Hydrogen Storage

DOE Hydrogen Program

Developing safe, reliable, compact, and cost-effective hydrogen storage technologies is one of the most technically challenging barriers to the widespread use of hydrogen as a form of energy. To be competitive with conventional vehicles, hydrogen-powered cars must be able to travel more than 300 miles between fills. This is a challenging goal because hydrogen has physical characteristics that make it difficult to store in large quantities without taking up a significant amount of space.

Where and How Will Hydrogen be Stored?

Hydrogen storage will be required onboard vehicles and at hydrogen production sites, hydrogen refueling stations, and stationary power sites. Possible approaches to storing hydrogen include:

- Physical storage of compressed hydrogen gas in high pressure tanks (up to 10,000 pounds per square inch);
- Physical storage of cryogenic liquid hydrogen (cooled to -253°C) in insulated tanks; and
- Storage in advanced materials — within the structure or on th e surface of certain materials, as well as in the form of chemical precursors that undergo a chemical reaction to release hydrogen.

What Are the Challenges?

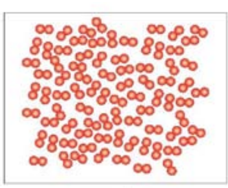
Hydrogen has a very high energy content by weight (about three times more than gasoline), but it has a very low energy content by volume (about four times less than gasoline). This makes hydrogen a challenge to store, particularly within the size and weight constraints of a vehicle.

A light-duty fuel cell vehicle must carry approximately 5-13 kilograms of hydrogen on board (depending on the size and type of the vehicle) to allow a driving range of more than 300 miles, which is generally regarded as the minimum for widespread public acceptance. Drivers must also be able to refuel at near room temperature and at a rate comparable to the rate of refueling today's gasoline vehicles.

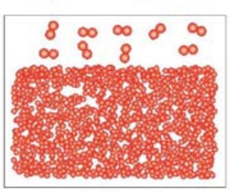
Using currently available storage technology, placing a sufficient quantity of hydrogen onboard a vehicle to provide a 300-mile driving range would require a very large tank — larger than the trunk of a typical automobile. Aside from the loss of cargo space, there would also be the added weight of the tank(s), which would in turn reduce fuel economy. Low-cost materials and components for hydrogen storage systems are needed, as well as low-cost, high-volume manufacturing methods for those materials and components.

Hydrogen can be stored in different forms

In tanks...



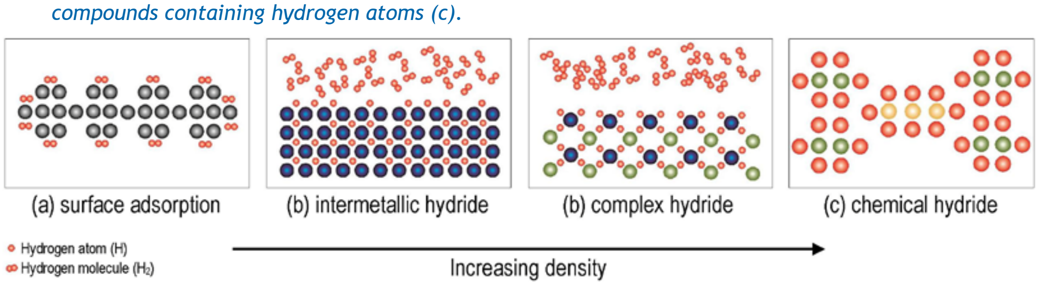
compressed gas



cryogenic liquid

And in materials...

Hydrogen can be stored on the surfaces of solids (by adsorption) or within solids (by absorption). In adsorption (a), hydrogen attaches to the surface of a material either as hydrogen molecules (H_2) or hydrogen atoms (H). In absorption (b), hydrogen molecules dissociate into hydrogen atoms that are incorporated into the solid lattice framework - this method may make it possible to store larger quantities of hydrogen in smaller volumes at low pressure and at temperatures close to room temperature. Finally, hydrogen can be strongly bound within molecular structures, as chemical compounds containing hydrogen atoms (c).



Research Directions

Reducing our dependence on foreign oil for transportation is a key driver for using hydrogen as a form of energy. Hydrogen storage research, therefore, is focused primarily on technologies and systems used onboard a vehicle. Scientists in government, industry, and academia are working to improve the weight, volume, and cost of current hydrogen storage systems, as well as identify and develop new technologies that can achieve similar performance, at a similar cost, as gasoline fuel storage systems.

Compressed gas and liquid hydrogen tanks

- Current compressed hydrogen gas tanks are much larger and heavier than what is ultimately desired for light-duty vehicles. Researchers are evaluating light-weight, safe, composite materials that can reduce the weight and volume of compressed gas storage systems.

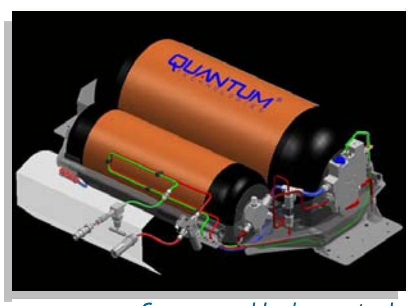
- Liquefied hydrogen is denser and has a higher energy content than gaseous hydrogen in a given volume. Liquid hydrogen tanks can store more hydrogen than compressed gas tanks, but it takes energy to liquefy hydrogen, and the tank insulation required (to prevent hydrogen loss) also affects the weight and volume of hydrogen that can be stored. Researchers are studying a hybrid tank concept that can store high-pressure hydrogen gas under cryogenic conditions (cooled to around -120 to -196°C) — these "cryo-compressed" tanks would allow relatively lighter weight, more compact storage.

- Gasoline tanks used in cars and trucks today are considered conformable and take maximum advantage of available vehicle space. Researchers are evaluating concepts for conformable high-pressure hydrogen tanks as an alternative to cylindrical tanks, which do not package well in a vehicle.

Materials-based storage

- Hydrogen atoms or molecules bound tightly with other elements in a compound (or potential storage material) may make it possible to store larger quantities of hydrogen in smaller volumes at low pressure and near room temperature.

- Scientists are investigating several different kinds of materials, including metal hydrides, carbon-based materials, and chemical hydrides, as well as identifying new materials with potential for storing hydrogen.



Compressed hydrogen tank. Photo courtesy of Quantum Fuel Systems Technologies

- Hydrogen storage in materials offers great promise, but additional research is required to better understand the mecha nism of hydrogen storage in materials under practical operating conditions and to overcome critical challenges related to capacity, the uptake and release of hydrogen, management of heat during refueling, cost, and life cycle impacts.

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Did you know...

Hydrogen is an energy carrier, not an energy source, meaning that it stores and delivers energy in a usable form.

Hydrogen can be produced using abundant and diverse domestic energy resources, including fossil fuels, such as natural gas and coal; renewable energy resources, such as solar, wind, and biomass; and nuclear energy.

Using hydrogen as a form of energy can not only reduce our dependence on imported oil, but also benefit the environment by reducing emissions of greenhouse gases and criteria pollutants that affect our air quality.

The DOE Hydrogen Program supports research and development of fuel cell and hydrogen production, storage, and delivery infrastructure technologies needed to support hydrogen fuel cells for use in transportation and electricity generation.

The DOE Hydrogen Program works with industry, academia, national laboratories, and other federal and international agencies to overcome critical technology barriers, facilitate the development of model codes and standards, validate hydrogen fuel cell technologies in real world conditions, and educate key stakeholders who can facilitate the use of hydrogen and fuel cell technologies.

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