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MICRO-SPHERES (15 μm - 240 μm) IN CARBON-ARC SOOT

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Abstract

Some physical characteristics of spheres contained in the soot of a high temperature carbon arc, are discussed.

Key words: Micro-spheres, carbon-arc soot.

1. Introduction

As a preliminary to setting up a laboratory demonstration of the Fullerenes C_{60} and $C_{70.}$ the soot produced in a projector arc lamp was examined. The arc lamp had a spark gap which could be manually adjusted or servo controlled and the provision for convenient insertion and removal of the carbon electrodes. It therefore possessed the basic set up for vapourising carbon and producing carbon soot as specified in the pioneering experiments[1] and discussed further by Huffman[2]. A jet for blowing Helium gas into the spark gap was inserted through the projector lens port after removing the lens.

Samples of carbon soot produced with an arc (10A), after it was left for a few days to soak in Benzene , was put on slides and examined through an optical microscope. Typical observations are given in Figs. (1, 2, 3). These consist of essentially opaque black or dark brown pieces (graphite) as background in which were interspersed a few crystalline mustard yellow, (C_{60}), wine red (C_{70}) and colourless pieces of various shapes and sizes. The most prominent among them were transluscent bead like spheres. It is these spheres that are discussed here.

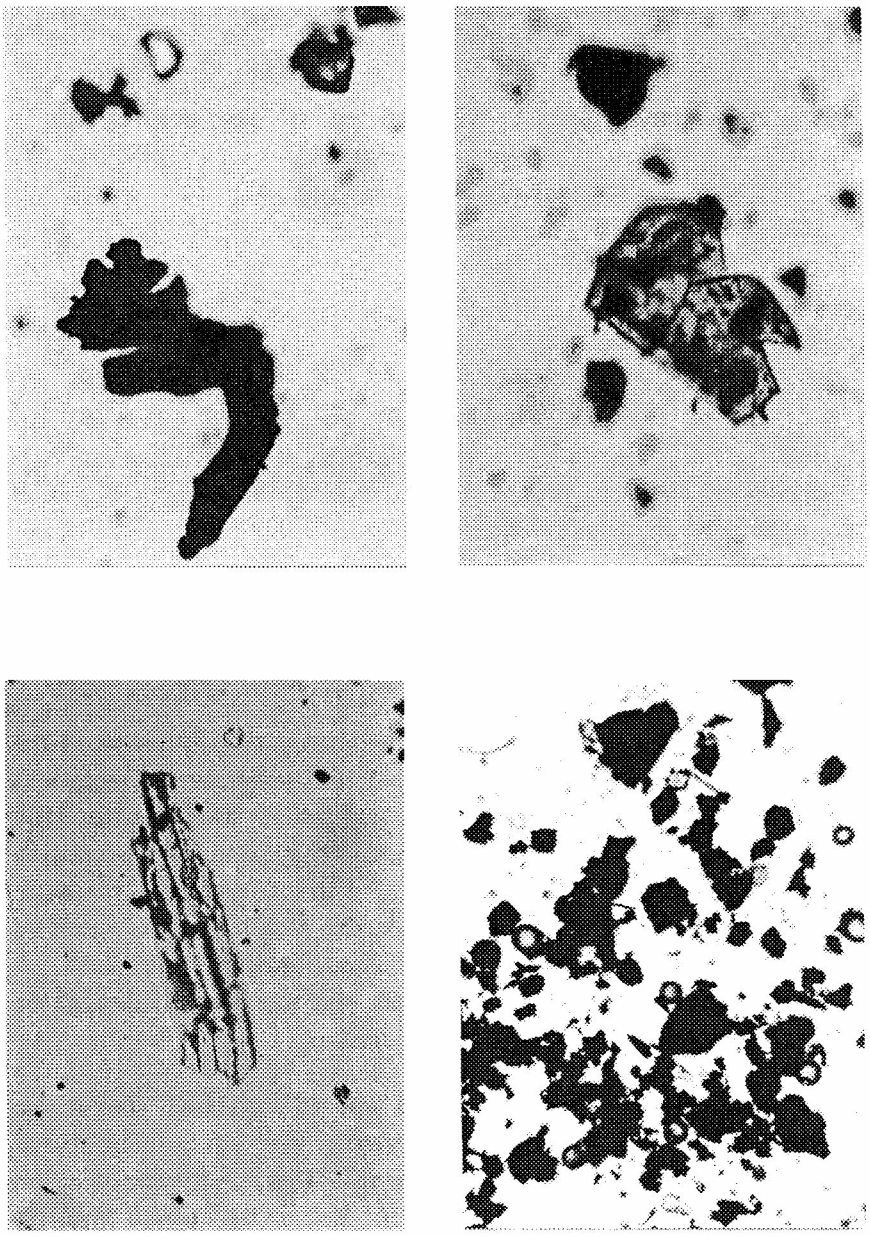

Fig. 1 Typical specimens a. C_{70} (wine red crystalline) b. C_{60} (mustard yellow crystalline) c. colourless crystalline d. spheres and graphite pieces.

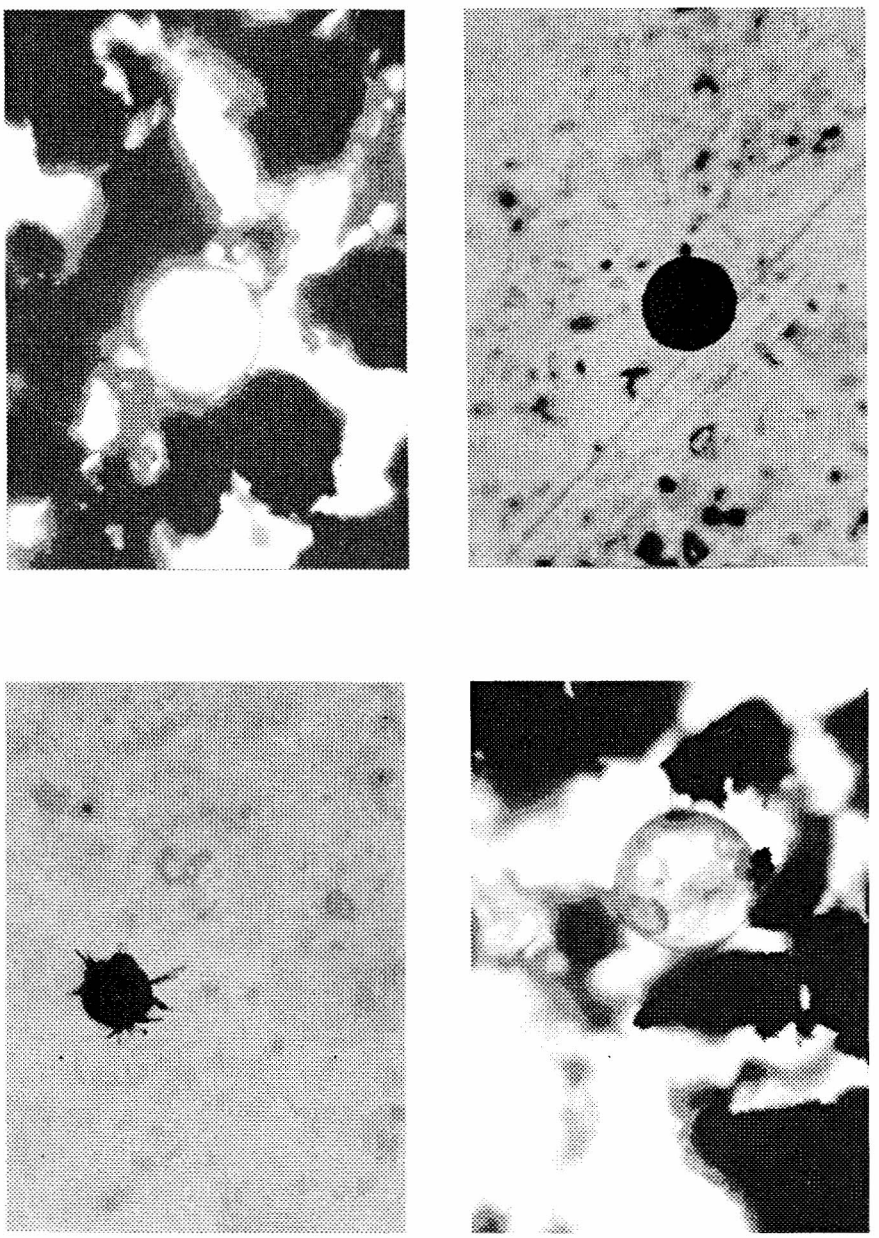

Fig 2, Typical spheres a. yellow b. black c. black with pins sticking out d. colourless

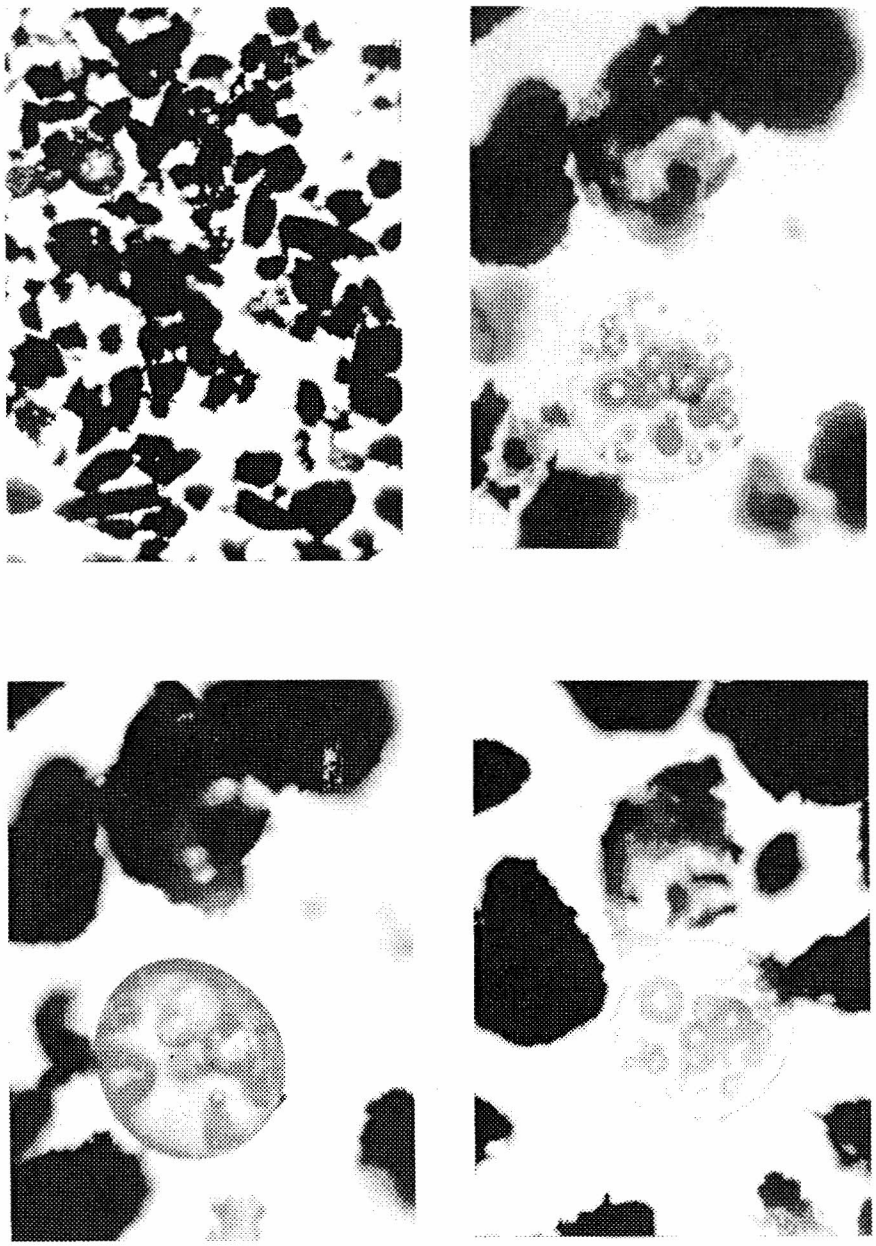

Fig 3. Large spheres immersed in Benzene a. low power view b, c, d high power view - clusters of small spheres, colourless

Conditions for sphere formation

It was observed that the formation of spheres is favoured when the arc is struck in air (Oxygen and Nitrogen) rather than in Helium. Helium seems to inhibit the production of spheres although it favours the formation of the wine red and mustard yellow crystals.

Sphere characteristics

The spheres produced were mostly transluscent and colourless with a yellowish tinge. Opaque spheres were formed at times. These were probably the transluscent ones which were covered by a graphite coating, since cracks in these often show up a transluscent core. A most interesting feature was observed for very large spheres viewed immersed in Benzene, when the outer surface is optically removed by matching the refractive index of the material of the spheres with that of Benzene. Here, clusters of small spheres are visible within the large sphere (Fig. 3). This also indicates that the spheres have a shell like outer surface, also evident in the electron micrograph (Fig 4).

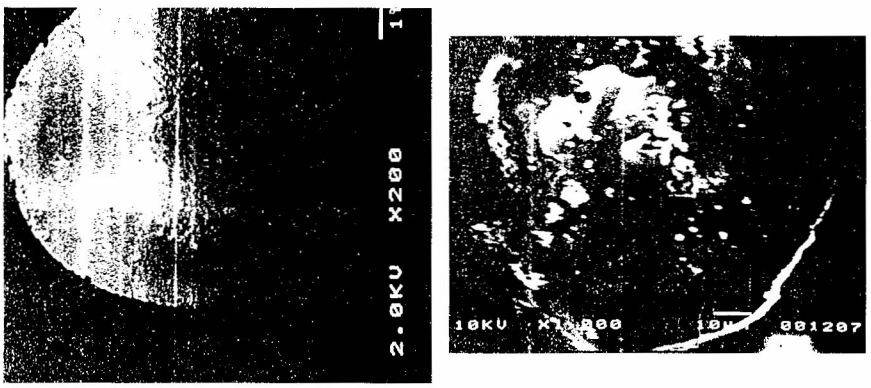

Fig 4. Electron micrograph a. large sphere (low power) b. broken sphere (higher power)

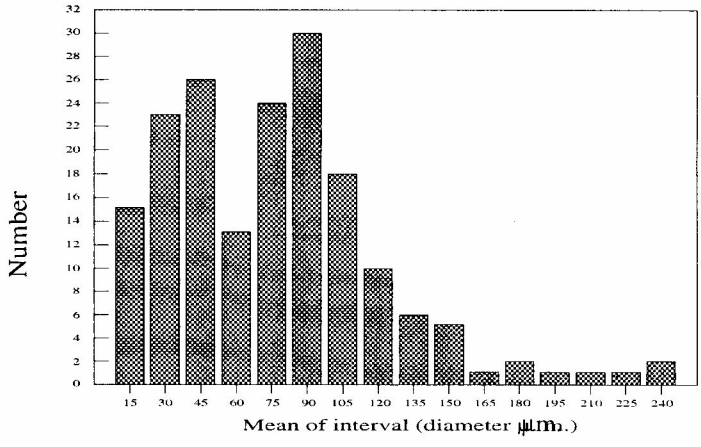

Fig. 5 Size Distribution of Spheres

Size distribution of spheres

The spheres produced in 18 separate 10 minute runs of the arc was a total of 180 spheres. The size of the spheres varied from 10 μm. to 240 μm. Spheres larger than 240 μm. were rare. In fact spheres of diameter > 120 μm. were only 10% of sample. The lower limit 15 μm. counts are naturally open to error as these spheres could get covered up by the background of the graphite particles and the number detected could be very much less than the actual figure. The size distribution obtained is given in the histogram of Fig. (5). The mean size of particles in the sample studied is 75 μm. with standard deviation of 40 μm.

Discussion

Experimental

Conclusive evidence for the spheres being carbon related and not due to impurities was achieved by producing the spheres in soots of different arc rods, such as graphite pencil cores and dry cell battery electrodes and particularly lumps of high purity graphite obtained directly from a local graphite mine (Bogala Graphite).

Theoretical

Graphite films subjected to intense electron beam irradiation in a high resolution electron microscope produce concentric graphitic shells which have been referred to as carbon onions[3,4] and are considered related to fullerences.[5]

The important part played by them as nanoscopic pressure cells in diamond formation from graphite has been demonstrated recently by Banhart and Ajayan[4] using a 1250 keV microscope to bombard a graphite film with electrons. The onion shells produced have dimensions of the order 20 nm. Ugarte[3] with a 300 keV HREM microscope had observed earlier, spherical graphite shells upto 47 nm and about 70 shells. An upper size of several μm in a few rare cases with prolonged irradiation were obtained by Ugarte. The larger spheres, Ugarte states, points to the route for obtaining macroscopic spheres of carbon.

The spheres observed in this paper are about a few thousand times larger than the nanospheres referred to above. Hence these spheres are conveniently observed visually in an optical microscope where the three dimensional features could also be seen.

The reason that we obtain larger spheres, perhaps, stems from the fact that the arc electrons are at energies only about 30 to 40 ev compared to the 300 kev.

A separate paper will examine theoretically[6] the sphere size relationship to bombarding energy of electrons.

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6. Paper to be submitted.