

Hydrogen Sorption by Carbon-Based Substances Formed in Carbon–Helium Plasma

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Received September 17, 2004

Abstract—Hydrogen sorption by various carbonaceous products formed during arc discharge in carbon–helium plasma has been studied. The main product fractions included a fullerene-containing soot, a fullerene mixture extract, a condensate containing carbon nanotubes, and carbonized aluminum oxide. Molecular hydrogen is most effectively sorbed by single-wall carbon nanotubes contained in the carbon condensate fraction.
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Economic and technological development, with due allowance of ecological safety, require the search for and implementation of new energy sources. Considerable attention in this respect is devoted to the development of hydrogen power engineering, where the key problems are related to the safe storage and transport of hydrogen. It is believed that the most promising solutions are offered by carbon-based sorbents [1]. Unfortunately, published data on sorption efficiency, even for the same substance, are frequently contradictory [2, 3]: the relative amount of hydrogen per unit weight of sorbent may range from a fraction of a percent to tens of percent. The discrepancies may be related to differences in the structure of objects studied by various researchers.

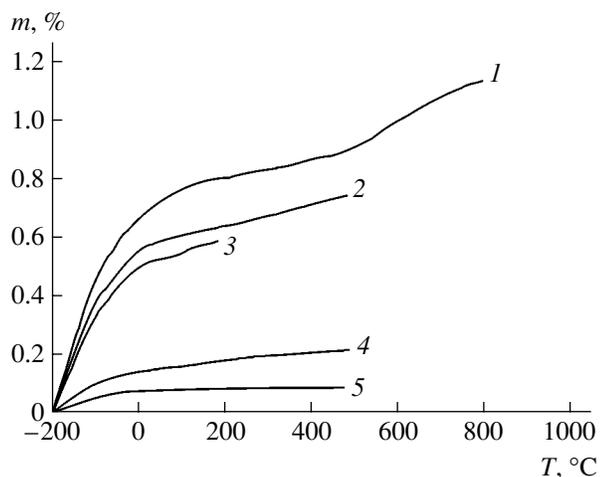
This Letter reports the results of the investigation of hydrogen sorption by various carbonaceous products formed during arc discharge in carbon–helium plasma. The main product fractions were as follows: (F) a fullerene mixture containing 60% C₆₀, 25% C₇₀, and 15% of higher fullerenes; (T) a condensate including 15–20% of multiwall carbon nanotubes (MWNTs) of 120- to 160-nm diameter and turbostratic graphite [4] (with interplanar spacing in both MWNTs and graphite being 0.342 nm); (S₁) a fullerene-containing soot including about 9% fullerenes and more than 40% of single-wall carbon nanotubes (SWNTs); (S₂) a fullerene-containing soot including about 8% of fullerenes and 15% of carbon nanotubes; and (A) carbonized aluminum oxide (Al₂O₃ containing about 2 wt % of carbon) with a particle size of 5–40 μm and a specific surface of 119 m²/g [5].

The samples of S₁, F, T, and A fractions were synthesized in a flow of carbon–helium plasma at atmospheric pressure in a setup described in detail elsewhere [6]. The discharge was operating between an external (cylinder) and an internal (rod) graphite electrodes. The

sample of fraction S₁ was taken from a liquid-nitrogen trap purifying the gas flow at the output of the chamber in the course of synthesis. Fraction T was collected on the external electrode, where a carbonaceous deposit was formed in the course of synthesis. Fraction F was obtained by extraction with benzene from sample S₁. Fraction A was collected upon the introduction of Al₂O₃ particles into the flow of carbon–helium plasma. The sample of fraction S₂ was obtained in a setup for the fullerene synthesis according to the Kratschmer method [7].

The experiments on hydrogen sorption in the samples of carbonaceous products described above were performed as follows. Each sample was heated to 600°C in a vacuum of 10^{−4} Torr created by roughing (mechanical) and oil-diffusion pumps via a liquid-nitrogen trap. Then, the pumping stage was disconnected and the chamber was filled by hydrogen at a pressure of 100 bar. The hydrogen pressure was maintained constant while the sample was cooled to −180°C and kept under these conditions for 20 min. In order to desorb the stored hydrogen, the sample was gradually heated to 800°C. The amount of liberated hydrogen was measured under normal conditions with the aid of a U-shaped manometer.

The temperature dependence of the mass of hydrogen desorbed from various samples is presented in the figure. As can be seen, the amount of liberated hydrogen in all cases increased with the sample temperature. The maximum yield was observed for the samples of fraction S₁. A relatively small degree of hydrogenation observed for Al₂O₃ can be explained by the process of aluminum reduction competing with the sorption process. Thermogravimetric analysis of the samples of fraction S₂ in the initial state and upon hydrogen sorption showed that heat evolution in the hydrogenated



The temperature dependence of the relative mass of hydrogen (percentage of the sorbent weight) desorbed from various samples: (1) S₂; (2) S₁; (3) T; (4) F; (5) A.

sample is higher than in the initial state and agrees with the amount of sorbed hydrogen.

Thus, the results of our investigation showed that the most effective sorption of molecular hydrogen takes place by a fraction containing single-wall carbon nanotubes.

Acknowledgments. This study was supported by the Human Capital Foundation.

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Translated by P. Pozdeev