

Simple Preparation of Carbon-Nanotubed Field Emitting Surface Using a Welding Arc Torch

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Graphite (C) and catalyst (Ni/Y)-contained graphite (C-Ni/Y) substrates were processed by a welding torch arc in both DC and AC mode under open air. Multiwall carbon nanotubes were obtained at the arc spot surface on C-Ni/Y substrate for DC and AC arc, and on C substrate for AC arc. The field emission abilities of these arc spot surface were tested in a diode system. The emission current increased in the order of the surfaces of C-Ni/Y substrate for AC arc, of C substrate for DC arc, and of C-Ni/Y substrate for DC arc. This order was the same as the increase of nanotube density and the decrease of coexisting nanoparticle density.

Keywords: carbon nanotubes, welding arc torch, graphite substrate, catalyst, field emission

Carbon nanotube is one of the candidates for cathode materials of field emitters⁽¹⁾⁻⁽³⁾, since it has a unique shape in nanometer-order scale. The carbon nanotube was first found in the cathode deposits of low-pressure arc discharges between graphite (C) electrodes used to produce fullerenes⁽⁴⁾. To date, a variety of methods of carbon nanotube synthesis have been developed.

With regard to the arc method, we have found that multiwall carbon nanotubes (MWNTs) are produced on a cathode surface of pure graphite by the cathode spot⁽⁵⁾⁻⁽⁹⁾, but only a negligible amount was produced on anode surface of pure graphite by the anode spot⁽⁵⁾⁻⁽⁹⁾. However, it was also found that the MWNTs were created on the anode surface of catalyst-contained graphite in a low-pressure arc⁽⁹⁾. These results indicate the possibility that the MWNTs may be produced on the anode if the graphite anode contains catalyst as the principal factor. In the present study, in order to provide a practical method of manufacturing the field emitter of nanotubes, the welding arc torch was employed to produce a nanotubed surface on graphite and catalyst-contained graphite substrates.

A general welding arc torch for tungsten-electrode-inert-gas (TIG) welding (Hitachi: power supply, ARC-PAIR AD-STX 200A; torch, N-351W) was used, though a tungsten (W) electrode of the torch was replaced with a pure graphite one of 3 mm in diameter in order to prevent the contamination of W vapor or macrodroplets. The substrates (2 mm in thickness) which functioned as the counterelectrodes of the torch arc, were pure graphite (C) and graphite containing metal catalysts (Ni, 4.2 wt% and Y, 1.0 wt%) (C-Ni/Y). The arc was operated in open air (1 atm) in the DC or AC (60 Hz) mode at an arc current of 100 A. Shielding

argon (Ar) gas of 1.8 L/min flowed through the welding torch. The gap length between the torch electrode and the substrate was approximately 2 mm. The arcing period was approximately 1 s. Hereafter, DC-C, DC-cat, AC-C, and AC-cat denote the cases of the C substrate processed in the DC mode, the C-Ni/Y substrate processed in the DC mode, the C substrate processed in the AC mode, and the C-Ni/Y substrate processed in the AC mode, respectively.

The diameters of arc spots on the substrate were approximately 4 mm, 5 mm, 2 mm, and 5 mm for DC-C, DC-cat, AC-C, and AC-cat, respectively. The spot sizes slightly fluctuated, since the experiment was manually executed. The surface of the arc spot was observed using a high-resolution scanning electron microscope (HR-SEM; Topcon, ABT-150F). HR-SEM micrographs of the arc spot surface are shown in Fig. 1.

For DC-C, the surface was formed by many particles; nanotubes and fibers were rarely observed, as shown in Fig. 1(a). In this case, the C substrate was the anode of the arc discharge so that the result was consistent with the fact that the nanotubes were hardly formed on a pure C anode in a low-pressure arc⁽⁵⁾⁻⁽⁹⁾. For DC-cat, as shown in Fig. 1(b), abundant nanotubes were observed on the surface. The nanoparticles were comparably few and small metal particles were observed upon higher magnification.

On the other hand, for the AC mode, a considerable amount of nanotubes, was observed even on the C substrate, as shown in Fig. 1(c). In the AC mode, the substrate was alternated anode and cathode. Thus, the nanotubes were produced on the C substrate, similar to the reported formation of MWNTs on graphite by the