Use of High-Pressure TGA (TGA-HP) to Investigate Carbon-Based Hydrogen Storage Materials

ABSTRACT

This paper discusses the use of high-pressure TGA (TGA-HP) to investigate the hydrogen storage capacity of a carbon-based matrix.

INTRODUCTION

Storing enough hydrogen onboard a vehicle to achieve a driving range of greater than 300 miles is a significant challenge. On a weight basis, hydrogen has nearly three times the energy content of gasoline (120 MJ/kg for hydrogen versus 44 MJ/kg for gasoline). However, on a volume basis the situation is reversed (8 MJ/liter for liquid hydrogen versus 32 MJ/liter for gasoline). On-board hydrogen storage in the range of 5-13 kg H_2 is required to encompass the full platform of light-duty vehicles.

The energy density of gaseous hydrogen can be improved by storing hydrogen at higher pressures. This requires material and design improvements in order to ensure tank integrity. Advances in compression technologies are also required to improve efficiencies and reduce the cost of producing high-pressure hydrogen. There are presently three generic mechanisms known for storing hydrogen in materials: absorption, adsorption, and chemical reaction.

Absorption. In absorptive hydrogen storage, hydrogen is absorbed directly into the bulk of the material. In simple crystalline metal hydrides, this absorption occurs by the incorporation of atomic hydrogen into interstitial sites in the crystallographic lattice structure.

Adsorption. Adsorption may be subdivided into physisorption and chemisorption, based on the energetics of the adsorption mechanism. Physisorbed hydrogen is more weakly energetically bound to the material than is chemisorbed hydrogen. Sorptive processes typically require highly porous materials to maximize the surface area available for hydrogen sorption to occur, and to allow for easy uptake and release of hydrogen from the material.

Chemical Reaction. The chemical reaction route for hydrogen storage involves displacive chemical reactions for both hydrogen generation and hydrogen storage. For reactions that may be reversible on-board a vehicle, hydrogen generation and hydrogen storage take place by a simple reversal of the chemical reaction as a result of modest changes in the temperature and pressure. Sodium alanate-based complex metal hydrides are an example. In many cases, the hydrogen generation reaction is not reversible under modest temperature/pressure changes. Therefore, although hydrogen can be generated on-board the vehicle, getting hydrogen back into the starting material must be done off-board. Sodium borohydride is an example.

RESULTS & DISCUSSION

High-Pressure TGA is an excellent tool to investigate a material's efficiency for absorbing and storing gases such as hydrogen, at a variety of temperatures and pressures. The TA Instruments TGA-HP Series products are specialty gravimetric analyzers designed to provide unique capabilities for High-Pressure, Ultra-High Vacuum, and High-Temperature under static or dynamic reactive atmospheres. These instruments are designed for sorption studies using water vapor, organic vapors, hydrogen, methane and carbon dioxide as well as permanent gases and corrosive gases.

Using the continuous flow method, the TGA-HP Analyzers provide isotherms, isobars and time course data for the study of…

- General gas/solid reactions
- Oxidation/reduction of metals
- Degradation of ceramics
- Catalysts, zeolites, activated carbons and other specialty materials
- CO_2 Sequestration techniques

The data in Figure 1 show the adsorption of H_2 gas onto an activated carbon matrix at 25°C (273 K) as measured by the TGA-HP system. Note how the gravimetric adsorption is quantified over the wide pressure range from sub-atmospheric to nearly 80 Bar (ca. 1150 PSI)

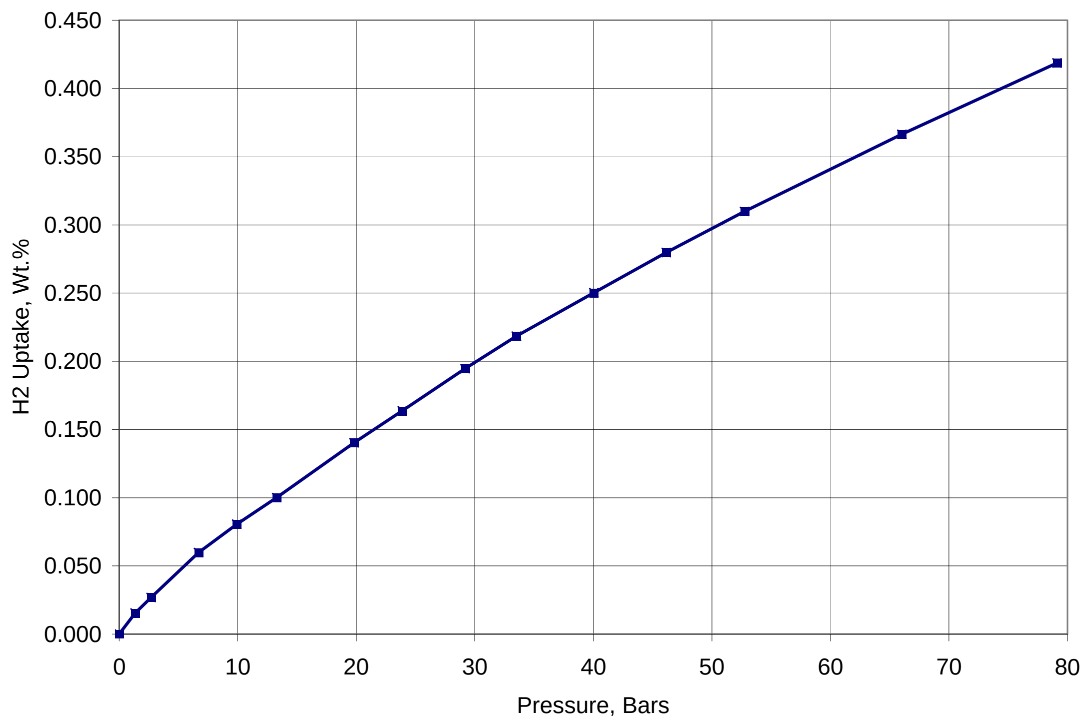

Figure 1: TGA-HP Data showing the quantitative absorption of H_2 gas onto an activated carbon matrix

REFERENCES

http://www.eoearth.org/article/Hydrogen_storage

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