Instant insight: Nano-forms of carbon

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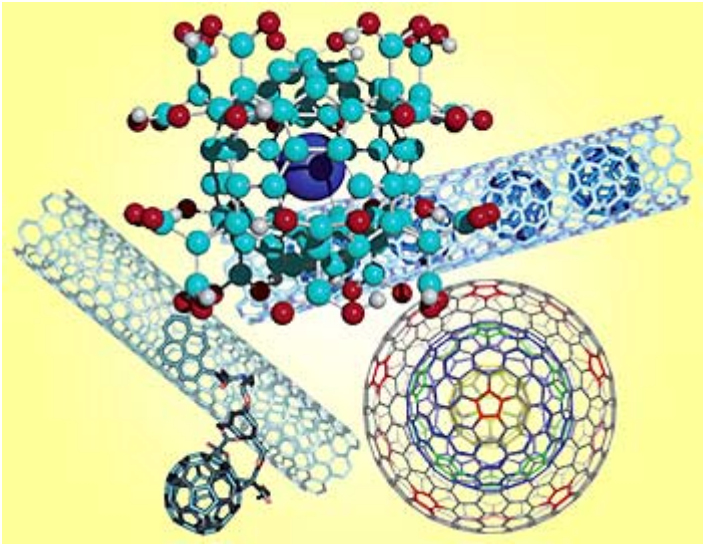
Juan Luis Delgado, María Ángeles Herranz and Nazario Martín at Complutense University of Madrid, Spain, explore the cutting-edge in nanostructures made from carbon

Carbon is a singular chemical element with a unique ability to join together forming a wide variety of fascinating molecules, ranging from a few carbon atoms to long complex chains. This ability has allowed the creation of numerous new materials and molecules of interest for a very diverse range of applications.

The discovery over two decades ago that carbon can form stable and ordered structures other than graphite and diamond, stimulated researchers all over the world to search for other allotropes – structural forms – of carbon. The discovery of fullerenes in 1985 was followed by another key finding in 1990: the multigram production of C60 using a simple arc-evaporation apparatus that is readily available in most labs. The following year using a similar evaporator, Sumio Iijima discovered fullerene-related multiwalled carbon nanotubes (MWNTs). This was followed two years later by tubes containing only one graphitic sheet, known as single-walled carbon nanotubes. These are made by doping one of the electrodes used to produce MWNTs with metals such as Fe or Co.



Different nanoforms of carbon

Also in the early 1990s, new types of structures started to be made that consist of carbon spheres of increasing diameters layered on top of each other, akin to the wooden Russian dolls. Due to their layered design these were coined nano-onions. The nano-onions were only the tip of the iceberg, with a wide variety of new carbon nanostructures such as endohedral fullerenes, cup-stacked nanotubes, nanohorns, nanotori, nanobuds and graphenes now emerging as new and fascinating forms of carbon whose chemical and physical properties are currently being unravelled.

Of particular interest are endohedral fullerenes – carbon cages that encapsulate atoms or molecules in their inner space. Made using the so called 'molecular surgery' approach - the

fullerene cage opens in a controlled way, allowing atoms or small molecules to enter, and then closes to reform the pristine fullerene structure. Alternatively, the interesting family of trimetallic nitride templated endohedrals are obtained directly with relatively high yields, by varying the composition of the cooling gas atmosphere in the arc-burning process used in the production of fullerenes. They have an inner metal cluster that can stabilise a large variety of carbon cages that can not exist otherwise.

Graphenes – materials that are single atomic flat layers of carbon atoms - were considered one of the biggest breakthroughs in 2007. This carbon form was found to be a useful sensor able to detect a single molecule of gas.

"NASA researchers have resparked interest in the original carbon nano-onions, considering them as potential additives for aerospace applications." NASA researchers have resparked interest in the original carbon nano-onions, considering them as potential additives for aerospace applications. The nano-onions have demonstrated superior lubrication properties to other conventional lubricants, and we foresee a very promising future for these and other new and still unexplored forms of carbon.

Although the scientific community are not yet entirely satisfied with all the expectations and excitement that emerged from the initial discovery of fullerenes and carbon nanotubes, the spectacular properties that these species reveal day by day will make them play an essential role in the future.

Read Nazario Martín et al's feature article 'The nano-forms of carbon' in issue 13, 2008 of Journal of Materials Chemistry

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