

HYDROGEN STORAGE IN ACTIVATED CARBONS

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Introduction

Hydrogen is the ideal alternative for fossil fuel systems [1]. From environmental point of view hydrogen is the cleanest fuel known until recently [1], and from economic point of view hydrogen technology will be able to revolutionize the transport and energy market. This field is starting to be known as "hydrogen economy" [2].

From an application point of view it is necessary to find the most effective way to store hydrogen and then, to replace the current fuel systems. Different approaches to store hydrogen have been studied but none of them was completely satisfactory [2].

Hydrogen storage in solid materials is the most recent system proposed [3,4]. Initially the research was based on cryogenic systems [5], which are unprofitable from an economic point of view. Recently the studies have focused in the search of the ideal adsorbent to be used at room temperature [3,6]. Since the density of the adsorbed gas is higher compared to compressed gas, and closer to the liquid density, the volumetric capacities of adsorbed gas are predicted to be higher than those of compressed gases [7].

Among the possible materials potentially useful as adsorbents, porous carbon materials such as activated carbons, activated carbon fibers and graphite nanofibers are interesting candidates [6,7] compared with other adsorbents and with the compressed hydrogen.

The objective of this work is to analyze hydrogen storage in several porous carbon materials and its relation with the porous texture.

Experimental

Activated carbon fibers (prepared by us at different burn-off and commercially available) and granular activated carbon (chemically activated by us and commercially available) have been used in this work. All samples reported a high development in microporosity.

CO₂ and N₂ adsorption isotherms were measured in an Autosorb-6 apparatus. Hydrogen adsorption isotherms at 293 K up to 70 MPa and high pressures have been obtained in a high-pressure volumetric system.

Table 1 summarizes the porous texture of the materials analyzed. It includes BET surface area from N₂ adsorption at 77 K, micropore volumes calculated from the application of the Dubinin-Radushkevich (DR) equation to the CO₂ and N₂ adsorption isotherms at 273 K and 77 K, respectively. The mean pore size of each sample obtained from CO₂ and N₂ adsorption was determined by applying Dubinin-Radushkevich [8] and Stoekli equation [9]. The table also includes the density of adsorbed hydrogen in each sample.

Table 1. Porous Texture

Sample	BET (m ² /g)	Micropore Volume (cc/g)	Mean Pore Size (nm)	Density of adsorbed hydrogen (kg/m ³)
CF	0	0.176	0.41	8.2
ACFC26	1079	0.395	0.75	21.5
ACFC50	1738	0.781	1.36	27.1
A20	2206	0.791	1.46	27.1
KUA1	1058	0.514	0.66	45.1
AC35	1204	0.540	1.54	19.3
AX21	2575	0.861	1.48	19.4

Results and Discussion

Porous texture of the different materials analyzed (Table 1) show that all the samples used in this work have a high micropore volume except for carbon fiber (CF).

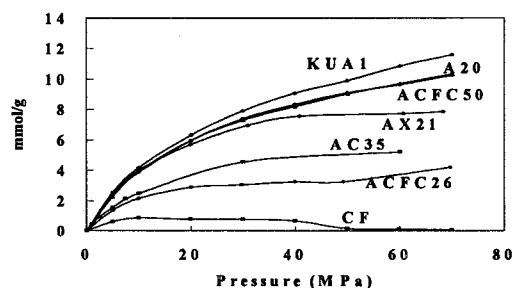


Figure 1. Excess of adsorption of hydrogen at 293 K

The materials studied have a wide distribution of microporosity, from the non-activated carbon fiber with narrow porosity not accessible to N₂ at 77 K, to samples with a mean pore size of 1.5 nm.

Figure 1 contains the hydrogen isotherms obtained at 293 K to a pressure of 70 MPa for the materials studied. The isotherm of CF sample shows a maximum because excess of adsorption of hydrogen is lower than the amount of gas compressed at high pressures. In general, as the micropore volume increases the hydrogen adsorption is higher except for the case of the sample that seems to have pore size close to the optimum for hydrogen storage (sample KUA1) [10].

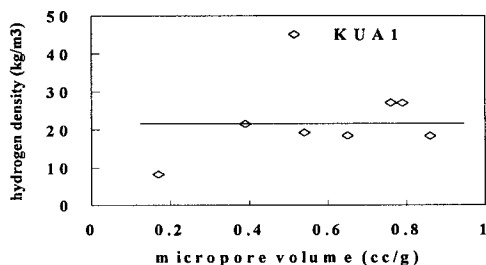


Figure 2. Density of hydrogen vs. Micropore Volume.

Figure 2 shows the evolution of hydrogen density with micropore volume. We can observe that the density of the adsorbed hydrogen is nearly constant for all samples except for that with the narrowest micropore distribution (sample CF) and sample KUA1.

Figure 3 plots the volumetric storage capacity at 70 and 10 MPa versus mean pore size estimated from gas adsorption. The experimental results show a maximum in the volumetric storage capacity, which occurs for sample KUA1. This is in agreement with previous theoretical studies that show the existence of an optimum pore size to store hydrogen in porous adsorbents [10].

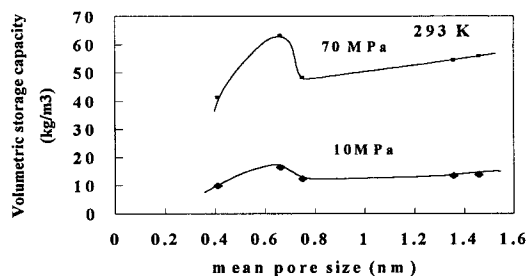


Figure 3. Volumetric storage capacity vs. mean pore size

From Table 1 it is possible to see that the sample with the maximum volumetric storage capacity does not have the maximum micropore volume and, the values are less than half compared with other materials (i.e. AX21 and A20).

Conclusions

The relation between hydrogen adsorption capacity and micropore volume for an extensive number of carbon based samples was analyzed.

This study corroborates theoretical studies made for physical adsorption of gases in microporous materials with slitpores [10] and shows the existence of an optimum pore size for hydrogen adsorption.

General-purpose activated carbon fibers and chemically activated carbons specifically prepared may be materials with interesting applications as adsorbents for hydrogen storage systems.

Acknowledgements

The authors thank DGICYT and CICYT (Projects AMB96-0799 and QUI97-2051-CE) for financial support. MCL thanks the MEC for the Ph.D. Thesis grant.

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