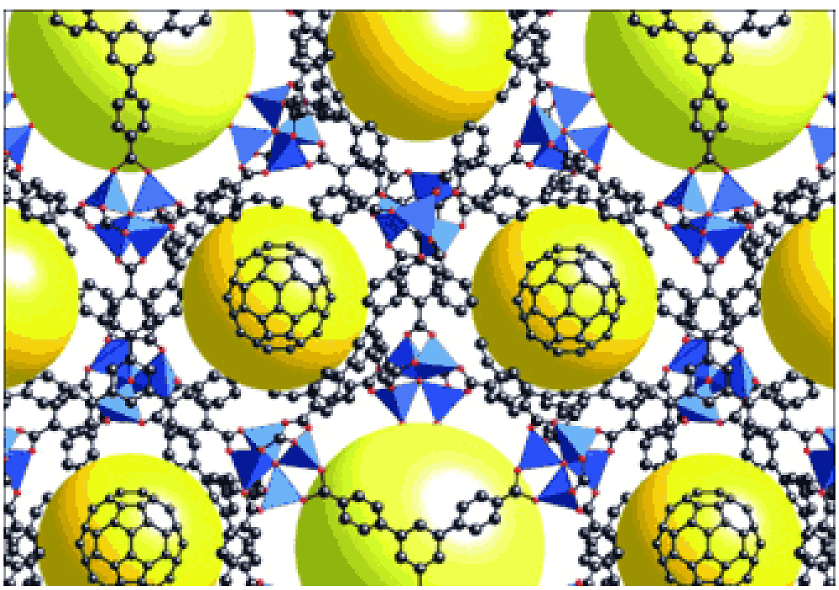
Storage of Hydrogen in carbon Nanotubes

For the last 160 odd years, we have been using carbon as a medium to store hydrogen fuel. We call this method of hydrogen storage "Fossil Fuels". So using carbon as a device on/in which to store hydrogen is nothing new. Examples of natural hydrogen on carbon storage are alcohols, vegetable oils & sugar.

The main problem with this method of hydrogen storage has been that, when hydrogen atom is transferred from carbon atom on which it is stored to an oxygen atom, carbon storage atom also binds to an oxygen atom, creating the green house gases Carbon monoxide / carbon-di- oxide as a byproduct. These are the gases which are currently contributing to global warming / climate change and this is the main motivation to implement clean energy sources.



Reasons for use of Hydrogen as an Energy carrier:

As an energy carrier hydrogen is attractive for many reasons.

1) The gas can be burned / combined with oxygen in a fuel cell to release energy and produce water with no pollutants.
2) The reactions do not generate green house gases.
3) Hydrogen can be produced from plentiful resource such as water, thereby reducing the growing dependence on fossil fuels.

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 and Volume

The weight and volume of hydrogen storage systems are presently too high, resulting in inadequate vehicle range compared to conventional petroleum fueled vehicles. Materials and components are needed that allow compact, lightweight, hydrogen storage systems while enabling greater than 300-mile range in all light-duty vehicle platforms.

Efficiency

Energy efficiency is a challenge for all hydrogen storage approaches. The energy required to get hydrogen in and out is an issue for reversible solid-state materials. Life-cycle energy efficiency is a challenge for chemical hydride storage in which the by-product is regenerated off-board. In addition, the energy associated with compression and liquefaction must be considered for compressed and liquid hydrogen technologies.

Durability

Durability of hydrogen storage systems is inadequate. Materials and components are needed that allow hydrogen storage systems with a lifetime of 1500 cycles.

Refueling Time

Refueling times are too long. There is a need to develop hydrogen storage systems with refueling times of less than three minutes, over the lifetime of the system.

Cost

The cost of on-board hydrogen storage systems is too high, particularly in comparison with conventional storage systems for petroleum fuels. Low-cost materials and components for hydrogen storage systems are needed, as well as low-cost, high-volume manufacturing methods.

Codes & Standards

Applicable codes and standards for hydrogen storage systems and interface technologies, which will facilitate implementation/commercialization and assure safety and public acceptance, have not been established. Standardized hardware and operating procedures, and applicable codes and standards, are required.

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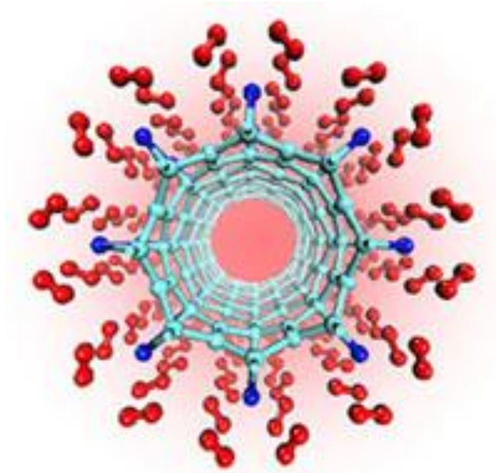
Carbon nanotubes

Conceptually, Single walled carbon nanotubes can be considered to be formed by the rolling of a single layer of graphite (called a graphene layer) into a seamless cylinder. A multi walled carbon nanotube can be considered to be a coaxial assembly of cylinders of single walled carbon nanotubes, one within the other.

Unlike traditional hydrocarbon chains, in which hydrogen atoms are bound to specific carbon atoms, in nanotubes the hydrogen atoms are drawn to carbon atoms, which make up the tubes but do not seem to actually bond to them. This makes it much easier to fill the nanotube assembly with hydrogen and conversely to remove the hydrogen from the nanotubes.

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.

Technical Barriers :

1)The carbon nanotubes that are commercially available do not have the capacity to store enough hydrogen in a given quantity of nanotube material.

It has been discovered that by decorating the outside walls of carbon nanotubes with metals like titanium, the storage capacity of of the tubes for hydrogen can be increased.

2) Lack of Understanding of Hydrogen Physisorption and Chemisorption

3) Test Protocols and Evaluation Facilities

4) Dispensing Technology

The main approach that the scientists follow, for producing large quantities of consistent structure carbon nanotube material, are

• Attempt to create a weak covalent hydrogen bond.
• Dope carbon nanotubes with transition metals and alloys
• Dope carbon nanotubes with other elements and metal clusters
• Tune material for hydrogen sorption to occur at desired temperature and pressure

Advantages:

Hydrogen can be stored and removed from the carbon nanotube without making a bond with the carbon and also not reacting with oxygen to form carbon monoxide / Carbon – di- oxide gases. This will allow the hydrogen fuel to be produced from a clean, renewable source such as water.

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.

Conclusion:

Using water as a source of energy to produce hydrogen can come from unlimited resources like solar and wind energy. The hydrogen so produced could be loaded in a carbon nanotube storage and distribution tanks for transportation to customers either locally or over a significant distance with a degree of safety that equals to transporting gasoline today. Carbon nanotubes may one day open the door to the widespread use clean non polluting hydrogen fuel for all the needs for which we use fossil fuels today

Switching from petroleum to hydrogen may offer major benefits in terms of pollution, energy security and other issues. Numerous technological and scientific hurdles need to be overcome before we switch to hydrogen can be implemented on a large scale.