

B-T-018en

Reproducibility and effective adsorption loading amount evaluation of high-pressure CO₂ adsorption isotherm of activated carbon (@25 °C, 120 °C)

Introduction

To achieve carbon neutrality by the year 2050, the development of Carbon Capture and Storage (CCS) technology, which can significantly mitigate the CO₂ emitted into the atmosphere, is rapidly progressing. In large-scale CO₂ emission sources such as chemical plants, pre-combustion CO₂ separation and recovery technology is used, therefore it is necessary to evaluate CO₂ adsorption under conditions close to the actual environment where the temperature and pressure of the gas to be treated are high. Generally, when separating and recovering CO₂ using adsorption technology, the Pressure Swing Adsorption (PSA) process is considered. In addition, it is also important to consider CO₂ separation and recovery (and transportation) and utilization (CCU). When separating, recovering and transporting at high pressure and room temperature, and desorbing CO₂ by heating, the Pressure-Temperature Swing Adsorption (PTSA) process can be considered. Fig.1 shows the low temperature (T_{low}) and high temperature (T_{high}) CO₂ adsorption isotherms, the concept of PSA, TSA, PTSA processes, and their relationship with the effective adsorption amount. For example, effective adsorption amount of the pressure swing adsorption process (PSA②) using a material that adsorbs only CO₂ single component, the adsorption amount at adsorption pressure P_{high} and desorption pressure P_{low} on the T_{low} adsorption isotherm is defined as the difference between n_4 and n_3 ($n_4 - n_3$). The effective adsorption amount of each process can be calculated as shown in the table in Fig.1.

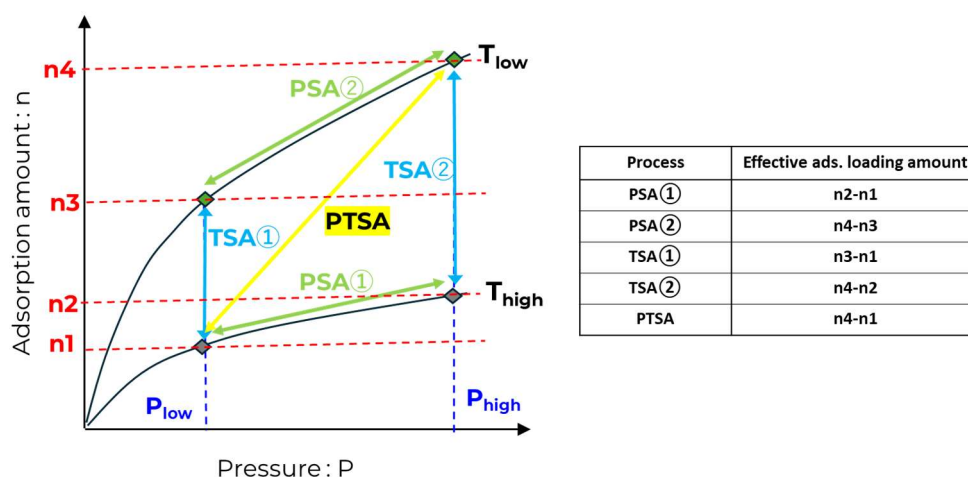


Fig.1. PSA, TSA, PTSA process concept diagram and effective adsorption loading amount of each process.

This application note introduces examples of single-component CO₂ adsorption isotherm measurements at room temperature (25 °C) and at high temperature (120 °C) using activated carbon, which is a potential CO₂ separation material, and examples of effective adsorption amount evaluation assuming each of the adsorption processes.

Experiment

Activated carbon (Shirasagi LH2c20: Osaka Gas Chemical Co., Ltd.) was pretreated by heating in vacuum at 200 °C for 3 hours, and the CO₂ adsorption (ads.) isotherm evaluation from vacuum to 900 kPa at room temperature (25 °C) and high temperature (120 °C) was performed using BELSORP MAX X HP (maximum measurement pressure: 900 kPa). The ads. isotherm at room temperature was measured using a water bath (measurement temperature range: -10 °C to 80 °C) and high temperature isotherms were collected using a heater (measurement temperature range: 50 °C to 400 °C). In addition, the reproducibility of CO₂ ads. and desorption (des.) measurements at high temperature (120 °C) was confirmed by repeating the measurements twice.

Furthermore, using the ads. amounts at P_{high} : 900 kPa and P_{low} : 100 kPa on the ads. isotherms at two different temperatures, the effective ads. amount for each ads. process shown in Fig.1 was calculated.

Results and Discussion

The ads. isotherms shown in Fig.2 represent the equilibrium pressure of CO₂ (kPa) on the X-axis and the ads. amount of CO₂ (mmol) per 1 g of sample on the Y-axis. The results of the effective ads. amount evaluated for each ads. process are shown in Table 1.

For example, when CO₂ is adsorbed at an ads. temperature of 25 °C and a pressure of 900 kPa and then depressurized to atmospheric pressure (about 101 kPa), the effective ads. amount of PSA② is 6.21 mmol/g, and the desorbed CO₂ can be recovered. When CO₂ is adsorbed at an ads. temperature of 25 °C and a pressure of 900 kPa and then heated to 120 °C, the effective ads. amount of TSA② is 6.02 mmol/g. When CO₂ is adsorbed at an ads. temperature of 25 °C and a pressure of 900 kPa and then heated to 120 °C while maintaining atmospheric pressure, the effective ads. amount of TSA① is 2.09 mmol/g. In addition, when CO₂ is adsorbed at 120 °C and 900 kPa and then desorbed at atmospheric pressure, the effective ads. amount of PSA① is about 2.28 mmol/g in the first measurement and about 2.29 mmol/g in the repeated measurement, confirming good reproducibility. The PTSA process, which has the highest effective ads. amount of 8.30 mmol/g, is the most effective among all the processes. By measuring single-component ads. isotherms at room temperature and high temperature from vacuum to high pressure (900 kPa), the effective ads. amount of each ads. process can be evaluated, and in this way, it is possible to easily screen ads. materials for process consideration. However, in practice, it is necessary to evaluate breakthrough curves in multicomponent systems under coexistence with water vapor (B-T-007, B-T-017, B-T-022).

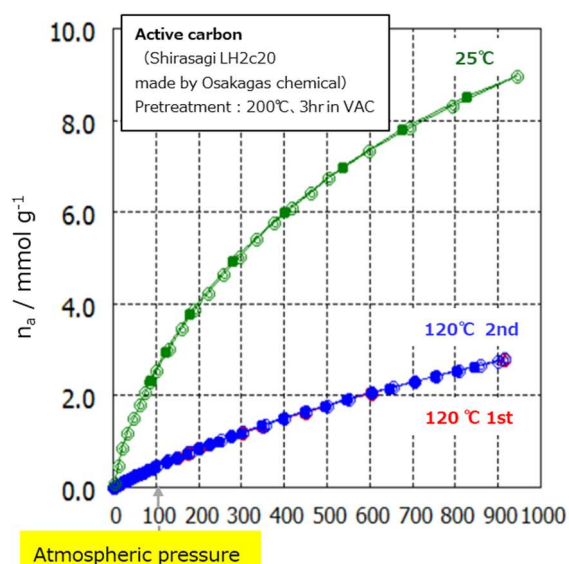


Fig.2. High-pressure CO₂ ads. isotherm measurement results of activated carbon (@25, 120 °C)

Table 1

Summary of CO₂ ads. amounts at atmospheric pressure (~101 kPa) and 900 kPa on ads. isotherms (@25 °C, 120 °C), and effective ads. amounts (recovery amounts).

	Ads. Temp. 120 °C				Ads. Temp. 25 °C	
	Adsorbed amount (mmol/g)	Effective adsorption amount (mmol/g)			Adsorbed amount (mmol/g)	Effective adsorption loading amount (mmol/g) 900 kPa → 100 kPa
		900 kPa → 100 kPa	25 °C → 120 °C	25 °C, 900 kPa → 120 °C, 100 kPa		
Atmos. pressure (ca. 101 kPa)	0.47	PSA①: 2.28	TSA①: 2.09	PTSA: 8.30	2.56	PSA②: 6.21
900 kPa	2.75	—	TSA②: 6.02	—	8.77	—

References

H. Zentou, M. Aliyu, M. A. Abdalla, O. Y. Abdelaziz, B. Hoque, A. M. Alloush, I. M. Tayeb, K. Patchigolla, M. M. Abdelnaby, Chem. Rec. vol 25, 1 (2025)

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