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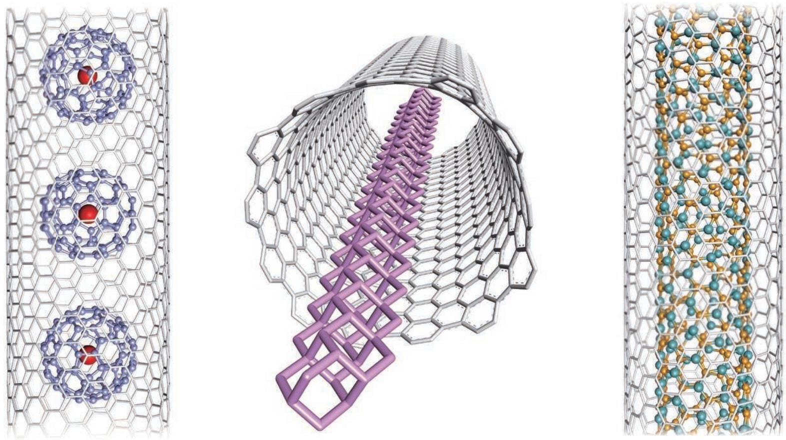
Family of nanopeapods



Metallofullerene   Diamond nanowire   Boron-nitride nanotube

Designed by Yusuke NAKANISHI

PERFECTING PEAPODS

Nagoya University's Shinohara laboratory is **SPEARHEADING RESEARCH** into the tiny 'nanopeapods' made by encapsulating materials in carbon nanotubes

Not all peapods are green. With advances in nanoscience, some peapods are tiny, black and contain peas made of diamond.

The Shinohara research laboratory at Nagoya University is exploring a brand-new class of hybrid carbon nanotube material known as 'nanopeapods' or simply 'peapods'. Chemically and mechanically robust, carbon nanotubes are flexible tube-shaped materials that are electronically and thermally well-conductive and environmentally friendly, with typical diameters of 1–10 nm.

'Peapods' are made up of atoms, molecules, or nanowires of various kinds encapsulated in the internal hollow spaces of carbon nanotubes. These are of great interest since the inner space of carbon nanotubes is very special in terms of its inherent one-dimensionality and small diameter. Interestingly, many different types of atoms and molecules have so far been encapsulated inside carbon nanotubes whenever their diameters and the 'encapsulates' fit properly with each other.

When atoms, molecules or nanowires are encapsulated in carbon nanotubes, properties of the carbon nanotubes often vary due to the electronic interaction generated between carbon nanotubes and their encapsulates. For example, when metallofullerenes (fullerenes with metal inside) are doped into single-walled carbon nanotubes, a substantial electron transfer occurs from the metallofullerenes to these carbon nanotubes, resulting in the emergence of a unique phenomenon called the 'band-gap modulation' of single-walled carbon nanotubes. When this occurs, the band gaps are not uniform along the single-walled carbon nanotube axis direction compared to conventional single-walled carbon nanotubes.

The inner hollow spaces of single- or double-walled carbon nanotubes can also be regarded as 'nano test tubes' for fabrication of one-dimensional nanomaterials, which are not available when using conventional bulk synthesis. One of the best examples is the synthesis of 'diamond nanowires' in carbon nanotubes.

'PEAPODS' ARE MADE UP OF ATOMS, MOLECULES, OR NANOWIRES ENCAPSULATED IN THE INTERNAL HOLLOW SPACES OF CARBON NANOTUBES

High temperature annealing of double-walled carbon nanotube peapods encapsulating a diamantane molecule ($C_{14}H_{20}$) at 870K induces the formation of so-called diamond nanowires in double-walled carbon nanotubes, in which all carbon atoms in the nanowires possess strong sp^3 bonds, as in the bulk diamond. Furthermore, single-walled boron-nitride (BN) nanotubes, which have not yet been synthesized in bulk, can easily be obtained in high yield in single-walled carbon nanotubes when ammonia-borane (NH_3BH_3) peapods are treated at high temperatures of 1,670K.

Nagoya University intends to keep at the forefront of nanopeapod research and continue exploring the inner space of carbon nanotubes and nano test tubes, an area which will be sure to tantalize physicists, chemists and material scientists for years to come. ■

NAGOYA UNIVERSITY

SHINOHARA GROUP

Professor Nori Shinohara,
Department of Chemistry,
Nagoya University.
noris@nagoya-u.jp