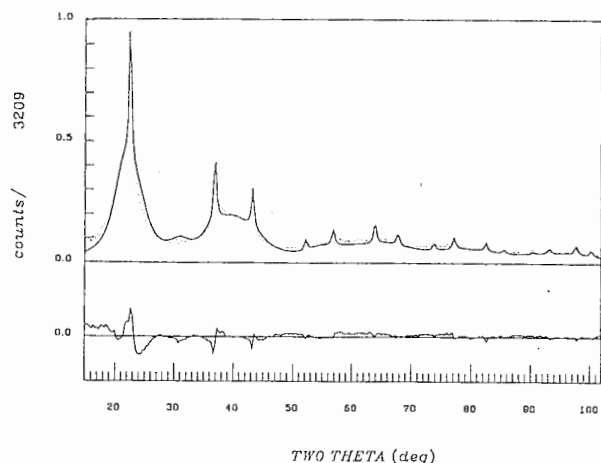


300 10-Physical and Chemical Properties of Materials in Relation to Structure (Superconductors, Fullerenes, etc)

In conclusion, fullerenes are stable when submitted to isotropic stress, but are squeezed by nonhydrostatic high pressures.  $C_{60}$  molecules contain a degree of  $sp^3$  as well as  $sp^2$  hybridization which could favor these different structural transformations and temperature is an important factor controlling the nature of the final phase.



MS-10.02.05 THE EXOHEDRAL CHEMISTRY OF FULLERENES, by R. M. Walton\*, School of Chemistry and Molecular Sciences, University of Sussex, Falmer, Brighton, BN1 9QJ, England, UK

Our knowledge of the factors affecting the exohedral chemical reactivity of  $C_{60}$  (Buckminsterfullerenes) and  $C_{70}$  in particular is slowly growing as the regioselectivity of additions to the cage begin to form a coherent picture. The current position will be reviewed in the context of recent results obtained at the University of Sussex.

PS-10.02.06 CRYSTALLOGRAPHIC COUNTING METHODS APPLIED TO FULLERENE CAGE ISOMERISM. J. S. Rutherford, Department of Chemistry, University of Transkei, South Africa.

The tessellation or lattice-projection method of generating fullerene structures considers the carbon cage to be formed from a graphite sheet by cutting, folding and gluing, during which process 12 hexagons are converted into the pentagons of the final cage. This approach provides a means to enumerate the cage isomers by symmetry, in what is essentially a counting of the corresponding two-dimensional derivative lattices.

This technique has already yielded the following results regarding possible cage isomers:

1. All fullerenes belong to infinite families,  $C_{nx}$ , with geometrically similar arrangements of the pentagons to that of a specific parent  $C_n$ , with  $x$  comprising the integral solutions of  $(h^2 + hk + k^2)$ .

2. The number of such solutions,  $N(x)$ , and their distribution by symmetry relative to that of the frame of pentagons, can be derived using Dirichlet generating functions.

3. The total number of cage stereoisomers of formula  $C_n$ , is roughly proportional to  $n^{10}$ .

PS-10.02.07

PREPARATION CONDITIONS OF CARBON NANOTUBES. By Yoshinori ANDO\*, Department of Physics, Meijo University, Tenpaku-ku, Nagoya 468, Japan, and Sumio IJIMA, Research and Development Group, NEC Corporation, 34 Miyukigaoka, Tsukuba, Ibaraki 305, Japan.

Carbon nanotubes are extremely thin filaments with helical tubular graphite structure (Iijima (1991). Nature **354**, 56, Ando and Iijima (1993). Jpn. J. Appl. Phys. **32**, L107) found in carbon deposits on the negative graphite electrode, formed during generation of fullerenes such as  $C_{60}$ . Recently, these nanotubes were used as moulds for the fabrication of metallic nanowires by capillary action (Ajayan and Iijima (1993). Nature **361**, 333). We report here on the preparation conditions of nanotubes in three kinds of atmospheres.

The evaporation of carbon has been carried out by dc arc discharge at about 220A between 10mm diameter graphite electrodes. He, Ar or  $CH_4$  at pressures of 10-200 Torr were used as the atmospheric gas, although it is known that fullerenes cannot be prepared in  $CH_4$ . The positive graphite electrode is consumed by evaporation. The evaporated carbon partially deposits on the negative electrode. This deposit was sectioned with a diamond saw and its surface was observed by high resolution SEM and TEM.

An example of SEM images obtained from the deposit produced by carbon evaporation in 50 Torr  $CH_4$  gas is shown in Fig. 1. A number of nanometer-size fibers and particles, called respectively "nanotubes" and "nanoparticles", are seen. The shape of nanoparticles is spherical, polyhedral or also elongated. Of course, the tubular structure of the fibers could be revealed only by high-resolution TEM.

The dependency on gas pressure is not very remarkable, but the proportion of carbon nanotubes in the deposit decreases with the decrease of gas pressure. Similar coexistence of nanotubes and nanoparticles could be found in deposits evaporated in atmospheres of He or Ar. On the other hand, fullerene formation is effective only in He gas environment, considerably reduced in Ar and absent in  $CH_4$ . The growth conditions of nanotubes and nanoparticles are therefore less restricted than those of fullerene.