

PITCH-BASED ACTIVATED CARBON FIBER AND ITS METHANE ADSORPTION

Xuejun Zhang, zengmin Shen, Xiaohong Shao, Wenchuan Wang
Beijing University of Chemical Technology, Beijing, 100029

Abstract

Activated carbonaceous adsorbents have drawn great attention for their high adsorption capacities of methane. In this paper, pitch-based carbon fibers(PACFs) were prepared from isotropic pitch-based carbon fiber immersed with cobalt salt solution before steam activation, and the specific surface area(SSA) and pore structures of the resultant PACFs were characterized by N₂ adsorption isotherm. The methane adsorption on PACFs was measured by the intelligent gravimetric analyzer at 258K and 298K. The results show that SSA plays an important role in methane adsorption at a given temperature, and the methane adsorption capacity increases linearly with SSA. The highest adsorption amounts for PACFs with SSA of 1511m²/g can reach 9.83 wt% and 13.75 wt% at 1.8 MPa at 298K and 258K, respectively. Correlations between methane adsorption capacity and SSA are also proposed.

Keyword

Activated carbon, Activation, Gas storage

Introduction

Activated carbonaceous adsorbents have drawn great attention for their high adsorption capacities of methane. Of all the activated carbonaceous adsorbents, activated carbon fibers have attracted considerable concerns because of their high adsorption capacities, ease of synthesis in various forms, and wide applicability. The materials would lead to a high packing density and volumetric capacity for methane storage. Lozano-Castello et al carried out a detailed study of methane storage in carbon materials, and the highest adsorption amount of methane can reach 15.4wt% at 4 MPa(Lozano-Castello D, 2002). In this paper, a series of pitch-based activated carbon fiber(PACFs) were prepared and the specific surface area(SSA) and pore structures of the resultant PACFs were characterized by N₂ adsorption isotherm and SEM. The methane adsorption on PACFs was also measured by the intelligent gravimetric analyzer at 258K and 298K, and then Correlations between methane adsorption capacity and SSA are also proposed.

Experimental

Sample preparation

Pitch-based CF were immersed in cobalt salt solution with different concentration and soak time, and then activated with steam at 1173K for 1 h.

Sample characterization

The Intelligent Gravimetric Analyser(IGA-003, Hiden) was used to measure N₂ adsorption isothermal at 77K and methane adsorption isotherm at 258K and 298K. 51 and 36 data points were measured in the pressure ranges P/P₀<0.4 and <0.05, respectively, to ensure the accuracy of the N₂ isotherm and its applications. To guarantee removal of impurities on micropores, the samples in the vessel of IGA-003 were vacuumed upto 10⁻⁵ Pa and out-gassed at 573K for 24h before the measurements. A built-in water bath was used in the experiment to maintain the temperatures. Methane used in this study is of the purity of 0.999(mol), produced by Haipu Gas Factory, Beijing, China.

Results and Discussion

The relationship between amount of cobalt and concentration

The amount of cobalt loaded onto carbon fiber was determined by concentration and soak time, which will have an obvious effect on the activation process, leading to different pore structure and surface area. The amount changes of cobalt with concentration as well as soak time were summarized in Table 1 and Table 2.

Table 1. The relationship between weight increment of carbon fiber and concentration

Sample	Concentration $\rho/\text{mol}\cdot\text{L}^{-1}$	Soak time t/h	Amount of cobalt wt%
C1	0.05	16	18.5
C2	0.10	16	35.0
C3	0.20	16	45.2
C4	0.50	16	76.6

Table 2. The relationship between weight increment of carbon fiber and soak time

Sample	Concentration $\rho/\text{mol}\cdot\text{L}^{-1}$	Soak time t/h	Amount of cobalt wt%
S1	0.01	19	36.3
S2	0.01	24	39.9
S3	0.01	42	45.8
S4	0.01	47	47.2

The data in these two tables show that the amount of cobalt increases with increasing the concentration and prolonging the soak time. However, cobalt salt will form blocks when it is too much, which will reduce its catalytic reaction, causing carbon fiber activated unevenly.

Methane storage of PACF

Two practical temperatures of room temperature 298K and the industry brine temperature 258K were adopted in this experiment. Methane storage capacities on ACFs calculated from their methane adsorption isotherms are list in Table 3.

Table 3. Methane storage of ACF samples at 1.8 MPa

Sample	BET specific surface area $S/\text{m}^2\cdot\text{g}^{-1}$	Pore size D/nm	Methane storage(wt%)	
			258K	298K
ACF1	813	0.97	11.30	8.35
ACF2	1256	1.03	13.15	9.75
ACF3	1511	1.12	13.75	9.83

From this table, it is found that the methane adsorption amount increases monotonically with increase of specific surface area as well as pore size both at 258K and 298K. The highest adsorption amounts for ACF3 can reach 9.83 wt% and 13.75wt% at 1.8MPa at 298K and 258K, respectively. Correlations between methane adsorption capacity and specific surface area at 258K and 298K are proposed, and the correlations are given by

$$\Gamma_{258} = 0.00224S + 5.28516$$

$$\Gamma_{298} = 0.00145S + 4.06788$$

Where S is the specific surface area, $\text{m}^2\cdot\text{g}^{-1}$, Γ_{258} and Γ_{298} are the adsorption amounts at 258K and 298K respectively. This indicates that the methane adsorption capacity increases linearly with specific surface area. It suggests that the specific surface area plays an important role in the adsorption capacity for the samples in this work. Using Grand canonical Monte Carlo method, the simulation of methane adsorption on ACF3 was carried out, and the results show that methane adsorption on ACF3 can reach 14.99wt% and 18.5wt% at 298K and 258K at 4.0MPa, respectively.

Conclusion

SSA plays an important role in methane adsorption at a given temperature, and the methane adsorption capacity increases linearly with SSA. The highest adsorption amounts for PACFs with SSA of $1511\text{m}^2/\text{g}$ can reach 9.83 wt% and 13.75 wt% at 1.8 MPa at 298K and 258K, respectively

References

Lozano-Castello D, Alcaniz-Monge J, de la Casa-Lillo MA, Cazorla-Amoros D, Linzres-Sohano A 2002. Advances in the study of methane storage in porous carbonaceous materials. Fuel, 81: 1777-803.