INTERACTION OF HYDROGEN WITH NANOPOROUS CARBON MATERIALS

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Introduction

Environmental concerns have renewed interest in hydrogen fuel for terrestrial transport applications. However, significant improvement in storage capacity must precede widespread implementation of hydrogen-fueled vehicles. Several reports have suggested that carbon nanomaterials (nanofibers, nanotubes, and fullerenes) possess higher capacity than other storage media [1-4], although recent computer simulations cast some doubt on these claims [5-7]. Driven by an interest in the fundamental interactions that determine storage capacity, we have investigated the adsorption of hydrogen on various nanoporous carbon materials.

Experimental

We used the following carbon materials in this study: single walled carbon nanotubes from Rice University [8] and the University of Kentucky [9], activated carbon (BPL from Calgon Carbon Corporation), and carbon nanofibers. We synthesized carbon nanofibers by catalytic decomposition of ethylene over nickel, iron, copper-nickel, and alumina-magnesia catalysts [10,11]. Calorimetry experiments made use of an isothermal flow microcalorimeter (CSC, model 4400) at 25 °C. We used a TA 2950 thermal balance to measure hydrogen uptake capacity at a constant temperature of 30 °C. Degassing samples at temperatures above 100 °C under vacuum or a helium purge minimized surface contamination by residual water.

Results and Discussion

Figure 1 shows the calorimetry results for activated carbon and the single walled nanotube samples. The results for the nanotube samples show comparable qualitative behavior, suggesting a similar pore structure. Integration of these curves gives the heat released per gram of sorbent. Table 1 shows the heat released per gram of sorbent for each material. The results show that hydrogen adsorption on the microporous activated carbon (BPL) releases more heat than does adsorption on nanotube samples. The BPL material either exhibits a higher adsorption capacity or a higher heat of adsorption than the nanotube samples.

To evaluate the heat of adsorption from the total heat released per gram of sorbent, hydrogen adsorption capacities are required. Attempts were made to measure the hydrogen adsorption capacities of these sorbents at atmospheric pressure using thermal gravimetric analysis, but the adsorption capacities were below the detection limit of the instrument (0.1%). The apparent low hydrogen adsorption capacities of these sorbents are consistent with handbook data for hydrogen adsorption on activated carbon [12].

Conclusions

The interaction of hydrogen with various nanoporous materials has been investigated using microcalorimetry. Our measurements show that these materials and activated carbon exhibit similar interaction with hydrogen. In the absence of increased hydrogen-sorbent interactions, these materials are not expected to offer improved storage capacity.

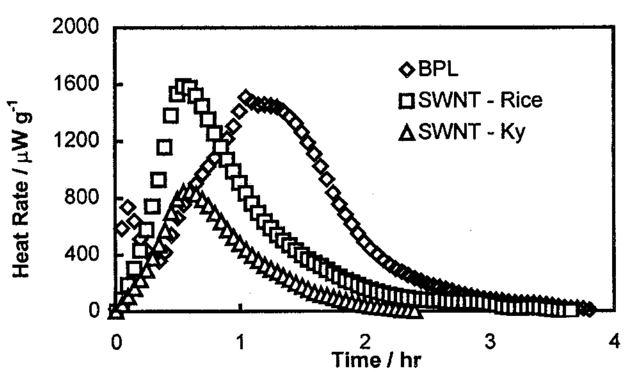

Figure 1: Calorimetry results for hydrogen adsorption.

Table 1: Calorimetry results for H_2 adsorption at ambient pressure and temperature.		
BPL	SWNT (Rice U)	SWNT (UKy)
7.9	2.6	5.5

References

1. Chambers A, Park C, Baker RTK, and Rodriguez NM. J. Phys. Chem. B 1998; 102: 4253.
2. Dillon AC, Jones KM, Bekkedahl TA, Kiang CH, Bethune DS, and Heben MJ. Nature 1997; 386: 377.
3. Yildirim T. Presented at the MRS Symposium, Boston MA, Paper S1.4, December 1998.
4. Brosha E. Presented at the MRS Symposium, Boston MA, Paper S2.9, December 1998.
5. Wang Q, Johnson JK. J. Phys. Chem. B 1999; 103: 277-281.
6. Wang Q, Johnson JK. J. Chem. Phys. 1999; 110: 577-586.
7. Wang Q, Johnson JK. Submitted to J. Phys. Chem. B.
8. cnst.rice.edu/tubes/index.shtml
9. www.carbolex.com
10. Rodriguez NM. J. Mater. Res., 1992; 8: 3233.
11. Rodriguez NM, Baker RTK. US Pat. 5,653,951.
12. Valenzuela DP, Myers AL, In Adsorption Equilibrium Data Handbook, Prentice Hall, 1989.