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Room Temperature Storage of Hydrogen by Carbons

Mitsunori Furuya, Ayaka Yanagitsuru, Yuuya Matsuo, Kenji Ichimura
Graduate School of Science and Technology, Kumamoto University, Kumamoto, Japan
Email: ichimura@kumamoto-u.ac.jp

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ABSTRACT

The adsorption states of hydrogen at around 300 K are found on carbons by means of thermal desorption measurements. This sorption ability has utility for energy technologies such as fuel cells.

Keywords: Hydrogen; Storage; Carbon; Absorption States

1. Introduction

We have reported the chemical interactions of hydrogen in the solids C_{60}, Na-C_{60}-H ternary systems (super-conducting (SC) and non-super-conducting non-SC Phases) and carbon nanotube [1-7], as shown in **Figure 1**.

This paper presents results in the thermal desorption of hydrogen from carbon blacks and carbon nanohorn.

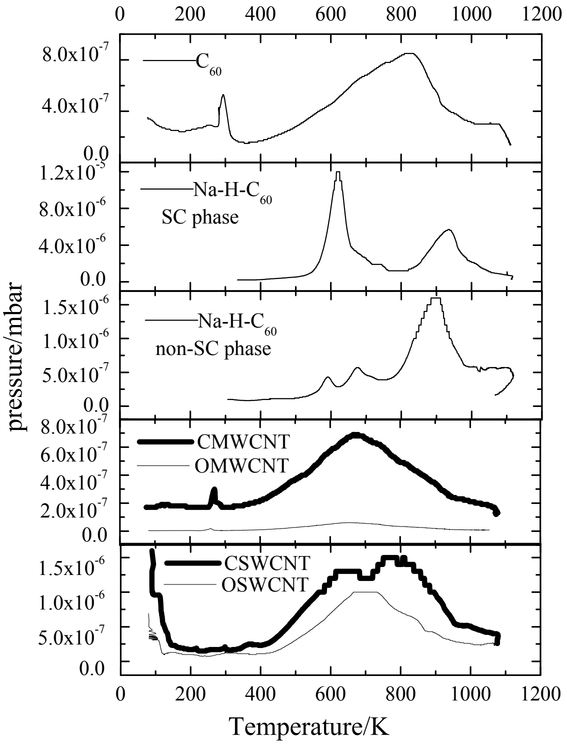

Figure 1. The thermal desorption of hydrogen from C_{60}, Na-H-C_{60} and carbon nanotubes.

2. Experimental

C_{60} (Hoechst, 99.98% purity) was used without further purification.

The synthesis of $Na_xH_yC_{60}$ was done as follows: The mixture of stoichiometric amounts of NaH and C_{60} powders was loaded in a quartz tube in a dry box filled with Ar gas. Then the sample in the tube sealed under the pressure of ~10^{-4} Pa was heated at 553 K for 1 h in a muffle furnace.

Capped and open (no endcaps) single wall carbon nanotubes (CSWCNT and OSWCNT, Bucky USA BU-202 (endcaps) and BU-203 (no endcaps), respectively, with 1.4 - 3 nm diameter and 10 - 50 µm length) were used without further purification for the adsorption studies. The only difference between BU-202 and BU-203 is the endcap structure at both ends, and other- wise the two structures are the same.

Carbon black (Seast 3HAF) and graphitized carbon blacks (#3855, #3845 and #3800) were supplied from Tokai Carbon Co. **Table 1** shows the characterizaion of samples.

Carbon nanohorn was synthesized by means of the arcing method and supplied by Yamaguchi and Iijima [8,9].

Table 1. Caracteristics of carbon blacks.

sample	weight/mg	Particle radii/nm	N_2 specific surface area/m^2/g
Seast 3HAF (S3)	32	28	79
#3855	32.2	25	90
#3845	33.1	40	57
#3800	32.1	70	27

After vacuum heating at 653 K or 1073 K, the samples were exposed to hydrogen (Nippon Sanso, >99.9999% purity) 1 to 1.4 atm, at 473 K for 3 - 5 days. After the sample was cooled to liquid nitrogen temperature, the sample tube was evacuated to ultra-high vacuum. Desorbed gas was analyzed by using two mass-spectrometers when the sample was heated at a temperature-rise rate of 5 K/min.

3. Results and Discussion

As shown in **Figure 1**, for C_{60} and carbon nanotubes, the desorption of hydrogen was observed below 300 K. The temperature region of desorption below 300 K suggests the interaction by van der Waals and/or weak chemical bonding. The further desorption peaks were observed at around 820 K for C_{60} and 650 K for carbon nanotubes. The temperature region of desorption above 300 K suggests the interaction by strong chemical bonding. In the $KC_8H_{0.6}$ ternary system, the hydrogen desorption peak appears at 512 K. The desorption peaks of hydrogen in Na-H-C_{60} appear at around 650 K and 900 K, in which hydrogen species at around 650 K has a strong correlation with super-conductivity. In these systems, hydrogen exists as H^- or $H^{\delta-}$. The hydrogen desorption peaks for carbon nanotubes are lower than C_{60}, indicating that the interaction of carbon nanotubes with hydrogen is weaker than that of C_{60}. The temperature region of desorption suggests that the charge transfer occurs hydrogen from C_{60} and carbon nanotubes.

For OMNT and CMNT, the absorbed amount of hydrogen for CMNT is larger than that for OMNT. As for the both, the basic structure is the same, and the difference of the both is only the presence of end caps. Therefore, this result that CMNT with end caps shows a larger amount of absorption indicates that sites which are composed of end caps are more active for the adsorption and absorp- tion of hydrogen on and in the used OMNT and CMNT in the temperature region above 77 K. C_{60} shows the de- sorption of hydrogen at around 300 K.

Figure 2 shows the thermal desorption of hydrogen from carbon blacks. An amorphous type carbon black S3 has sorption states for hydrogen at around 300 K. The sorption state of S3 appeared at 374 K changed to the higher temperature side by graphitization. However, graphitization causes the creation of the sorption states at around 230 K by appearance of new electronic states of micro-graphite. Among these carbon blacks, amorphous type carbon black shows the sorption characteristic for hydrogen sorption at around room temperature.

Figure 3 shows the hydrogen desorption from carbon nanohorn. The desorption feature is similar to the graphitized carbon blacks: The sorption states appear at around 130 K and 500 K. However, the sorption states appeared in the lower temperature side are stronger the than those of graphitized carbon blacks.

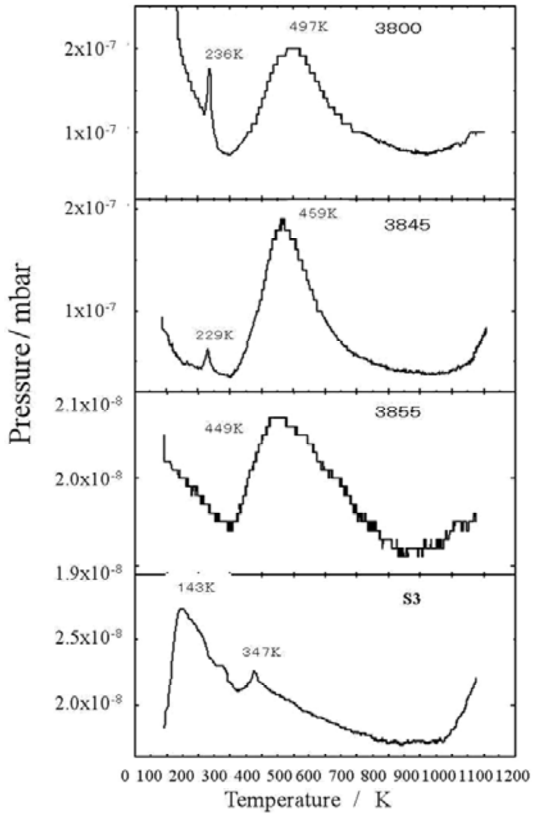

Figure 2. The thermal desorption of hydrogen from carbon blacks.

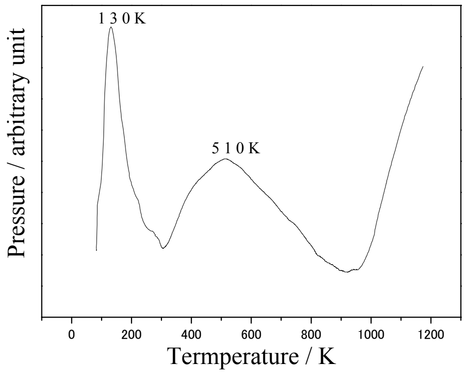

Figure 3. The thermal desorption of hydrogen from carbon nanohorn.

4. Conclusions

The sorption state at around 300 K is found in H_2 desorption from C_{60}, carbon blacks and carbon nanohorn. These sorption abilities have utility for energy technologies such as fuel cells. By changing the structure and aggregation states of carbons as shown in C_{60}, carbon blacks and carbon nanohorn, it is possible to create the new electronic state and their sorption characteristics for hydrogen sorption at around room temperature.

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