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# Chemistry, Physics and Materials Science Studies of Fullerenes

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The Fullerenes were discovered in 1985 during experiments which simulated the chemistry which occurs in the shells of Red Giant Carbon Stars. With the breakthrough in Fullerene production in 1990, the Family has now come down to Earth bringing us a vast range of new compounds with fascinating chemical, physical and materials properties.

## 1 Introduction

$C_{60}$ Buckminsterfullerene (Fig 1) has become the starting

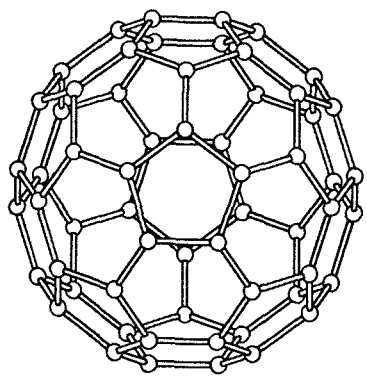


Fig 1 $C_{60}$

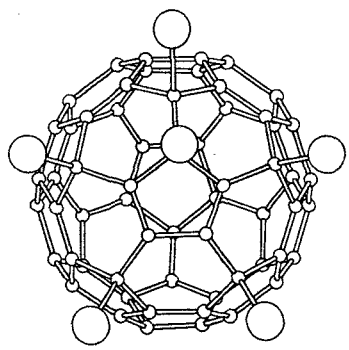
material for a whole range of new compounds and the chemistry, physics and materials science of these elegant molecule are now the focus of attention of numerous goups.

The first suggestion that $C_{60}$ might be stable is to be found in the studies of Osawa and Yoshida in 1970/71 and the discovery that the molecules, in particular $C_{60}$, could form spontaneously has its origins in research work at Sussex on the chemistry and spectroscopy of carbon chain molecules - the cyanopolyynes. These studies led to astrophysical programme (with Takeshi Oka and Canadian astronomers) which uncovered the existence of the carbon chains in interstellar space by Radioastronomy. This research programme then evolved even further into a Sussex-Rice collaboration to simulate, in the laboratory, plasmas similar to those which occur in red giant carbon stars. It was this joint Sussex-Rice carbon cluster programme which serendipitously uncovered the existence of $C_{60}$. Fullerenes were first extracted and characterised in 1990 by the Heidelberg/Tucson group of Krätschmer, Lamb, Fostiro-poulos and Huffman and shortly thereafter, independ-ently, at Sussex. Since then, fullerene science has exploded producing advanced materials with semi- and super-conducting, ferro-electric and opto-electronic and other exciting new properties.

The Sussex Program is now probing Fullerene Chemistry, Physics, Materials Science and Astrophysics:

**1. Fullerene Chemistry**

The Sussex Chemistry program has already been very successful, producing some of the first fully characterised analogues such as the halogenated materials: $C_{60}Br_n$ (n=6,8,24), $C_{60}Br_6$ and $C_{60}Cl_6$ (Fig 2) as well as the ferrocene complex $C_{60}(Cp)_2Fe$ (Fig 3) and a benzene solvate etc.



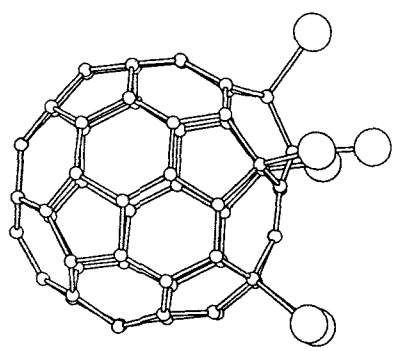


Fig 2 $C_{60}Cl_6$

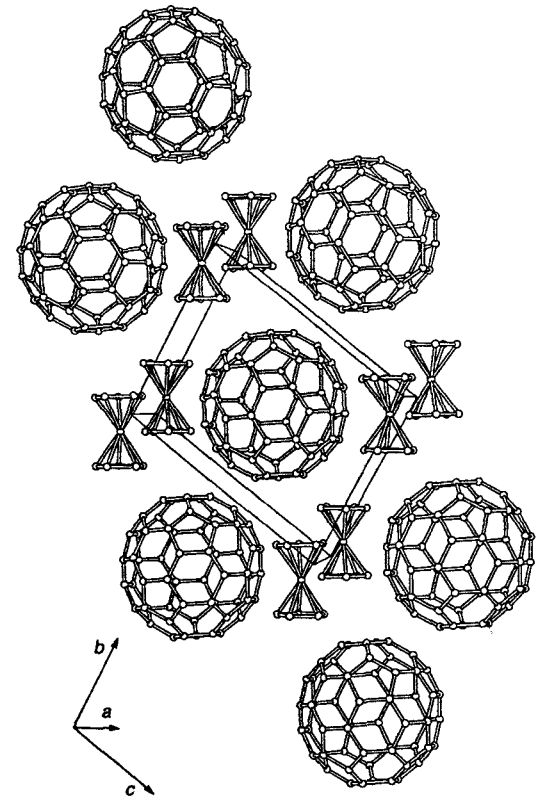



Fig 3 $C_{60}(Cp)_2$

Hydrogenated analogues and cycloaddition derivatives have also been prepared. Physical studies are being carried which have revealed fascinating information on the intra-molecular dynamics and detailed information on how the motion is affected by intermolecular interactions.

**2. Materials Science**

Nanoparticle and Nanofiber studies indicate that there is an intimate relationship between carbon chains, fullerenes and

graphite particles with fascinating implications for carbon fibers. For instance the nanotubes appear to be elongated giant fullerenes (Zeppelenes), Fig 4.

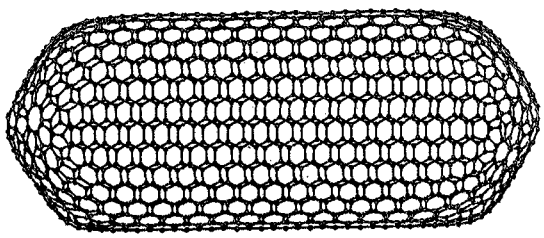


Figure 4. A nanotube

Studies of onion-like nested giant fullerenes and nanofibers are revealing unexpected structures. It is now clear that pyrolytic nanofibers can be produced which have highly exciting properties and from our work (with M Endo of Shinshu University) we are obtaining a better understanding of the mechanism of formation

**4. Cluster Beam Studies**

Supersonic Jet Cluster Beam studies show that sub-$C_{60}$ fullerenes: $C_{24}$, $C_{28}$, $C_{32}$ etc.. form during laser vaporization so confirming earlier Sussex work which predicted that fullerene-28 might form stable derivatives such as $C_{28}H_4$ (Fig 5). Some evidence for the smallest fullerene, $C_{20}$, has also been obtained.

**ACKNOWLEDGEMENTS**

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