HYDROGEN AS FUEL CARRIER IN PEM FUELCELL
FOR AUTOMOBILE APPLICATIONS

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Abstract. The present work focuses the application of nanostructured materials for storing of hydrogen in different carbon materials by physisorption method. To market a hydrogen-fuel cell vehicle as competitively as the present internal combustion engine vehicles, there is a need for materials that can store a minimum of 6.5wt% of hydrogen. Carbon materials are being heavily investigated because of their promise to offer an economical solution to the challenge of safe storage of large hydrogen quantities. Hydrogen is important as a new source of energy for automotive applications. It is clear that the key challenge in developing this technology is hydrogen storage. Combustion of fossil fuels and their overuse is at present a serious concern as it is creates severe air pollution and global environmental problems; like global warming, acid rains, ozone depletion in stratosphere etc. This necessitated the search for possible alternative sources of energy. Though there are a number of primary energy sources available, such as thermonuclear energy, solar energy, wind energy, hydropower, geothermal energy etc, in contrast to the fossil fuels in most cases, these new primary energy sources cannot be used directly and thus they must be converted into fuels, that is to say, a new energy carrier is needed. Hydrogen fuel cells are two to three times more efficient than combustion engines. As they become more widely available, they will reduce dependence on fossil fuels. In a fuel cell, hydrogen and oxygen are combined in an electrochemical reaction that produces electricity and, as a byproduct, water.

1. Introduction

Nanomaterials have attracted great interest in recent years because of the unusual mechanical, electrical, electronic, optical, magnetic and surface properties. The high surface/volume ratio of these materials has significant implications with respect to energy storage. Both the high surface area and the opportunity for nanomaterial consolidation are key attributes of this new class of materials for hydrogen storage devices. Recent investigations have shown that nanoscale materials may offer advantages if certain physical and chemical effects related to the nanoscale can be used efficiently. The present review focuses the application of nanostructured materials for storing of hydrogen in different carbon materials by physisorption method. To market a hydrogen-fuel cell vehicle as competitively as the present internal combustion engine vehicles, there is a need for materials that can store a minimum of 6.5wt% of hydrogen. Carbon materials are being heavily investigated because of their promise to offer an economical solution to the challenge of safe storage of large hydrogen quantities. Hydrogen is important as a new source of energy for automotive applications. It is clear that the key challenge in developing this technology is hydrogen storage. Hydrogen is clean and renewable
energy carrier and an Hydrogen energy system is expected to progressively replace fossil fuels in future. Due to compressed gas, containers in vehicles have less volume than the classic ones. A clear picture of the true capacity of nanotubes for hydrogen storage is still being developed by efforts in experiment and theory. Because CNT received directly after synthesis, generally, have closed caps, methods for chemical activation are required to achieve their full potential. These selected carbon nanomaterials are characterized by the different techniques, for structural characterization and crystallite size determination XRD is used. SEM for the morphological study and FTIR for the spectral data of carbon nanomaterials were used. The surface areas of Selected Carbon nanomaterials were measured using BET.

2. Hydrogen Adsorption Principle
In hydrogen adsorption studies, the hydrogen concentration absorbed by Carbon Nano materials can be determined by various techniques such as the gravimetric, electrolytic and the gasometric methods. From the gravimetric methods, the hydrogen concentration present in the material can be obtained by the change the mass of the material before and after hydrogen adsorption. The sample forms one of the electrodes in the case of electrolytic method, where hydrogen is given by the electrolyte (e.g., KOH) when a known current passed through the circuit. In gasometric method, the hydrogen concentration present in the material can be obtained from volumetric or pressure reduction technique. In volumetric technique, the measurement of the change in the volume gives the hydrogen concentration of a material at a constant pressure and temperature. In the pressure reduction technique, hydrogen concentration is calculated from the observed pressure change before and after hydrogen adsorption at a constant calibrated volume and at a constant temperature. The hydrogen adsorption capacity of selected carbons is expressed in terms of wt%. It is defined as

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\text{Weight Percent (Wt\%)} = \frac{\text{Weight of the hydrogen molecule}}{\text{Weight of the material}} \times 100
\]

3. Experimental Methods
A test of five different carbon samples, such as Commercial CNTs, Carbon Black, Activated Carbon, Exfoliated Graphite, Graphitic Flakes are assembled. Experiments have been carried on these samples at room temperature of 297 Kelvin (24°C) using hydrogen gas to be adsorbed. The parameters taken while conducting the adsorption experiment have been studied and maintained in a proper manner so that the measurement is accurate. Different temperatures and pressure ranges are taken to study the possibilities of hydrogen intake for selected carbon materials.

4. Results and Discussion
The data of hydrogen adsorption on different carbon materials produced by arc-discharge at different experimental conditions with a constant amount (0.1 gram) was carried out. Selected samples were examined for their ability to adsorb H₂ at pressures up to 100 millibars. Surface area for the selected samples is shown in Table 1. Hydrogen adsorption isotherms of selected samples of selected carbons are shown in Figure 6.

Table 1. BET Surface Area of Selected Carbon Nano Materials

| Sample           | BET Surface area (m²/g) |
|------------------|-------------------------|
| Activated Carbon | 1050                    |
| Carbon Black     | 70                      |
| Graphite Flakes  | 30                      |
Figure 1. X-Ray Diffraction of Synthetic Graphite, the peaks are identified for their lattice structure and the orientation.

Figure 2. TG/DTA/DTG of Graphitic Flakes, There is a drastic weight loss with almost 55% of weight loss can be seen.

Figure 3. SEM of Exfoliated Graphite, has domain of multilayer structure with many diamond shaped pores.

When heating at 350°C, an apparent volume change of the exfoliated graphite is observed. It can be seen in Figure 3., that Exfoliated Graphite is worm-like or accordion-like and graphite layers are held together at their edges. It is clear that the exfoliated domain has a multilayer structure with many diamond shaped pores. The particles have an average diameter range between 50-300 nm and lengths upto 10-60 µm.

Figure 4. SEM of Graphite Flakes,

Figure 5. SEM of Carbon Black. Based on the variable thickness of the particles.

A study conducted by SEM is conclusive to characterize the texture (elemental particles and their aggregating) as well as the structure of the carbon black Figure 6. It shows that the arc-discharge plasma process is a versatile process for growing a wide range of carbon black.
From the results, it can be noticed that the hydrogen adsorption capacities of different carbon samples in the range of 0.8 wt% - 4.0 wt%.

In the case of Graphitic flakes, the sample showed the adsorption capacity of 4.4 wt% at high pressures (100 millibars).

Figure 6. Adsorption isotherm of Graphite Flakes

Figure 7. Adsorption Isotherms of H\textsubscript{2} on Selected Carbon

Figure 7 shows the uptake of hydrogen begins at 46\textdegree C giving rise to 0.8 wt% and continuously shoots up to 68\textdegree C to 2.7 wt%, and at 112\textdegree C to 5.5 wt% respectively. At temperature 114\textdegree C the uptake gradually slows down to 4.6 wt%. The maximum hydrogen adsorbed can be noticed to be 5.5 wt% at 112\textdegree C. Isotherm of graphite flakes, the adsorption of gas suddenly decreased to 5.9 wt% which is almost equal to 6 wt% at 37\textdegree C, due to reason that flake graphite has a distinctly flaky or platy morphology.

5. Conclusion

Hydrogen storage in carbon single-wall nanotubes has become the focus of numerous research groups in the world. However, obtaining activated SWNT hydrogen storage materials with highly reproducible adsorption capacities has not yet been achieved. One reason for this may be that hydrogen storage is only optimized for a very specific and narrow distribution of SWNTs of distinct types and diameters.

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Acknowledgement
Author would like to thank Center for Nano Science and Technology, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad, Center for Environmental Science, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad for supporting me and arranging me the laboratory instruments to carry on my Project work and Authors would like to thank, Department of Carbon Materials, The International Research Center for Powder Metallurgy and New Materials, (ARCI) Balapur Village, Hyderabad, an autonomous R&D center, Government of INDIA, Department of Science and Technology (DST), for providing the Carbon Materials and detailed Characterization analysis.