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Adsorption of Aromatic Vapors by Porous Template Carbon Material Synthesized from Polyfurfuryl Alcohol

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A porous carbon material synthesized from polyfurfuryl alcohol shows effective adsorption of several aromatic solvents' vapors as compared with a common activated carbon (N_2-BET specific surface area; 1310m^2/g). The porous carbon material has been prepared by template method, and a natural soil or clay was used for template. The material has a wide pore size distribution in micro porous region, significant growth of meso pores, and high hydrophobicity in comparison to the referential activated carbon. The porous characters seem to contribute to adsorbability, especially adsorption rate, of the aromatic vapors by the specimens. The porous carbon material can be useful for improvement of air purification in work places.
Keywords: Porous carbon materials; Template method; Adsorption; Application of natural resources; Air purification.

1. INTRODUCTION

Currently, porous materials as typified by activated carbons or zeolites serve to an important role in hygienics (public and industrial hygiene) for adsorbents of harmful substances. Especially, activated carbons have high adsorbability of organic solvents' vapors or organic gases, and such porous carbons surpass other artificial porous materials in safety, stability and levity. On this account, further application of porous carbons for environmental improvement, particularly in air purification, is prospected in the day ahead.

Adsorbability by porous materials is largely affected by porous growths and pore size distributions of them. Activated carbons on the market for adsorption of organic solvents' vapors or organic gases have several values of surface area respectively [1-3]. However, their pore size distributions are not quite different especially in micro porous region (radius of pores; $r<$ 1.0nm) [1, 3]. In contrast to this, synthesis of porous carbon materials by template method can easily realize various specimens [4-19], whose pore size distributions and porous growth are unique for each template and raw substance of carbon [4, 14, 16-19]. So it is expected that each porous carbon material also has a unique adsorption character for organic solvents' vapors.

In the previous report [3], we have prepared several porous carbon materials from polyfurfuryl alcohol and template materials such as silica gel and natural soils or clays and minerals. They have certainly unique porous growth and adsorption character of several organic solvents' vapors in contrast to a common activated carbon, and we have pointed out their capability of usefulness for improvement in air purification of work places.

Among them, the specimen C2 (prepared by a kind of natural soil for template) shows an effective result in adsorption of vapor of Toluene. In this report, we have additionally investigated its adsorption character in detail, especially taking notice of the character for vapors of several aromatic compounds analogical to Toluene.

2. EXPERIMENTAL

The specimen in this report is corresponding to the specimen C2 in the previous report [3], and details of synthesis and evaluation of the specimen are also already reported in the paper. N_2-BET specific surface area and pore size distribution of the carbon material have been measured by BELSORP 36 (BEL JAPAN Inc.) with the use of N_2 gas (≥99.9995%). In addition, elemental analysis (CHN) has been carried out by FISONS Instruments EA1108 in Institute of Industrial Science, The Univ. of Tokyo, and we have also performed XRF (X-ray Fluorimetry) measurements by Rigaku RIX 2000.

Adsorption character of the specimens has been evaluated by an apparatus drawing upon the system stated by JIS K 1474 (Japanese Industrial Standard K 1474, Test methods for activated carbon) [20]. Vapors of the solvents are made by bubbling of dry air. The air flow is sent at the rate of 0.1L/min. into the glass bottle, which has each aromatic solvent. Each measurement has been performed upon about 100mg of the specimen, which is settled into the glass column (ϕ =8mm), at room temperature (T≒298K). In regard to adsorbability, amount of adsorption by each specimen is measured by increase of weight of the column. We have confirmed that temperature was almost constant in each measurement. All of the aromatic solvents used in this research are products of Wako pure chemical industries Inc..

We have also used a conventional common activated carbon (N_2–BET specific surface area; 1310m^2/g) [3], which has comparative high surface area for an adsorbent of organic vapors or gases, for reference in this research.

3. RESULTS AND DISCUSSION

Table I shows properties of the referential activated carbon and the specimen C2 in this research. We have used an activated carbon, which is applied for adsorbents of organic solvents' vapors in work places in Japan, for reference in evaluations of adsorption character of the specimen C2. The reference has N_2–BET specific surface area of 1310m^2/g, and the value is comparatively high among various common activated carbons which are supplied for adsorption of organic vapors [1–3]. That is, the reference has high adsorbability among them.

As compared with the reference, rate of content of carbon in C2 is clearly low. Actually, as a result of XRF measurements, we have confirmed existence of calcium compounds clearly in C2 and most of the porous carbon specimens synthesized in the previous report. The compounds seem to be residual component of template materials, and assuming that they are removed completely, the specimens have higher specific surface area, moreover, higher adsorbability.

Fig.1 shows N_2 adsorption and desorption isotherms at 77K of the reference and C2. The isotherm of the reference (Fig.1 (a)) has a characteristic flat feature of microporous materials. In fact, most of activated carbons, which are supplied on the market for adsorbents of organic solvents' vapors in Japan, are made from coconut shells and almost microporous carbons. On the other hand, C2 has a hysteresis in the isotherm, and it indicates that the specimen is a mesoporous carbon material (Fig.1 (b)). Fig.2 shows pore size distributions of the reference and C2 calculated by MP and Dollimore–Heal (D–H) method. In Fig.2 (b), porous growths of C2 surpass that of the reference in meso porous region (radius of pores; 1.0nm $<R_p<$ 15nm) considerably. Of course C2 has also microporous structure. Fig.2 (a) shows that C2 has a wide pore size distribution in the region which activated carbon has extreme few pores in micro porous region (r≒0.5–1nm). From these results, it is expected that C2 has a unique adsorption character as compared with the referential activated carbon. Particularly, the remarkable mesoporous growth of C2 seems to have positive effect on its adsorption rate of organic vapors.

Fig.3 shows adsorption of several organic solvents' vapors by the reference. The reference is really excellent in adsorption of vapor of

Table I. Properties of the carbon materials in this research. V_{micro} is pore volume calculated by MP method, and V_{meso} is that calculated by D–H method. (Extraction from Ref. [3])

SAMPLE	Reference (activated carbon)	C2
N_2-BET specific surface area (m^2/g)	1310	883.2
Density (g/cm^3)	2.059(2)	1.915(6)
V_{micro} (ml/g)	0.574	0.418
V_{meso} (ml/g)	0.0618	0.3897

SAMPLE	C (wt %)	H (wt %)	N (wt %)
Reference (Activated carbon)	91.1	0.4	0.2
C2	51.1	1.1	0.1

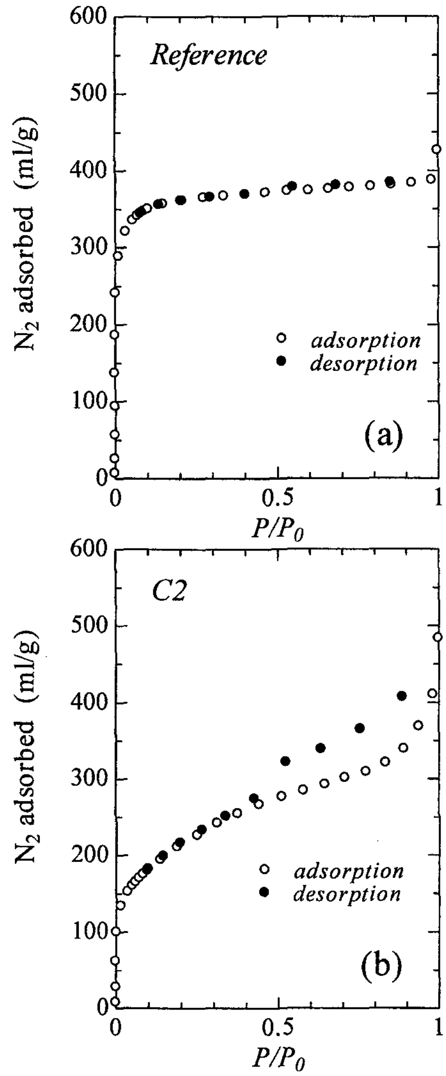

Fig.1. N_2 adsorption and desorption isotherms at 77K of the reference (a) and the specimen C2 (b).

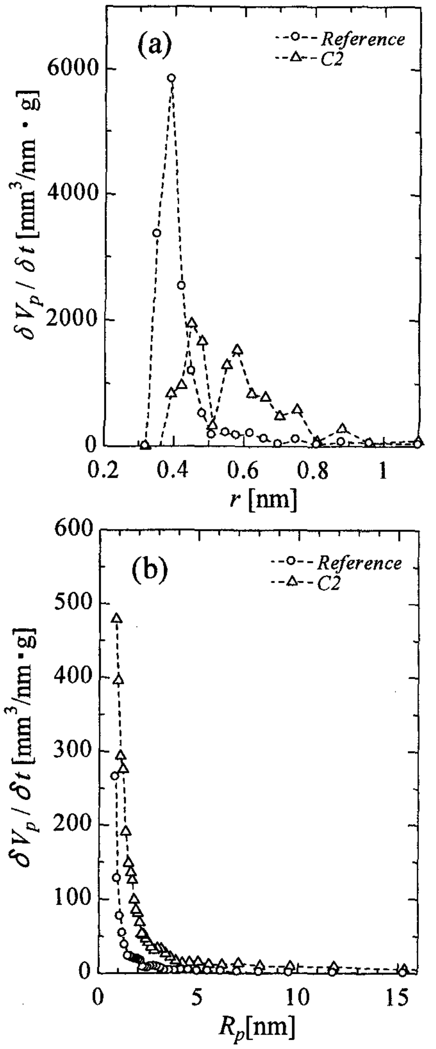

Fig.2. Pore size distributions of the reference and the specimen C2 calculated by MP (a) and Dollimore–Heal (b) method. (Extraction from Ref. [3])

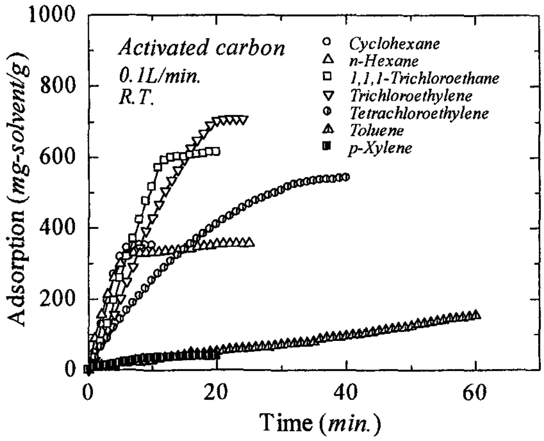

Fig.3. Adsorption of several organic solvents' vapors by the reference (activated carbon). (Extraction from Ref. [3])

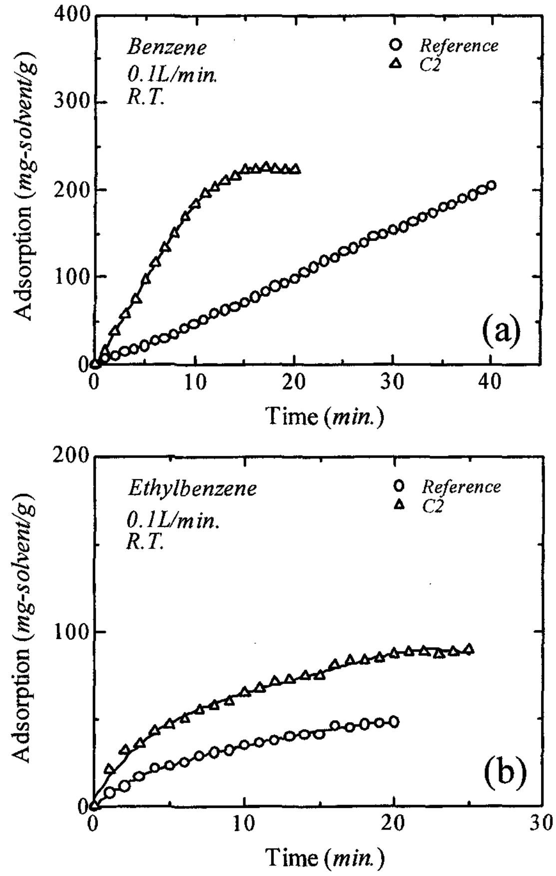

Fig.4. Adsorption of vapor of Benzene (a) and Ethylbenzene (b) by the reference and the specimen C2.

cyclohexane and several chain compounds (hydrocarbons). In contrast to this, the reference shows comparatively slow adsorption for some kinds of vapors; Toluene and p-Xylene. From above results, we have additionally investigated adsorption character of C2 for vapors of several aromatic compounds in detail.

Fig.4 (a) and (b) show adsorption of vapor of Benzene (a) and Ethylbenzene (b) by the reference and C2. In Fig.4 (a), the referential activated carbon shows moderate adsorption even at the point of 40 min.. C2 seems to be inferior to the reference in total amount of adsorption, however, it has remarkable superior adsorption rate.

On the other hand, in Fig.4 (b), C2 adsorbs approximately double amount of the vapor as compared with the reference per unit weight. Besides, C2 surpasses the reference also in adsorption rate obviously.

Adsorption characters for several aromatic compounds' vapors are summarized in Fig.5. In the figure, vertical axis indicates each amount of adsorption at the point that the amount by the reference and C2 become stable or the point that difference of adsorbability between the reference and C2 becomes clear (Benzene). As compared with the reference, C2 also shows effective adsorption of vapor of p-Xylene.

In contrast to this, approximately equivalent results are found in adsorption of o- and m-Xylene. One of the reasons for the results is assumed to be effects of molecular size of each isomer (o-, m- > 0.6nm > p-) [21], however, this can not be confirmed accurately only by pore size evaluation of the carbon materials by N_2 gas in this research.

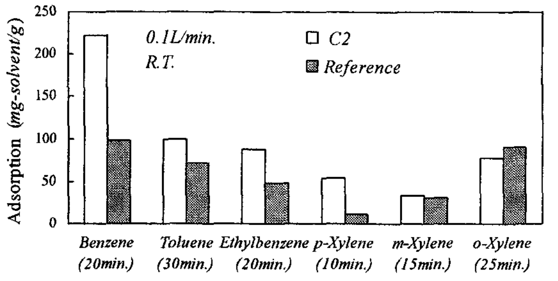

Fig.5. Adsorption characters for several aromatic vapors by the reference and the specimen C2.

As a result, C2 can adsorb vapors of several kinds of aromatic compounds effectively. Of course, this result is also based on surface chemical effect besides pore size distribution of porous carbon materials. In this respect, furfuryl alcohol seems to be effective raw material of porous carbons for adsorbents of several organic solvents' vapors [3, 7]. Further, we have found that C2 has high hydrophobicity more than that of the reference from measurements of adsorption of H_2O vapor. It seems that this surface chemical property also have good effects on adsorption of aromatic vapors, which are also hydrophobic. We have also found that resole resin is not as effective as polyfurfuryl alcohol for raw material of porous carbons, which is synthesized by the technique in this research, for adsorbents of aromatic vapors.

Surface chemical effect is also an important factor on development of porous materials for adsorbents. Further investigation of the effect and appropriate adoption of raw material for carbon are desirable to materialize more effective adsorbents for organic vapors.

4. CONCLUSIONS

A porous carbon material has been synthesized from polyfurfuryl alcohol by template method with the use of a natural soil for template. In porous character, the carbon material has a wide pore size distribution in micro and meso porous region. As compared with a common activated carbon, growth of meso pores in the carbon material is remarkable. The material shows effective adsorption of several aromatic solvents' vapors, and the adsorption character particularly excels in adsorption rate in comparison to the referential activated carbon.

Moreover, the adsorbability indicates that the material is very useful for air purification in work places where aromatic solvents are used with frequently.

In addition, this result shows that synthesis of porous carbon materials by template technique is useful in development of effective adsorbents for hygiene issue.

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