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Graphite cathode spot produces carbon nanotubes in arc discharge

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Abstract. A dc arc discharge was generated between graphite (C) and molybdenum (Mo) electrodes at 25 kPa of He gas ambient for a period of about 1 s in order to reveal the relation between nanotube growth and arc discharge phenomena. Numerous multiwall carbon nanotubes and nanocapsules were observed at the cathode spot area of the C-cathode. However, almost no nanotubes were observed at the C-anode, Mo-anode, and Mo-cathode. These results clearly indicated that the nanotubes were grown by the cathode spot of the C-cathode. Based on the results, a logical explanation of the growth of soft-core containing nanotubes and a hard-shell in the usual arc with a C-cathode and C-anode electrode system was presented.

1. Introduction

In 1991, Iijima discovered carbon nanotubes in the cathode deposit in a carbon arc discharge [1]. Nowadays, carbon nanotubes can be prepared using several other techniques, such as pyrolysis, laser ablation, and electrolysis, as summarized by Terrones *et al* [2], as well as by the sublimation method [3, 4]. It is important to precisely understand the phenomenon of nanotube growth in a carbon arc discharge not only from the viewpoint of the nanotube growth mechanism but also to gain a further understanding of arc physics, as arc technology has been widely employed in several industrial applications, such as electrical switchgears, arc welding, and arc deposition.

To date, several models of nanotube growth in the carbon arc method have been presented [5–11]. However, they have never taken into account macroscopic phenomena of thermal arc plasma such as the electrode spot, electrode jet, and material flow. The majority have been based on the assumption that the behaviour of the materials, which are evaporated from the anode, plays the key role.

In this study, in order to determine the true actual phenomenon behind nanotube growth in a carbon arc discharge, a dc arc discharge was generated between graphite and molybdenum electrodes by changing the electrical polarity. Electrode surfaces were observed with a scanning electron microscope (SEM; JEOL, JSM-6300) and a high-resolution scanning electron microscope (HR-SEM; Topcon, ABT-150F). A logical explanation, taking into account the

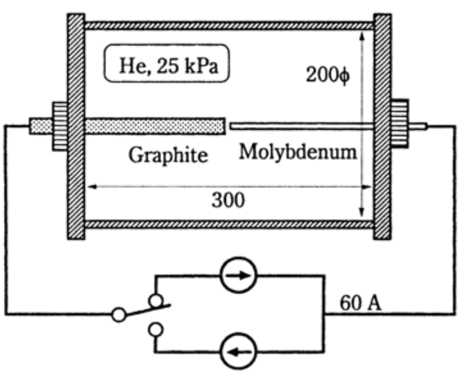

Figure 1. Arc discharge apparatus with a C–Mo heteroelectrode system, operated at an arc current of 50 A under 25 kPa of He gas ambient.

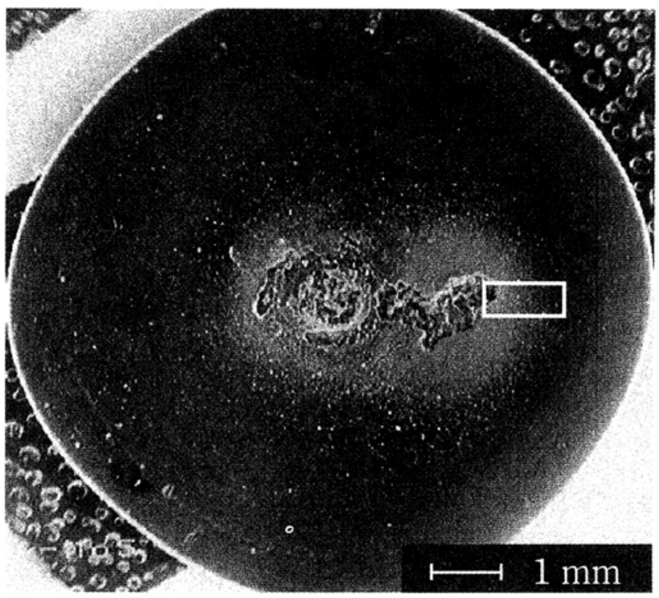

Figure 2. SEM image of the C-cathode surface (anode, Mo), showing cathode spot craters.