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Preparation of Carbon Nanohorn Aggregates by Cavity Arc Jet in Open Air

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Carbon nanomaterials were prepared by a new cavity arc jet method under open-air conditions. The cavity arc jet was an electric arc plasma jet spouted from the narrow cavity formed by sandwiching a thin insulator with a partial notch between two graphite electrodes. The soot was obtained by quick cooling of the carbon arc jet, using the collection plate crossing the arc jet, and was mostly composed of round particles 30–150 nm in diameter. Microscopic observation revealed that more than 30% of the particles were carbon nanohorn aggregates. [DOI: 10.1143/JJAP.41.L852]

KEYWORDS: single-walled carbon nanohorn, aggregate particle, cavity arc jet, open air, arcing feature, SWCNT

Carbon nanomaterials, such as carbon nanotubes,[1)] nanohorns[2)] and nanocoils,[3,4)] are promising new materials for the new generation, with a variety of applications, including electron emitters and gas storage. In order to realize these applications, appropriate production methods should be established. For carbon nanotubes, various methods have been developed, the most important being carbon arc discharge,[1)] laser ablation,[5)] and chemical vapor deposition (CVD).[6)] However, the production of a considerable amount of carbon nanohorns (CNHs) has thus far been possible only by the laser ablation method, in which pure graphite is ablated by a high-power CO_2 laser under flowing Ar gas at a high flow rate (40 l/min).[2,7)] Small amounts of CNH have sometimes been observed in the soot prepared by the carbon arc discharge method,[8,9)] and frequently observed in the soot prepared by the torch arc jet method.[10)] CNH aggregates have a large surface area[11)] and are promised to be used as the support of platinum catalyst in fuel cell,[12)] storages of ethanol[13)] and methane,[14)] and a molecular sieve.[14)]

One of the present authors has been developing a method for open-air syntheses of multiwalled carbon nanotubes (MWCNTs)[15,16)] and single-walled carbon nanotubes (SWCNTs)[10)] using a welding arc torch. Various modified types of this open-air arc method have been tested; however, we have discovered a new method for selectively fabricating single-walled CNH aggregates with comparably high yields. In the present paper, this method is presented. The soot obtained by the new method was microscopically observed and analyzed by Raman spectroscopy.

Figure 1 depicts the experimental setup. Two graphite-plate electrodes (3 mm thick) were arranged to sandwich a larger thin polytetrafluoroethylene (PTFE) sheet (0.5 mm thick) with a V-shape cut (typically with a 5 mm base side and a 7.5 mm height) in open air. The electrodes and the notched PTFE sheet formed a thin cavity. The electric power was supplied to the electrodes using a welding power supply with an RF trigger starter. Then an electric arc discharge was generated between the thin-gap electrodes. Since a considerable amount of the graphite (C) anode was evaporated, the evaporated gas overflowed from the notched exit in the form of a plasma jet, which we called a cavity arc jet (CAJ). The CAJ was quickly cooled down on a collection plate made of stainless steel placed 15 mm from the cavity exit. The carbon soot was deposited on the collection plate. The typical arcing period was 1 to 2 s. The metal composite graphite (Ni, 4.2 mole% and Y, 1.0 mole%: hereafter, C–Ni/Y) was also used as the anode. For the C–Ni/Y anode, the arc was operated typically at dc 150 A, and the notch size was 10 mm on the base side with a 15 mm altitude, since the evaporation was much stronger than that for the C anode.

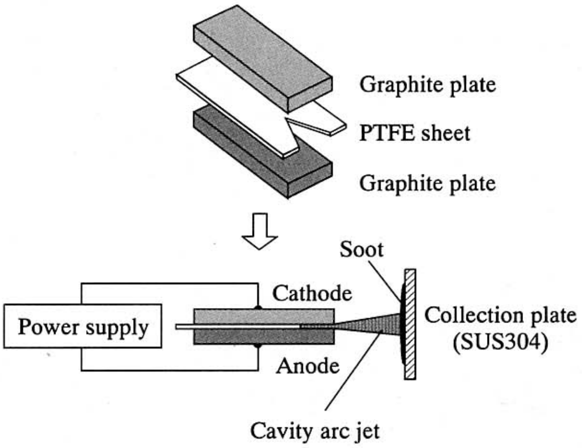

Fig. 1. Schematic diagram of the structure of the arcing cavity formed with two graphite electrodes and an insulating sheet (PTFE), and the experimental setup.

The soot obtained by the CAJ method was observed with a transmission electron microscope (TEM; JEOL, JEM-100S). Furthermore, the soots obtained by the CAJ, conventional carbon arc (CCA), and torch arc jet (TAJ) were analyzed with a Raman spectroscope (JASCO, NRS-1000; 532.18 nm laser). The CCA conditions were as follows: arc current, 100 A; ambient gas, He; pressure 90 kPa; C-cathode diameter, 10 mm; C–Ni/Y anode diameter, 6 mm; electrode gap, 1–1.5 mm; arcing period, 1 min. In the CCA, the analyzed soot was part of the web like soot bridging the cathode and anode. The TAJ conditions were as follows: arc current, 150 A; shielding gas, Ar (2 l/min); torch electrode, C (4 mm diameter); anode target, C–Ni/Y (2 mm thick).

The differences between the case in which CAJ was formed and the case in which it was not formed (i.e., no jet from the cavity) were the following. When the CAJ was successfully formed, the arc voltage was low (25 to 30 V) and stable, the