Development of Carbon Material
for Natural Gas Storage

Hiroshi Ogasa
Engineering Research Department M3, Tochigi R&D center, HONDA R&D CO.,LTD
4630 Shimotakanezawa, Haga-machi, Haga-gun, Tochigi 321-3393

Corresponding author e-mail address: Hiroshi_Ogasa @n.t.rd.honda.co.jp

Introduction

Worsening global environmental issues and the depletion of oil reserves have increased the necessity for the reduction of automotive exhaust gas emissions and the development of alternative fuels. The use of natural gas as an automotive fuel significantly reduces exhaust gas emissions. This paper focuses on adsorbed natural gas (ANG), a storage method which enables the gas to be stored at a low pressure in comparison to the most widely used form of gas storage, compressed natural gas (CNG), and discusses the performance of the carbon adsorptive materials which represent the core technology of ANG.

Experiments

A computer simulation was used to predict the ideal pore structure for a carbon material capable of efficiently adsorbing methane, the main constituent of natural gas. The pore structures of activated carbon and a carbon nano-material were improved and the methane storage capacity measured to find the ideal pore structure. Methane storage capacity was defined as the amount of gas able to be stored at a pressure of up to 3.5MPa by the different materials (with a binder added and formed by high-density compression) at a temperature of 25°C. Methane storage capacity was measured in NL/cm^3, expressing the amount of gas stored per unit of volume of the material. Activated carbon was studied first. In Step 1, the pore structure of steam activated coconut shell carbon was improved. Coal was employed in Step 2, given its low level of impurities and its high carbon content, and it was KOH activated. In Step 3 the activation conditions employed in Step 2 were improved, and this resulted in the material demonstrating a high methane storage capacity.
Research next turned to carbon nano-materials. The methane storage capacity of C_{60} and single-wall carbon nanotubes (SWCNT) was measured. Further, the methane storage capacity of C_{60} was measured after carbon dioxide gas and KOH activation. Transmission electron microscope (TEM) and Raman analysis were then applied to the $C_{60,}$ and showed that structural changes had occurred as a result of activation.

Results and discussion

First, the ideal pore structure for activated carbon was determined using a computer simulation, with the results shown in Fig. 1. A pore diameter of 0.78nm and a specific

surface area of 2630m^2/g was the pore structure able to adsorb the greatest amount of methane molecules. As shown in Fig. 2, activated carbon raw materials, activation methods and activation conditions were varied to attempt to produce this ideal pore structure, resulting in the fabrication of an activated carbon with a pore diameter of 0.78nm and a methane storage capacity of 0.155NL/cm^3.
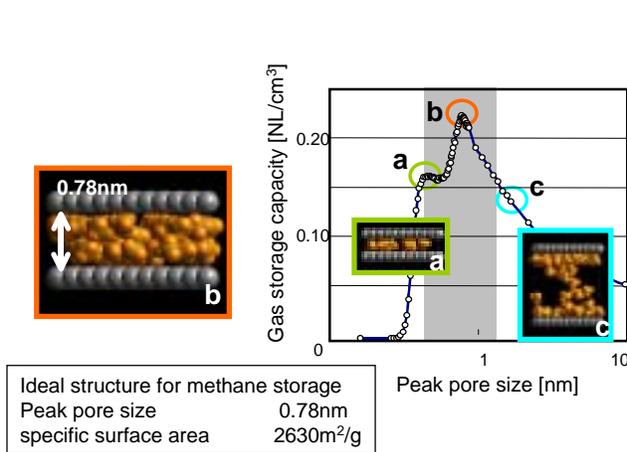

Ideal structure for methane storage
Peak pore size   0.78nm
specific surface area   2630m^2/g
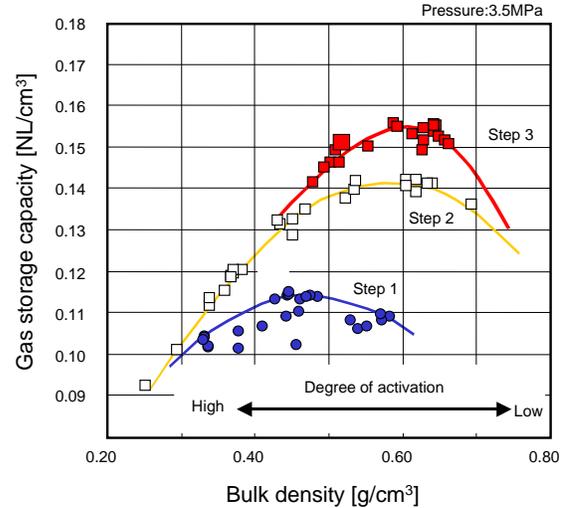
Fig.1 Pore size and storage capacity

Fig.2 Adsorption Performance
of Activated Carbon

The study next turned to carbon nano-materials, and measured the methane storage capacity of unactivated C$_{60}$, SWCNT and multi-wall carbon nanotubes (MWCNT). The results of these measurements showed the carbon nano-materials to have an extremely low methane storage capacity (0.02NL/cm^3) compared to the activated carbon. This led to a study of the methane storage capacity of C$_{60}$, a material which is easy to process and which contains relatively few impurities, when activated under identical conditions to the activated carbon. As Fig. 3 shows, the results showed a figure of 0.147NL/cm^3, close to the figure for the activated carbon.
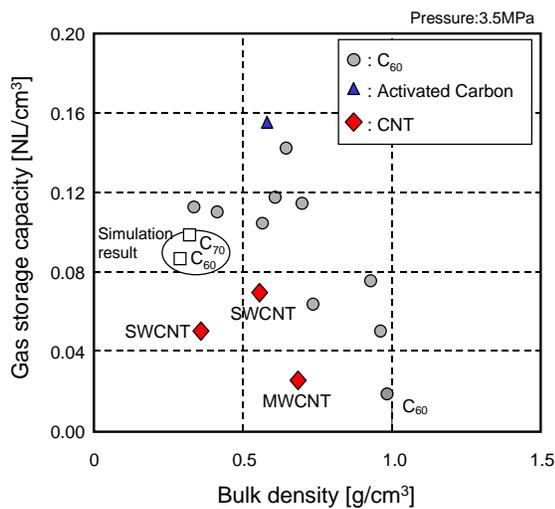

Fig.3 Adsorption Performance
of Nanocarbon
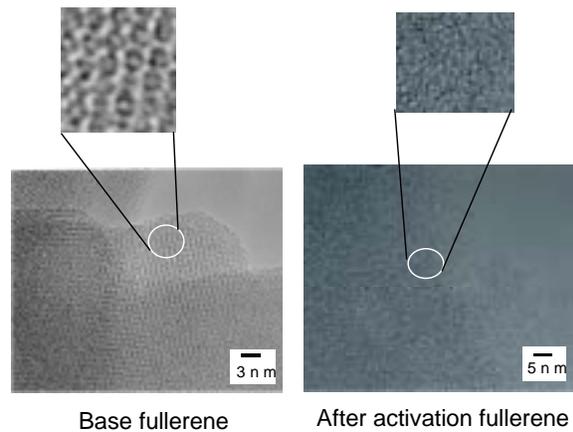

Base fullerene   After activation fullerene

Fig.4 TEM image of Fullerene

There are virtually no examples of the use of C_{60}, a representative carbon nano-material, as an adsorbent activated in an identical process to activated carbon. In addition, because the reason for the improvement in the storage capacity of C_{60} with activation is not clear, TEM and Raman analyses were conducted to determine whether or not activation had caused changes in the structure of the material. Fig. 4 shows TEM images of the base C_{60} and the activated C_{60}. Before activation, the C_{60} possesses a regular graphite crystal lattice structure, but this structure cannot be confirmed after activation. As Fig. 5 shows, Raman analysis also demonstrated that structural change occurred when the C_{60} was activated.

The results of these analyses have not enabled any clear answers to be given at this stage as to the exact nature of the structural changes activation produces in the C_{60}, or how these structural changes contribute to improved adsorption. This will therefore become the subject of future research. A Raman analysis was also carried out on the activated carbon. The results, shown in Fig. 6, demonstrated that no structural change occurred as a result of activation.
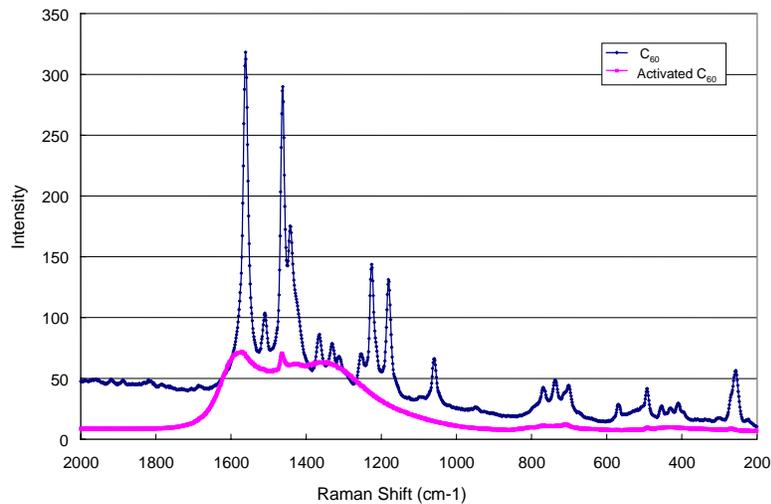

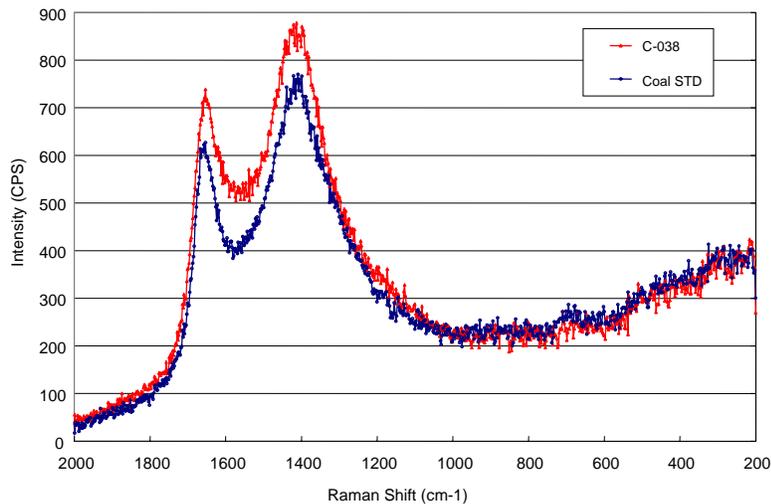
Fig.5 Raman Analysis of C60

Fig.6 Raman Analysis of Activated Carbon

Conclusion

Production of an activated carbon with the most effective pore structure for adsorption of methane molecules resulted in the achievement of a methane storage capacity of $0.155NL/cm^3$. When the same method of activation was applied to C_{60}, a methane storage capacity of $0.147NL/cm^3$, extremely close to that of the activated carbon, was produced. Analysis demonstrated that C_{60} differs from activated carbon in that activation significantly changes its internal structure.

Acknowledgments

References

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