

HYDROGEN ADSORPTION ON CARBON MATERIALS AT LOW TEMPERATURE

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Introduction

In the research field of hydrogen storage materials, hydrogen adsorption on a surface of porous materials has been widely studied, in which the pore size and surface area of the materials have been tried to be controlled. In recent years, it has been reported that the activated carbon with a high surface area of about 3000 m²/g exhibits a maximum hydrogen storage capacity of ~5 mass% at 77 K^[1,2] and of ~1 mass% at a room temperature under 10 MPa hydrogen pressure. Thus, many researchers in this field have focused on how the pore size and the surface area can be controlled to obtain high enough hydrogen storage capacity. On the other hand, Panella *et al.* focused on the adsorption potential of hydrogen on the surface of the materials by means of cryogenic techniques below 77 K^[3]. However, they reported on the hydrogen desorption properties on elevating temperature from 20 K under high vacuum condition. Moreover, in the best of our knowledge, adsorption properties at temperatures below 77 K has not been reported yet.

In this work, we have focused on the hydrogen adsorption properties at temperatures below 77 K. The measurements of the hydrogen adsorption amount on carbon materials were performed under the condition of temperatures below 77K and pressures below 1 MPa. The BET specific surface area of the carbon materials was evaluated by hydrogen adsorption, and then, compared with the result of nitrogen adsorption.

Experimental

A commercial activated carbon (Maxsorb[®]MSC30, Kansai Coke and Chemicals Co., Ltd) was used for this cryogenic experiment. In advance, the carbon material was heated under dynamic vacuum condition at 120 °C for 8 h to remove adsorbed molecules such as water on the surface of the activated carbon. Measurements were performed for the samples of 1 and 3 g at 28 or 77 K. Fig. 1 shows the schematic image of the experimental system. The temperature of sample container in the cryostat can be controlled down to 10 K with errors of ± 0.1 K.

The amount of introduced hydrogen was evaluated by using volumetric method. First of all, blank measurements

were performed at each temperature to estimate the volume of cooled part of the sample container. On the basis of the blank measurement results, the measurements for samples were carried out to examine how much amount of hydrogen was adsorbed on the activated carbon.

Results and Discussion

Fig. 2 shows the introduced amounts of hydrogen into the sample container (a) at 28 and (b) 77 K as a function of H₂ pressure. As shown in the results, the amount of hydrogen in the case of the system with the activated carbon was larger than that in the blank measurement at both the temperatures. At 28 K, hydrogen pressure was saturated at around 0.6 MPa, indicating that the introduced hydrogen was liquefied. The amounts of introduced hydrogen in the container with 1 g and 3 g sample under 0.5 MPa hydrogen are, respectively, 2 and 4.5 times larger than that of the blank. The results at 77 K also shows that the obtained hydrogen amount depends on the sample amount, where 1 and 3 g samples shows 2 and 3.5 times larger. From the above results, it is clarified that larger amount of the activated carbon leads to higher hydrogen capacity in the sample container.

Fig. 3 shows hydrogen capacity of the activated carbon at 28 and 77 K. At both the temperatures, the hydrogen capacities are almost the same in the different sample amount. The hydrogen capacities under 0.6 MPa of hydrogen pressure at 28 and 77 K were, respectively, about 11.5 and 4.0 mass%. These results indicate that a lower temperature leads to higher hydrogen capacity.

BET specific surface area is estimated from hydrogen isothermal adsorption curve to be about 3900 m²/g at 28 K. On the other hand, that obtained from nitrogen isothermal adsorption curve is estimated to be about 2600 m²/g at 77 K. Consequently, the BET specific surface area by hydrogen gas is about 1000 m²/g larger compared with that in the case of nitrogen gas. This fact indicates that the hydrogen molecule can reach the narrow pore, which does not permit the entrance of nitrogen molecule.

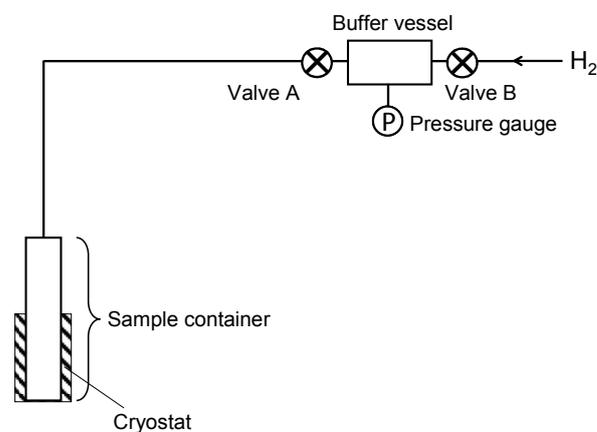


Fig. 1 Schematic image of experimental system

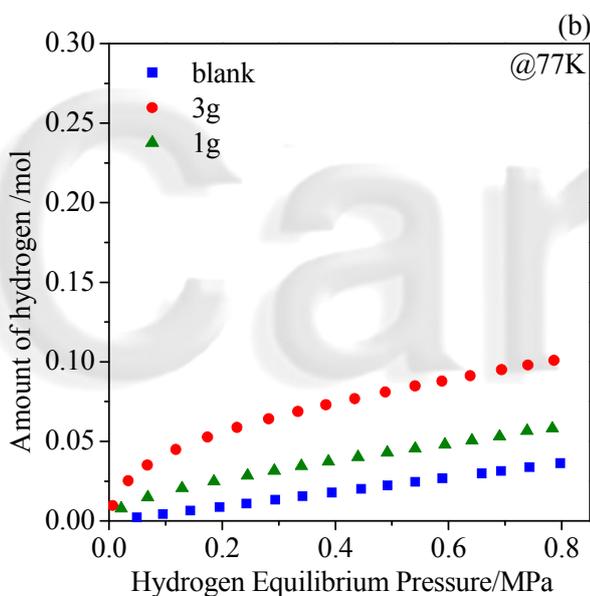
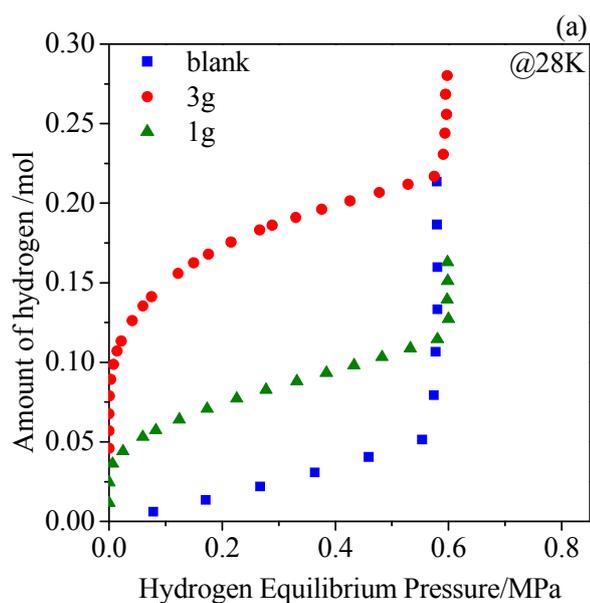


Fig.2 Amounts of hydrogen (a) at 28 K and (b) at 77 K as a function of H₂ pressure.

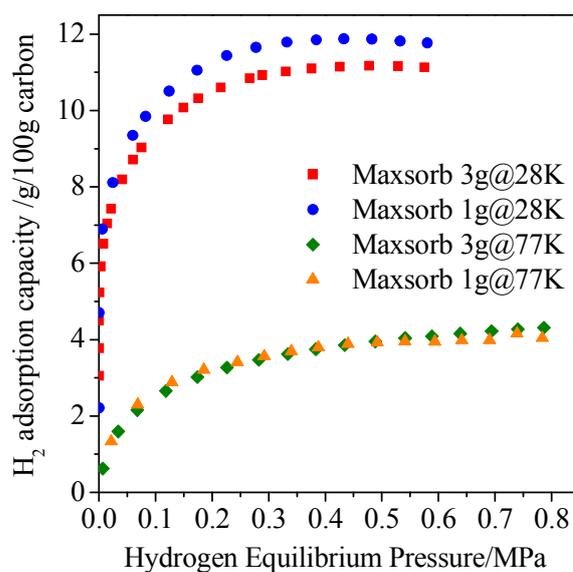


Fig. 3 Hydrogen capacity of carbon material at 28 and 77 K.

Conclusions

In this work, the amount of hydrogen adsorption on carbon material has been evaluated at lower temperature than a critical temperature of hydrogen. The hydrogen amount for the constant volume is enhanced by increase in the introduced sample amount. The hydrogen capacity per sample weight was hardly different, where it was about 11.5 mass% under 0.6 MPa of hydrogen equilibrium pressure at 28 K. The BET specific surface area obtained by using hydrogen gas is about 4000 m²/g at 28 K, which is 1.5 times larger than that obtained by nitrogen adsorption at 77 K.

References

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