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New advances in the creation of nanostructured materials*

N. Grobert, J. P. Hare, W.-K. Hsu, H. W. Kroto†, M. Terrones, D. R. M. Walton and Y. Q. Zhu

Fullerene Science Centre, University of Sussex, Brighton, BN1 9QJ, UK

Abstract: New advances have been made in the creation of nanostructured materials by pyrolytic and electrolytic methods. These experiments have shown that a wide range of nanostructures can be made using imaginative approaches.

ALIGNED NANOTUBES VIA PYROLYTIC ROUTES

Laser etching of thin cobalt films (Fig. 1) provides a novel route to catalysts which, in conjunction with the pyrolysis (Fig. 2) of organic precursors yield to partly aligned nanotubes of uniform length (<200 mm) and diameter (30–200 nm), and grow perpendicular to the catalytic substrate only over the etched regions (Fig. 3). The size and position of the catalytic particles play key roles in the self assembly reconstruction process. Interestingly, N-doped nanofibres can also be obtained. In this case melamine is used as a precursor.

ELECTROLYTIC FORMATION OF CARBON NANOTUBES

Using ionic salts as electrolyte and carbon as electrodes (Fig. 4) we have shown that carbon nanotubes can be formed (Fig. 5). The observed nanotubes can be many microns in length and ≈10 nm in diameter (Fig. 6). The wall structure varies depending on the electrolysis conditions and, in some cases it is well graphitised. In other cases the walls may be amorphous and the central cavity filled with metals. This has been observed when mixed electrolytes were used, (e.g. $LiCl/SnCl_2$ 99:1%).

SILICA NANOFLOWERS BY VAPOR-LIQUID-SOLID PROCESSES

Formation of novel radial flower-like silica structures [SiO_x ($x = 1$–2)/Co] have been created by pyrolysis of CO over a mixture of SiC and cobalt powders (Figs. 7–9).

Ni-ENCAPSULATED TAPERED NEEDLE-LIKE CARBON NANOTUBES

Thermolysis of a sandwich consisting of thin layers of successively deposited pure Ni and C (Fig. 10) yields novel needle-like carbon structures, resembling drawn-out capillaries, which are almost completely filled with Ni (Fig. 11). It is not clear how these novel structures are formed. The process appears to involve an axial growth, catalysed by Ni droplets, in which graphite is extruded, followed by thickening of the needle walls. In our experience, thermolysis of hydrocarbons or other organic precursors over catalysts (e.g. Ni, Fe, Co) rarely leads directly to such well-graphitised materials (Fig. 12). This probably due to the presence of hetero-atoms (e.g. H, N, etc.) during the creation of carbon networks. In this study the source is pure carbon. These results indicate that C_{60} holds considerable promise as a precursor for the creation of pure carbon nanostructures, particularly when metal catalysis is involved.

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†*Corresponding author:* E-mail: kroto@sussex.ac.uk

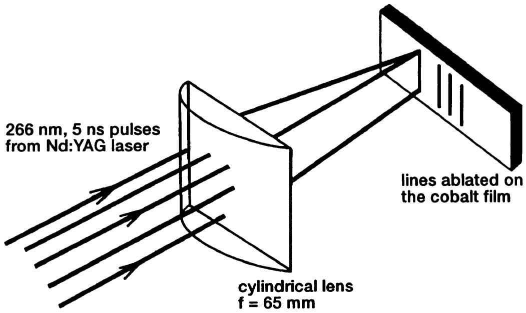

Fig. 1 Laser etching set-up.

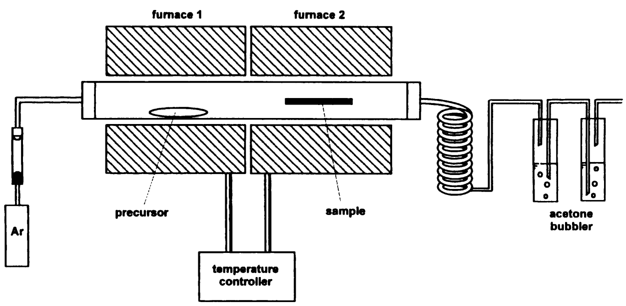

Fig. 2 Pyrolysis set-up.

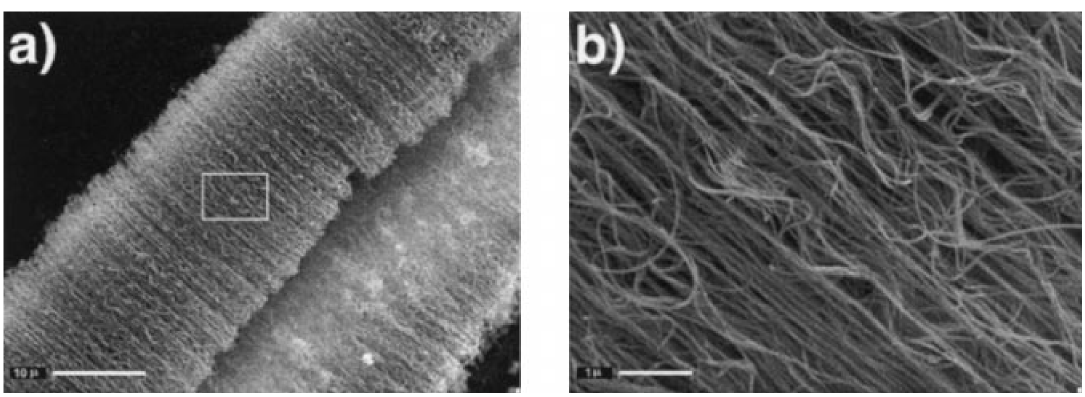

Fig. 3 (a) SEM images of aligned nanotube films grown on Co-etched substrates using amino-dichlorotriazine as the organic precursor. (b) Close-up of 3a.

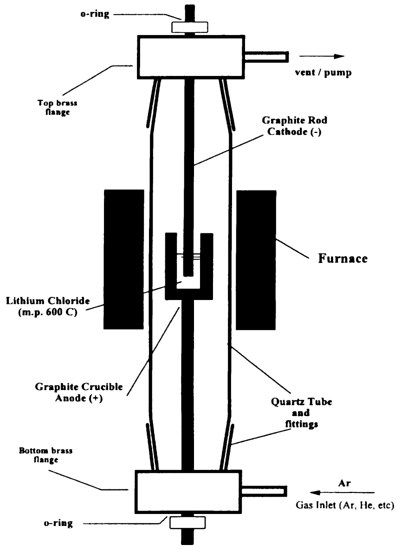

Fig. 4 Electrolysis set-up.

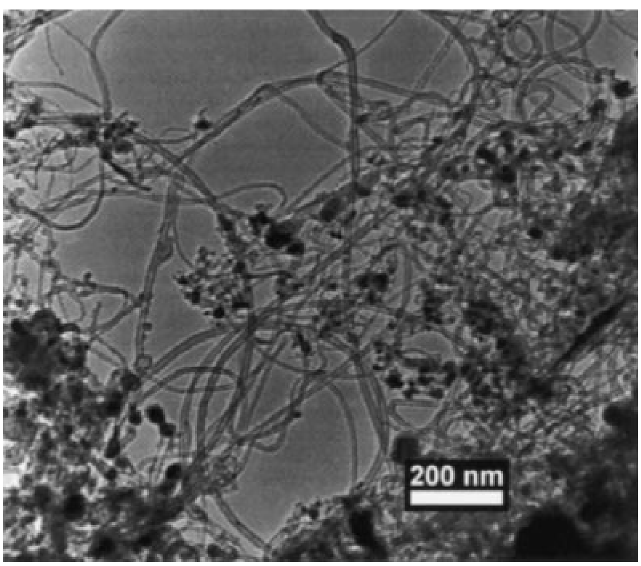

Fig. 5 Low resolution transmission electron micrograph of electrolytically produced carbon nanotubes.

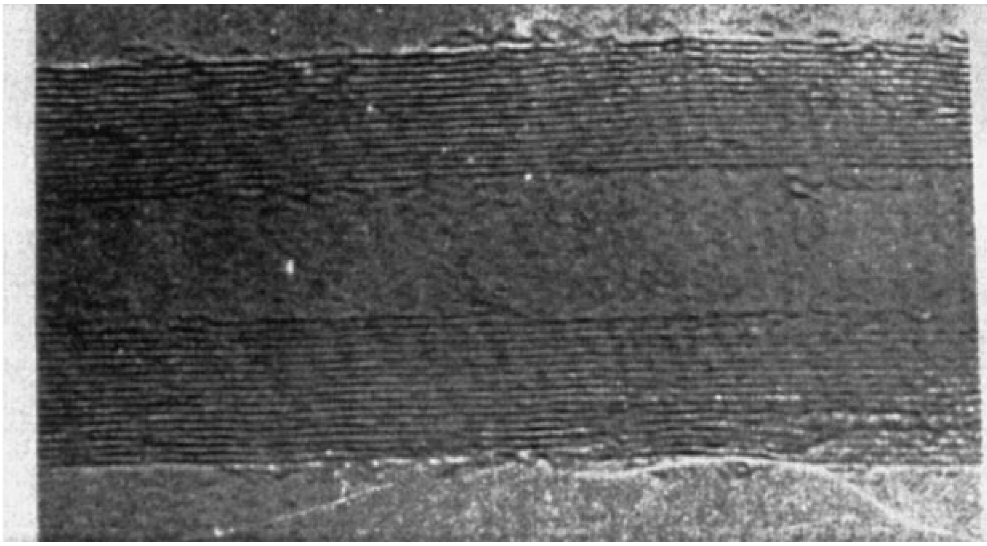

Fig. 6 High resolution transmission electron micrograph showing the degree of graphitisation of an electrolytically formed multi-walled carbon nanotube. The interlaying spacing of the graphene sheets is 0.34 nm.

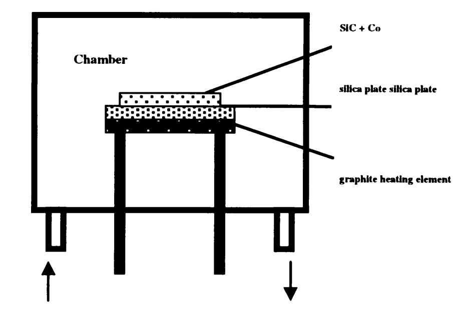

Fig. 7 Furnace assembly.

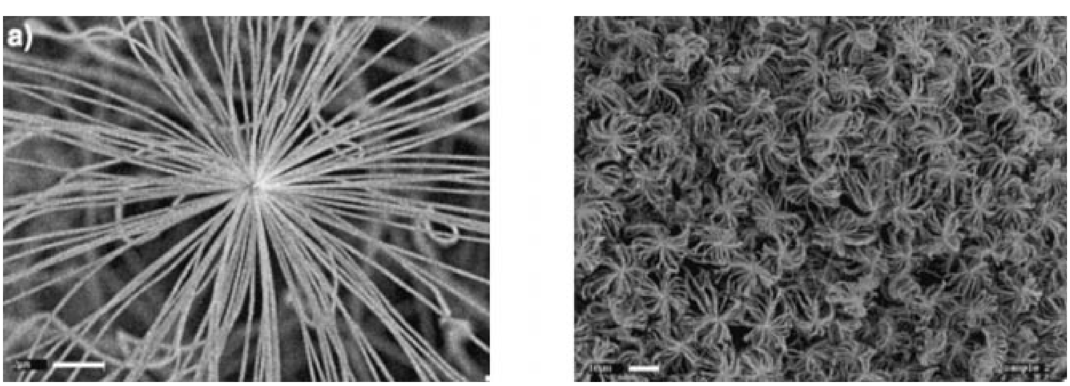

Fig. 8 (a) SEM image of a single silica nanoflower exhibiting radially attached fibres to a central sphere. (b) SEM image of a silica nanoflower film produced in the presence of CO.

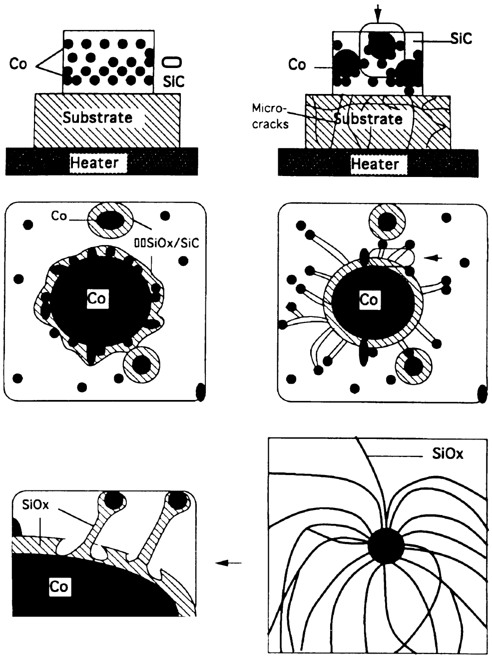

Fig. 9 Nanoflower growth model: (a) Heating assembly; (b) Fissured SiO_2 and agglomerated Co; (c) Spherical Co particles; (d) Initial growth stage; (e) Magnified nanotube growth; (f) Final stages of growth.

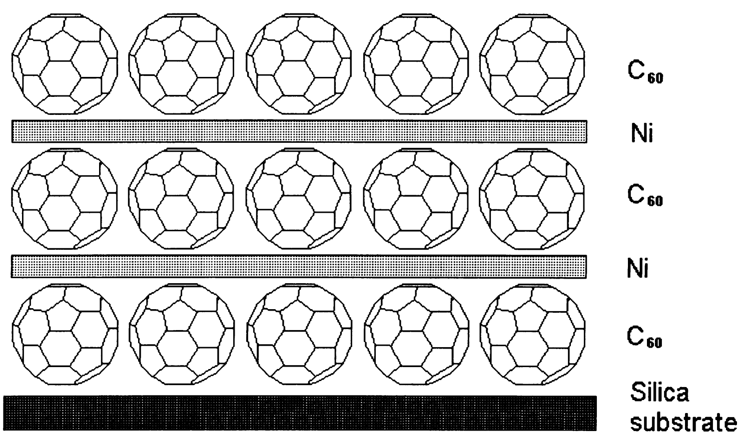

Fig. 10 Thin layers of successively deposited pure Ni and C_{60}.

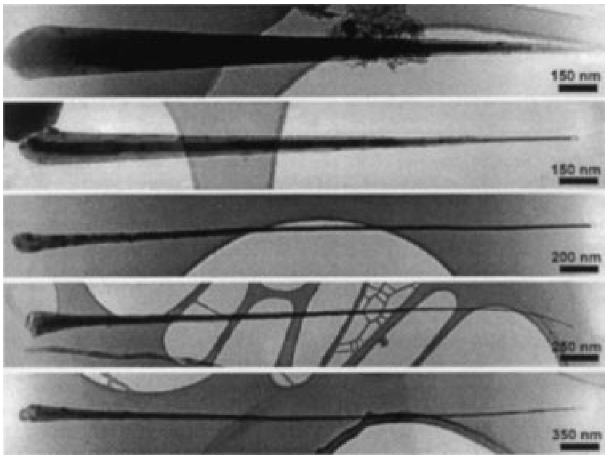

Fig. 11 TEM images of five representative needle-like structures which were almost completely filled with Ni.

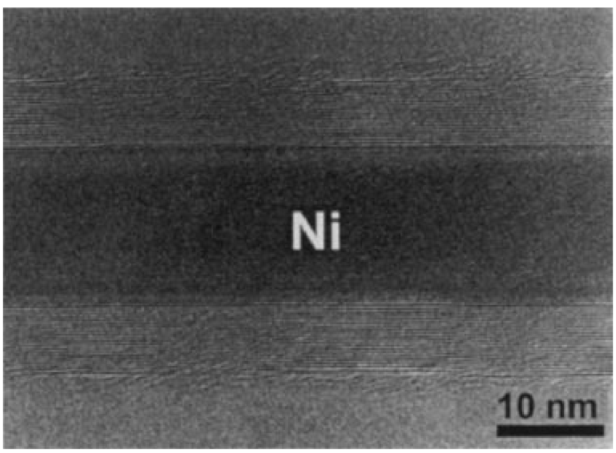

Fig. 12 HRTEM image of a highly graphitised Ni-filled carbon nanotube. The quality of graphitisation is unusual for pyrolytically grown materials.

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