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Carbon nanotubes in cathodic vacuum arc discharge

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Abstract. Multiwall carbon nanotubes (MWCNTs) were fabricated by a new cathodic vacuum arc method, in which the anode itself was the vacuum chamber and was inert. The cathodic vacuum arc discharge was performed at 0.5 Pa of He and H_2 gas atmospheres using a dc arc current of 100 A. The cathode materials were pure graphite and various metal-containing graphite electrodes. Microscopic observation revealed that MWCNTs were produced at the cathode crater generated by the cathode spot and on the surface of macrodroplets emitted from the cathode spot. A diamond-like carbon film that embedded the macrodroplets with MWCNTs was also deposited.

1. Introduction

Carbon nanotubes are considered to be a promising candidate as a next-generation material for use in an electrical field emitter device having excellent performance [1, 2]. To date, a variety of carbon nanotube fabrication methods have been developed [3], including the comparatively simple carbon arc discharge method. In the conventional carbon arc method, a thermally pinched arc plasma is generated between two graphite (C) electrodes with a short gap under low pressure. In other words, this is a homoelectrode system arc. In this method, multiwall carbon nanotubes (MWCNTs) are obtained at the soft core in the cathode deposit. A MWCNT is normally defined as a carbon nanotube having a tubular structure of multiple graphitic layers, and is distinguishable from a single-wall carbon nanotube (SWCNT) that has only one, or perhaps a few graphitic tubular layers. Recently, the authors tested the arc using a heteroelectrode system, namely, C and molybdenum (Mo) electrodes, and MWCNTs were revealed to grow only at the C cathode spot area [4], indicating that the C anode is not necessary in order to synthesize MWCNTs via the carbon arc method. This finding also suggests that an anode-free arc plasma may produce nanotubes. Thus, the authors employed a cathodic vacuum arc, having an inert anode, and found that MWCNTs existed at the traces of the cathode spot [5].

In the present paper, MWCNTs at the cathode spot in the vacuum arc are examined, and then MWCNTs on macrodroplets and MWCNT-embedded diamond-like carbon film are demonstrated.

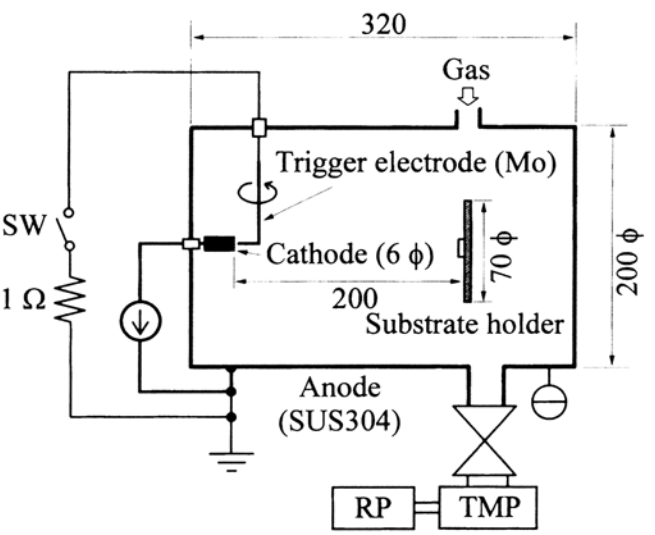

Figure 1. Schematic diagram of the cathodic vacuum arc apparatus. TMP is the turbomolecular pump and RP is the rotary pump.

2. Experimental details

The cathodic vacuum arc apparatus, which was originally designed for ceramic film deposition [6, 7], is depicted in figure 1. The cathode is located in a cylindrical stainless-steel vacuum chamber, which is the anode. The cathodic vacuum arc is a non-thermal plasma, but it has a hot cathode spot that provides the plasma source particles of electrons and ions. The plasma diffuses from the tiny cathode spot to the entire anode surface, and thus the anode becomes inactive and does not evaporate.

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