Energy of future – Hydrogen

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1.0 Introduction

Ever growing demand for energy and the rising concern caused by the use of conventional fossil fuels, call for new and clean fuels. Among all kinds of energy sources, hydrogen is the best choice as a clean fuel. The main advantage of hydrogen as energy source lies in the fact that its byproduct is water, and it can be easily regenerated.

Hydrogen is the simplest element; an atom of hydrogen consists of only one proton and one electron. It is also the most plentiful element in the universe. Despite its simplicity and abundance, hydrogen doesn't occur naturally as a gas on the Earth—it is always combined with other elements. Water, for example, is a combination of hydrogen and oxygen (H_2O). Hydrogen is also found in many organic compounds, notably the "hydrocarbons" that make up many of our fuels, such as gasoline, natural gas, methanol, and propane.

In this presentation we would like to highlight the production, storage, Transportation & application of hydrogen energy. We have focused on the storage of Hydrogen through carbon nanotubes. In its pure form, hydrogen is colorless and odourless gas. It is an energy carrier, not an energy source.

2.0 Production of Hydrogen:

The various technologies that are involved in the production of hydrogen are

- Thermo Chemical process.
- Electrolytic process.
- Photolytic process.

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Thermo Chemical Process:

1) Steam Methane Reforming: - High temperature steam is used to extract hydrogen from any methane source. This is the most common method of producing hydrogen.

2) Partial Oxidation: - Methods are being is explored in which simultaneously oxygen is separated from air and partially oxidizing methane to produce hydrogen.

3) Splitting water using heat from a solar concentrator.

4) Burning to generate gas, which is then reformed to produce hydrogen.

Electrolytic Process:

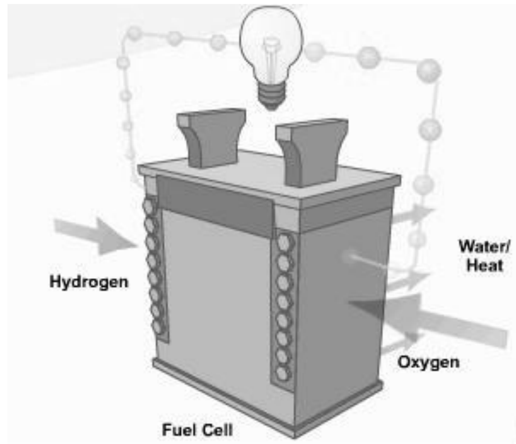
Electricity is used to separate water (H2O) into hydrogen and oxygen.

Photolytic Process:

In this, Sunlight is used to split water. Two photolytic processes are being studied.

1) Photo biological methods: - This involves the exposure of microbes to Sunlight, split water to produce Hydrogen.
2) Photo Electrolysis: - Here, Semiconductors, when exposed to Sunlight & immersed in water, generates enough electricity to produce hydrogen by splitting water.

Thus Hydrogen can be produced in large scale and transported or locally produced depending on the method used. The delivery infrastructure for hydrogen will require high-pressure compressors for gaseous hydrogen and liquefaction for Cryogenic Hydrogen. These methods have significant capital and operating costs. They also have energy inefficiency associated with them.



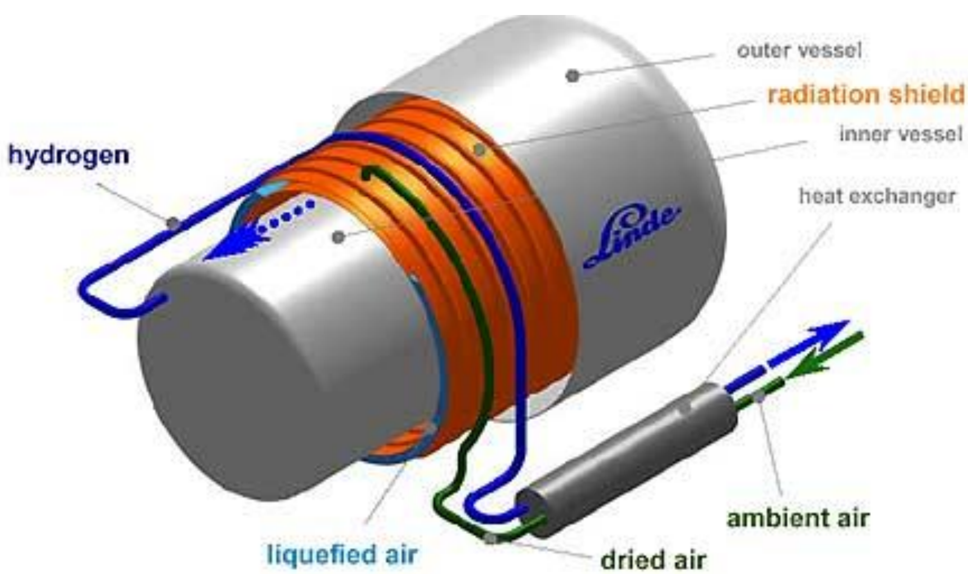
Fuel Cell

3.0 Storage Of Hydrogen

Various technologies are available for the storage of hydrogen.

- **High pressure tanks**: Hydrogen gas can be compressed and stored in storage tanks at high pressure. These tanks must be strong, durable Liquid Hydrogen: It can be stored as liquid but has to be kept at cold.
- Hydrogen combines with some metals which can result in higher storage capacity compared to high pressure gas or liquid.
- Carbon Nanotubes can store hydrogen.

Liquid Hydrogen Storage

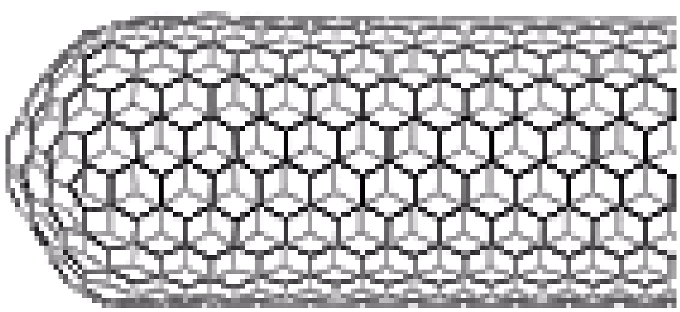


Challenges

For transportation, the overloading technical challenge for hydrogen storage is how to store the amount of hydrogen required for a conventional driving range, within the vehicular constraints of weight, volume efficiency, safety and cost. The performance lifetime durability of these systems must also be verified and validated. The main challenges are:

- Weight & Volume: - The weight and volume of hydrogen storage systems are presently too high.
- Efficiency: - Energy efficiency is a challenge for all hydrogen storage approaches.
- Durability: - Materials and components are needed that allow hydrogen storage systems with a lifetime of 1500 cycles.
- Refueling Time: - There is a need to develop hydrogen storage systems with refueling times being very low.
- Codes and Standards: - Codes and Standards for hydrogen storage systems and interface technologies which will help commercialization and implementation on a large scale and assure safety, have not been established.

3.1 Carbon Nanotube Fabrication

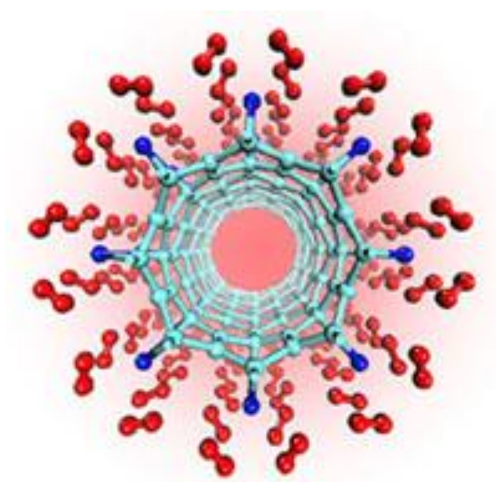


Many new methods use carbon as a storage medium and bring us a step closer to the widespread use of hydrogen as a fuel source. Scientists are using various approaches to shape carbon into microscopic cylindrical structures known as nanotubes.

The first method of producing nanotubes uses an electric arc to vaporize a metal-impregnated carbon electrode. The second method uses a laser to vaporize a heated carbon target that has been treated with a metal such as nickel, cobalt or iron.

The third method is known as catalytic chemical vapor deposition (CCVD), and researchers at Washington University in St. Louis believe this is the most promising approach. In the CCVD technique, a heated metal element breaks down a hydrocarbon gas (such as methane, ethylene, acetylene, etc.) into carbon and hydrogen. The hydrogen gas is released while the carbon is extruded as a nanofiber. The advantage of CCVD is that it is a low-temperature technique and is suitable for large-scale production.

3.2 Storage Of Hydrogen In Carbon Nanotube



One of the critical factors in nanotubes' usefulness as a hydrogen storage medium is the ratio of stored hydrogen to carbon. According to the US Department of Energy, a carbon material needs to store 6.5% of its own weight in hydrogen to make fuel cells practical in cars. Such fuel cell cars could then travel 300 miles between refueling stops.

Researchers at MIT claim to have produced nanotube clusters with the ability to store 4.2% of their own weight in hydrogen. In recent months, scientists from the National University of Singapore have released figures for nanotubes and nanofibers that can store 10-20% of their weight in hydrogen. These results, when combined with new car manufacturing technologies have the potential of transforming our transportation industries.

Single-walled carbon nanotubes are remarkable forms of elemental carbon. Their unique properties have stimulated the imaginations of many scientists and engineers to propose a wide range of applications.

Nanotubes do have a dramatic visual Impact. If beauty rests on symmetry, nanotubes have inherent beauty. Further, their cylindrical structures led to suggestions that they would be ideal gas storage materials. The appearance of these potential storage materials conveniently coincided with the revivification of interest in the hydrogen economy. The potential for coupling carbon-based storage materials to supply pure hydrogen to automotive fuel cell power plants was quickly seen. Initial reports of experiments showing high levels of hydrogen storage were encouraging. Theoreticians were then quick to calculate the possible amounts of hydrogen that could be stored using arrays of tubes of various sizes and packing parameters. Since the appearance of the initial reports, the results have been varied and controversial. Some are higher, some lower; some imply physisorption, and some chemisorption. It is clear that storage is a complex issue, partly because the, materials are more far complex than the visual comprehension of the single ideal nanotube would allow.

Studies have been conducted and it has been found that purified Multi walled carbon nanotubes (MWNT) can be used for bulk storage of hydrogen. Multi walled carbon nanotubes have been synthesised by catalytic decomposition of hydrocarbon using a floating catalyst method. The mean diameter of the MWNTs was found to be 5.1 nm. The MWNTs are then purified and hydrogen storage techniques are used. It is found that the gravimetric hydrogen storage capacity of purified MWNTs is much higher than that of as-prepared one which means that purification process is very important for hydrogen storage. This could be attributed to the fact that there is more exposure to more surfaces of the multiwalled nanotubes. The ends were seen to be opened up. This allowed hydrogen to more easily move into the hollow core of MWNTs.

XPS spectra of C1s of the purified sample is narrower and has no notable peak in the range of high electron binding energy. This indicates that the sample is in simple chemical state. This simple chemical state of C and lower oxygen contained groups correspond higher hydrogen storage capacity of carbon nanotubes.

There are many questions that must still be answered regarding nanotube hydrogen storage: How do we make process more efficient at lower temperatures in order to increase supply and decrease cost? What is the capacity loss with each storage cycle? Can other forms of carbon produce the same results just as effectively? What additional applications can increase demand and research into nanotubes?

4.0 Existing Transport and Storage Methods

Hydrogen is currently stored in tanks as a compressed gas or cryogenic liquid. The tanks can be transported by truck or the compressed gas can be sent across distances of less than 50 miles by pipeline

5.0 Hydrogen Safety:

Safety is essential in the entire energy conversion process. This begins with production, storage, transport, distribution and utilization. Each energy form poses its own specific risk, which should be taken care. The safety of combustible energy carriers in their ignition, combustion, explosion and detonation behaviour when mixed with air is still under study.

6.0 Applications:

Hydrogen is high in energy, yet an engine that burns pure hydrogen produces almost no pollution. NASA has used liquid hydrogen since the 1970s to propel the space shuttle and other rockets into orbit. Hydrogen *fuel cells* power the shuttle's electrical systems, producing a clean byproduct—pure water, which the crew drinks. You can think of a fuel cell as a battery that is constantly replenished by adding fuel to it—it never loses its charge. A device has been designed to generate hydrogen to drive a cellular phone.

Fuel cells are a promising technology for use as a source of heat and electricity for buildings, and as an electrical power source for electric vehicles. Although these applications would ideally run off pure hydrogen, in the near future they are likely to be fueled with natural gas, methanol, or even gasoline. Reforming these fuels to create hydrogen will allow the use of much of our current energy infrastructure—gas stations, natural gas pipelines, etc.—while fuel cells are phased in.

In the future, hydrogen could also join electricity as an important *energy carrier*. An energy carrier stores, moves, and delivers energy in a usable form to consumers. Renewable energy sources, like the sun, can't produce energy all the time. The sun doesn't always shine. But hydrogen can store this energy until it is needed and can be transported to where it is needed.

Some experts think that hydrogen will form the basic energy infrastructure that will power future societies, replacing today's natural gas, oil, coal, and electricity infrastructures. They see a new *hydrogen economy* to replace our current energy economies, although that vision probably won't happen until far in the future.

REFERENCES

Journal of Physical Chemistry B 2002
US Department of Energy