ORGANIC VAPOR ADSORPTION ON COAL- AND WOOD-BASED CHEMICALLY ACTIVATED CARBONS

W.H. Lee, P.J. Reucroft, M. Jagtoyen* and F.J. Derbyshire*

Dept. of Chemical and Materials Engineering
* Center for Applied Energy Research
University of Kentucky, Lexington KY 40506

INTRODUCTION

Microporous activated carbons have been widely used for air pollution control, waste water treatment, gold recovery and catalytic supports because of their excellent adsorption capacities [1,2]. In recent research, coal- and wood-based activated carbons were prepared using a chemical activation route with varying heat treatment temperature employing KOH and H_3PO_4 as chemical activants [3,4]. In the present study, the physical adsorption characteristics of some of these carbon samples with CCl_4 and acetone vapors as adsorbates have been investigated. Results on H_3PO_4 activated carbons and some KOH activated carbons from coal were described previously [5]. Micropore volumes and characteristic adsorption energies were obtained by applying the Dubinin-Radushkevich (DR) equation [6].

EXPERIMENTAL

CCl_4 and acetone adsorption isotherms were obtained with a gravimetric adsorption system at 296 K over a wide range of relative pressure ($P/P_0 = 10^{-4}$ - 0.6). The adsorption isotherms were evaluated using the Dubinin-Radushkevich equation in order to determine the micropore volume and the characteristic adsorption energy. The results were compared with BET surface area measurements. BET surface areas (S_{BET}) were determined using N_2 at 77 K. Carbon preparation details have been described previously [3,4].

RESULTS AND CONCLUSIONS

BET surface areas of the coal and wood based chemically activated carbon samples are listed in Table 1. It was found that the surface area development was enhanced by increasing the heat treatment temperature.

CCl_4 and acetone adsorption at room temperature is plotted versus relative pressure in Figs. 1 and 2. Typical type I isotherms were obtained. A flat plateau region was observed at $P/P_0 < 0.1$ in the case of the coal based carbon samples. The flat plateau region generally started at a higher relative pressure ($\approx$ 0.3) in the case of the wood-based carbons. This result implies that activated carbon samples obtained from coal as a starting material have more uniform micropore distributions than those obtained from wood.

The adsorption isotherms were plotted as ln W versus A^2 in order to estimate the maximum micropore volume per gram of each carbon sample (W_0) by applying the DR equation :

$$\ln W = \ln W_0 - (A/\beta E_0)^2$$

where W is the volume of adsorbate per gram of carbon sample at relative pressure P/P_0, E_0 is the characteristic adsorption energy, β is the affinity coefficient and $A = RT \ln(P/P_0)$. The resulting W_0 values are listed in Table 1. The values of W_0 obtained from the CCl_4 adsorption isotherms were, in general, somewhat lower than those obtained from the acetone adsorption isotherms for both coal and wood based activated carbon samples. This indicates a possible influence of adsorbate polarity on the adsorption capacity of the carbon samples investigated. Acetone is a polar vapor and carbon tetrachloride is non-polar. Figs. 3a and 3b show plots of S_{BET} versus W_0 for both CCl_4 and acetone adsorption. The two straight lines in Fig. 3a show that there is generally a good correlation between micropore volume and S_{BET} in the case of coal based carbon samples. Wood-based carbon samples showed an ambiguous correlation.

The characteristic adsorption energy (E_0) was calculated from the slope of the ln W versus A^2 plots using an affinity coefficient (β) of 1.08 and 0.83 for CCl_4 and acetone, respectively. These values were obtained from the adsorbate molar volumes using benzene as a reference [7]. The E_0 values are also listed in Table 1. Plots of the characteristic adsorption energy versus S_{BET} for the coal-based carbon samples in Fig. 4a indicate that E_0 for CCl_4 and acetone adsorption generally increases with increasing BET surface area. On the other hand, E_0 values for wood-based carbon samples were relatively constant over the BET surface area range from 200 to 1800 m^2/g. The DR equation provides a good fit to the CCl_4 and acetone adsorption data and allows a full evaluation of adsorption parameter for a series of coal-based chemically activated carbons. The DR equation can also be used to interpret

the adsorption properties of wood based carbon samples to a more limited extent. This may be attributed to the different pore structures of wood- and coal-based carbon samples. Wood-based carbons contain both micropores and mesopores, and coal-based carbon samples contain mainly micropores [3,4].

REFERENCES

1. J. Wilson, *Fuel*, **60**, 823 (1981)
2. R. Bansal, J. Donnet and F. Stoeckli, "Active carbon" Chapter 6, Marcel Dekker, INC. (1988)
3. M. Jagtoyen, M. Thwaites, J. Stencel, B. McEnaney and F.J. Derbyshire, *Carbon*, **30**, 1089 (1992)
4. M. Jagtoyen and F.J. Derbyshire, *Carbon*, **31**, 1185 (1993)
5. P.J. Reucroft, W.H. Lee, M. Jagtoyen and F.J. Derbyshire, 21st Biennial Conference on Carbon (1993)
6. M. Dubinin and L. Radushkevich, Pro., Acad., Sci., USSR, **55**, 331 (1947)
7. M. Dubinin and D. Timofeyev, Pro., Acad. Sci., USSR, **54**, 701 (1946)

Table 1. Maximum micropore volume (W_0) and adsorption characteristic energy (E_0)

No.	S_{BET} m^2/g	W_0 (cc/g)		E_0 (kJ/mol)	
		CCl_4	acet.	CCl_4	acet.
1	580	0.14	0.24	10.7	11.0
2	835	0.30	0.39	15.0	17.2
3	1081	0.43	0.51	19.6	18.5
4	1583	0.61	0.61	21.9	21.4
5	1605	0.63	0.64	22.4	23.0
6	257	0.20	0.24	9.3	14.9
7	935	0.11	0.25	7.4	13.9
8	1075	0.28	0.33	12.6	16.4
9	1807	0.76	0.78	7.9	13.4

- Samples 1-5 were obtained from coal with KOH as a chemical activant and samples 6-9 were obtained from wood with H_3PO_4 as a chemical activant.

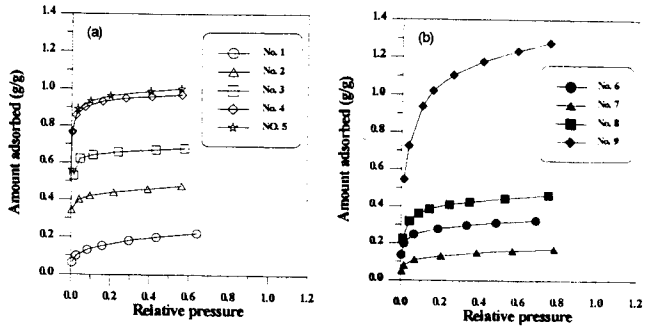

Fig. 1. CCl_4 adsorption on (a) coal and (b) wood based carbon samples

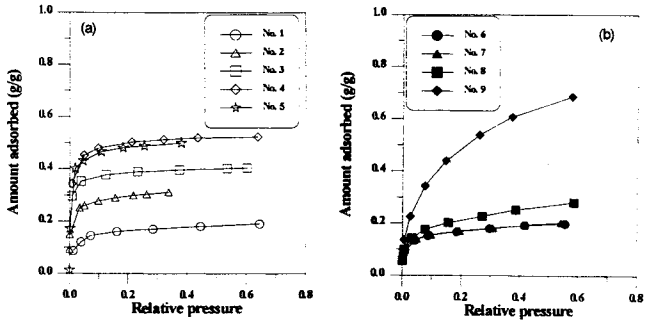

Fig. 2. Acetone adsorption on (a) coal and (b) wood based carbon samples

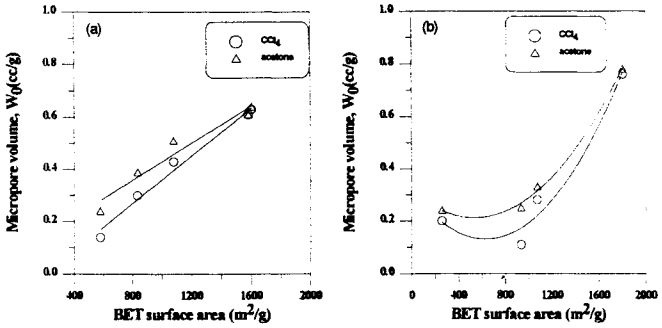

Fig. 3. W_0 versus S_{BET} for (a) coal and (b) wood-based carbon samples

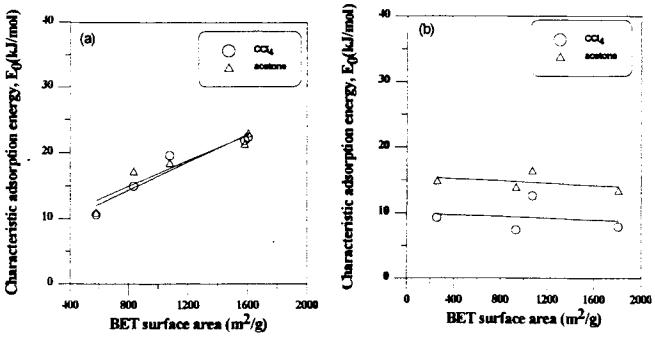

Fig. 4. E_0 versus S_{BET} for (a) coal and (b) wood-based carbon samples