as a hydrogen storage medium. However, when the LiBH4 breaks down between 380 and 680 degrees Celsius at a pressure of 1 bar, only 13.8 weight percent of the hydrogen is liberated; the bulk of the hydrogen is released as LiH, free boron. Figure [1] displays the most important alkali and alkali earth borohydrides, as well as Zr and Al borohydrides and their breakdown temperatures. Rb, Cs, Fr, Sr, and Ra borohydrides are not included due to their low capacity or Td values above 600 °C [1]. LiH must be rehydrated at high hydrogen pressure and temperature conditions of over 600 °C. Due to the characteristics of LiBH4's hydrogen absorption and desorption, it is not suitable for use as a hydrogen storage material, particularly for mobile applications. One of the most alluring unstable hydride systems is the stoichiometric mixture MgH2:2LiBH4 or the so-called Li-RHC system [1].

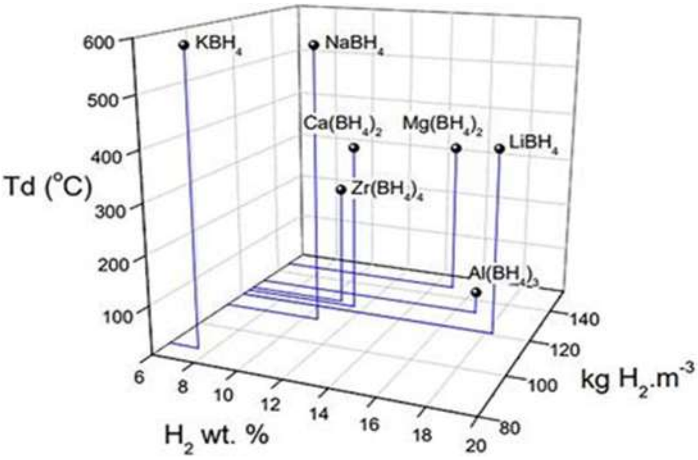

Figure 1: Hydrogen gravimetric capacity (wt.%), volumetric capacity (kg H2·m−3) [1]

1.2 The MgH2-2LiBH4 system is unstable:

Even if that catalyst can considerably enhance the de-/re hydrogenation. kinetics of this material, MgH2 thermodynamic characteristics change. One of the most attractive very unstable hydride systems is the stoichiometric mixture MgH2 2LiBH4, often known as the Li-RHC system (Reactive Hydride Composite). Under the destabilizing hypothesis, the putative overall reaction enthalpy of the process under standard conditions is dramatically lowered to 46 kJ mol-1 H2, in contrast to MgH2 (76 kJ mol-1 H2) and LiBH4 (67 kJ mol-1 H2 for breakdown to LiH, B, and H2) [1]. According to the RHC theory, the exothermal synthesis of MgB2 during dehydrogenation lowers the reaction's enthalpy, shattering both hydrides. According to Figure [2], the mutual destabilization of LiBH4 and MgH2 has a free energy per mol of H2 and standard enthalpy of reaction per mol of H2.

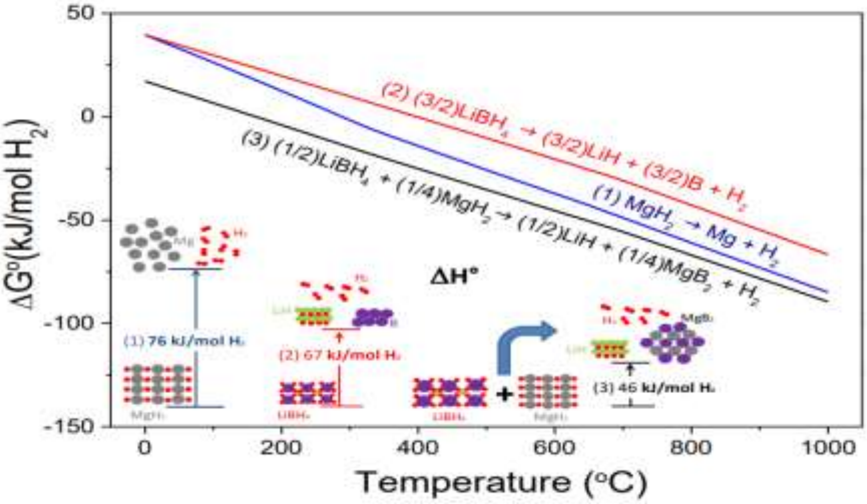

Figure 2: Free energy per mol of H2 and the standard enthalpy of a reaction that involves the hydride system 2LiBH4 + MgH2 as a function of temperature [2]

1.3 Using Nanotechnology to Improve Hydrogen Storage:

The development of unique storage systems with increased capacity reduced weight, and greater stability has always been a goal of numerous technological undertakings, notably in the realms of portable electronics and moving vehicles [7]. It follows that the development of a reliable, expensive storage system is essential for the use of hydrogen as a clean energy source in the future. The employment of metal hydrides offers an advantage in terms of safety when the entire weight of the tank system is present but falls short for the majority of materials. Carbon can circumvent this issue by using Vander Waal forces to attract undissociated hydrogen molecules to its surface because of its low atomic weight and microporous structure [7]. The synthesis of many carbon materials ideal for hydrogen storage, such as activated carbon, graphite, carbon nanotubes, and carbon nanofibers, as well as ways to increase hydrogen storage capacity. the creation of numerous carbon compounds, including activated carbon, graphite, carbon nanotubes, and carbon nanofibers, which are excellent for storing hydrogen.

1.3.1 Improve hydrogen storage capacity of carbon nanofibers:

A mixture of hydrogen and carbon-containing gases can be used to make carbon nanofiber structures at high temperatures [3]. Using catalysts built of alloys based on nickel and iron, it can also be specially produced from hydrocarbons. It is possible to create many various types of carbon nanofibers with different morphology, crystalline structure, and shape by changing the nature and geometry of the catalyst as well as reaction conditions. By creating additional locations that favour the adsorption of hydrogen, nanofibers widen the distance between two adjacent crystal layers. Improvements in hydrogen adsorption can be made by eliminating amorphous carbon from graphite nanofibers, and adding more planes for hydrogen adsorption can be achieved by removing caps from graphite layers [6].

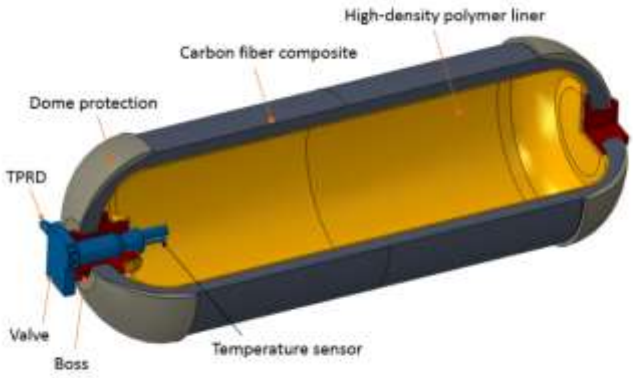

Figure 3: Carbon fiber tank for hydrogen gas storage [3]

2. LIQUID HYDROGEN STORAGE:

Another choice is to keep hydrogen in liquid form. The cryogenic hydrogen should be kept in specially insulated tanks at a temperature of -252.8 °C. Liquid hydrogen (gas at 3000 K and 1 bar pressure) requires about 47 MJ/kg [8]. The facility's size has an impact on energy as well. With more recent technology and tiny facilities that use magnetic regenerative liquefaction, about half of this energy would be sufficient. As a result, there may be a 10%–20% reduction in the amount of electricity needed for such bulk storage of cryogenic liquid hydrogen gas. Because liquid hydrogen tends to permeate construction materials at high pressures and cause them to become brittle, this is because liquid hydrogen exists in a gaseous form. Hydrogen must be kept at cryogenic temperatures to be stored as a liquid since it has a boiling point of -252.8°C at one atmosphere of pressure. Cryogenic storage methods, such as unique thermally insulated containers, were necessary for liquid hydrogen [8]. There are some alloys that we can use to hold liquid hydrogen, including titanium alloy, aluminum alloy, and others.

2.1 Aluminum alloy:

Having a cubic crystal structure, aluminum alloy. The aluminum alloy has a low apparent ductile-brittle transition temperature and is impact resistant. Because of its high specific strength, good processability, and low sensitivity to hydrogen embrittlement, aluminum alloy is commonly used in liquid hydrogen tanks [8]. The tensile strength and yield strength of aluminum alloy increase with a drop in temperature, However the yield strength ratio with plasticity and cracks is unaltered. Aluminum alloys are therefore used as the primary materials in liquid hydrogen tanks for space rocket launches [8]. In the study of liquid hydrogen tanks, welding technology has always been a popular subject. Liquid hydrogen tanks are commonly produced using sheet metal forming, machining, welding, and other manufacturing techniques. The welding area has three main types of fractures: storage cracks, liquefaction cracks, and crystallization cracks. These fracture forms are a result of changed microstructure in the weld and heat affected zone.

2.2 Titanium Alloy:

Strong corrosion resistance, high-temperature resistance, low thermal conductivity, and a moderate coefficient of expansion are a few of titanium alloy characteristics that contribute to its high specific strength [8]. Titanium alloys perform quite well in cold settings as well. The hydrogen storage tanks and hydrogen pump impellers of the hydrogen-oxygen vehicles were primarily made of titanium alloys. By lowering the concentration of chlorine as well as C, H, O, and other interstitial elements, titanium alloys' low-temperature performance can be enhanced [8].

2.3 Insulation System:

Most materials, including composite materials, stainless steel, aluminum alloy, and titanium alloy, whose behaviors have been studied, are brittle under cold conditions. Grade 316L stainless steel, which has a low carbon content, is frequently utilized. Stainless steel has a thermal conductivity of approximately 10 W/(m. K) at 200 K in contact with LH2, compared to around 16 W/(m. K) at room temperature [4]. Thermal resistance can be viewed as a representation of the cylindrical inner wall for conduction. Copper, which insulates less well than steel, might potentially be used to make the inner vessel. Studies that have hitherto been done have only examined the insulating effect. Instead, total efficiency should be considered while developing an LH2 tank for a vehicle. It is possible to build up the air layer in the space between the inner and outer vessel walls so that it radiates heat from one solid to another and transmits heat from solids to gases [4]. The outer vessel wall was cooled using air convection, and it was anticipated that radiation into the surrounding area would be at the same temperature as the air. As illustrated in Figure [4], 45 aluminum blankets and spacers. 3.53 cm of spray-on foam insulation and 3.75 cm of multi-layer insulation were used to insulate the 18.09 m3 tank in the multipurpose hydrogen test bed.

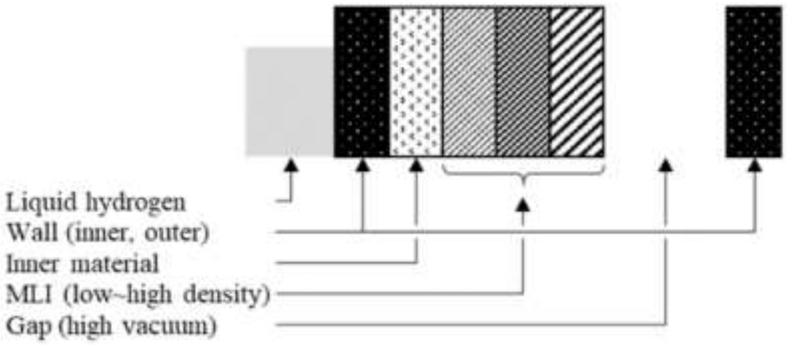

Figure 4: Insulation concept of the multi-purpose hydrogen test bed [4]

2.3.1Internal Materials:

Fiber-reinforced plastic (FRP), aerogel, glass bubbles, and hollow glass microspheres (HGM) have been used in place of the interior ingredients SOFI. Liquid hydrogen peroxide (LH2) must have a better insulating performance than polyurethane foam, which has been used to insulate liquefied natural gas (LNG). LH2 requires polyurethane foam insulation that is several meters [5]. MLI, whose thermal conductivity is significantly affected by variations in the degree of vacuum, was less affected by vacuum pressure. Fesmire investigated the effects of spray foam and stiff foam in non-vacuum settings to enhance insulation.

2.3.2Multi-layer insulation:

MLI and variable density MLI were investigated (VDMLI). MLI is composed of a reflector and a spacer with low thermal emissivity and conductivity, respectively. To stop heat transfer, spacers are used to separate the reflectors from one another. MLI made use of silica, layers of aluminium foil and glass fiber, and polyester sheets coated with alumina. Figure [4] depicts the MLI arrangement for insulating spacecraft. Previous research has demonstrated that the temperature distribution influences the ratio of heat flow components. MLI provides better insulating performance than MLI because spacer thickness can be altered.

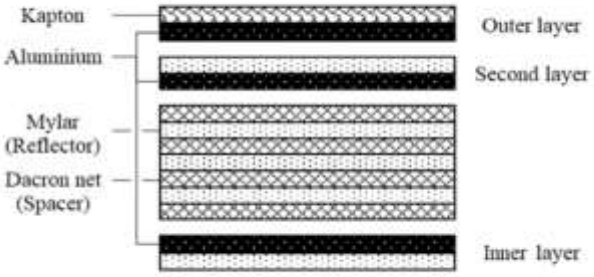

Figure 5: MLI configuration for insulating spacecraft [5]

2.3.3Vacuum insulation:

Vacuum insulation has proven to be the greatest method for maintaining cryogenic liquids at their precise temperature. Particularly for substances that may exist at extremely low temperatures, such as liquid hydrogen, which has a temperature of -252.8°C, this is essential. Vacuum insulation consists of two walls with a significant vacuum layer in between. In addition to providing double confinement, the high vacuum also provides incredibly high insulating value. If the internal wall begins to leak, there is always a backup wall [5,9]. The transfer lines that connect to the storage tanks as well as the tanks themselves are vacuum-insulated. This method of securing the liquid hydrogen from the tank via the application to the delivery truck is the best. Demaco is an expert in hydrogen infrastructures and vacuum insulation. Our professionals provide comprehensive solutions for hydrogen projects wherever in the world [5,9]. These could include hydrogen filters, ship loading arms with vacuum insulation, vacuum-insulated transfer lines, truck filling stations or loading docks, and many other things.

Conclusions

This article provides a summary of recent developments meta hydrides and boro hydrides to store hydrogen gas. Recently, nanotechnology has been developing in storing hydrogen gas. Using nano carbon fiber increases hydrogen storage capacity and also light weight, and improves stability. Since hydrogen has a boiling point 252.8 °C at one atmosphere of pressure, storing it as a liquid required cryogenic temperature. Liquid Hydrogen embrittlement can be prevented by minimizing contact between the metal and any sources of atomic hydrogen which means a thick vacuum layer between the walls can separate metal and sources.

References

1. Puszkiel, Julián, Aurelien Gasnier, Guillermina Amica, and Fabiana Gennari. "Tuning LiBH4 for hydrogen storage: Destabilization, additive, and nanoconfinement approaches." Molecules 25, no. 1 (2019): 163.
2. Puszkiel, J., Gasnier, A., Amica, G. and Gennari, F., 2019. Tuning LiBH4 for hydrogen storage: Destabilization, additive, and nanoconfinement approaches. Molecules, 25(1), p.163.
3. Rivard, Etienne, Michel Trudeau, and Karim Zaghib. "Hydrogen storage for mobility: a review." Materials 12, no. 12 (2019): 1973.
4. Kang, Daehoon, Sungho Yun, and Bo-kyong Kim. "Review of the Liquid Hydrogen Storage Tank and Insulation System for the High-Power Locomotive." Energies 15, no. 12 (2022): 4357.
5. Kang, D., Yun, S. and Kim, B.K., 2022. Review of the Liquid Hydrogen Storage Tank and Insulation System for the High-Power Locomotive. Energies, 15(12), p.4357.
6. Mohan, Man, Vinod Kumar Sharma, E. Anil Kumar, and V. Gayathri. "Hydrogen storage in carbon materials—A review." Energy Storage 1, no. 2 (2019): e35.
7. Eskander, Mona. "Recent Developments in Fuel Cells and Hydrogen Storage Methods Using Nanotechnology."
8. Qiu, Yinan, Huan Yang, Lige Tong, and Li Wang. "Research progress of cryogenic materials for storage and transportation of liquid hydrogen." Metals 11, no. 7 (2021): 1101.
9. Kim, Jeong Hwan, Dae Kyeom Park, Tae Jin Kim, and Jung Kwan Seo. "Thermal-Structural Characteristics of Multi-Layer Vacuum-Insulated Pipe for the Transfer of Cryogenic Liquid Hydrogen." *Metals* 12, no. 4 (2022): 549.