

# Silicon inclusion effect on fullerene formation under induction thermal plasma condition

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## Abstract

The radio frequency inductively coupled thermal plasma (RF-ICTP) was used to fabricate fullerenes ( $C_{60}$ ,  $C_{70}$  etc.) by direct evaporation of C or C-Si mixed powder by high enthalpy of the plasma. Spectroscopic observation of the plasma was made for molecular band spectra of  $C_2$  and atomic lines of C. The formation of fullerenes  $C_{60}$  and  $C_{70}$  as well as higher fullerenes was checked and recognized by TFMS (Time of Flight Mass Spectrometer). The results showed that Si mixing into C powder could increase the radiation intensity of  $C_2$  molecular as well as C atomic spectrums and decrease the plasma temperature, and showed a higher synthesis rate of fullerenes including higher order one, compared to pure C powder case. Discussions were made about the effects of  $O_2$  inclusion (from air leak) as well as Si injection on the concentrations of the C particle system (C,  $C_2$ ,  $C_3$ ,  $C_4$  etc.), and the influence of Si injection on the plasma temperature was also involved. © 2002 Elsevier Science B.V. All rights reserved.

**Keywords:** Inductively coupled thermal plasma; Fullerene synthesis; Silicon powder influence

## 1. Introduction

Since Kratschmer discovered the macroscopic properties of fullerene  $C_{60}$ , formed in a low-pressure carbon arc in 1990 [1], some experiments have been carrying out for the synthesis of fullerenes [2]. We have been trying to produce fullerenes by direct evaporation of pure C powder or C-Si mixed powder injected into the radio frequency inductively coupled thermal plasma [3]. In this paper, special attention was given on the effect of Si inclusion into C powder in the synthesis of fullerenes both experimental and theoretical viewpoint. Spectroscopic observation of the plasma was first made for molecular band spectra of  $C_2$  as well as for the C atomic lines which were emitted from induction thermal plasmas. This is because that  $C_2$ , C are the most basic units to form fullerenes. The experimental results of conventional arc discharge method also showed that the production rate of fullerenes is concerned with  $C_2$  spectral intensity [4]. The spectral intensities were compared between C and C-Si powder cases when consid-

ering the analysis data of the products by TFMS. Discussions were made about the effects of Si particle inclusion on the equilibrium compositions of C,  $C_2$ ,  $C_3$ ,  $C_4$  etc. and plasma temperature.

## 2. Experiments

### 2.1. Experimental set-up

Fig. 1 showed the induction plasma torch, which consists of a quartz tube with an inner diameter of 80 mm, a 3-turns coil and a 1.67 MHz oscillator with a maximal power up to 200 kW. Three kinds of gas flow were introduced into the plasma torch, these were the ‘sheath gas’ for protecting the quartz tube from hot plasma, the ‘center gas’ as main component of plasma medium and the ‘carrier gas’ to introduce solid or liquid materials into the plasma. The powder was fed into the plasma at a velocity of 5 g/min through the carrier gas. The plate power and the pressure inside the plasma were fixed at 30 kW and 150 torr, respectively, throughout the experiments. Typical experimental conditions were listed in Table 1, where condition #1 was the case for pure C powder, and condition #2 was that for mixed

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