

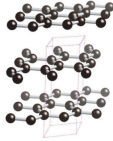
NBICS Technologies

Alexander Aksentyev

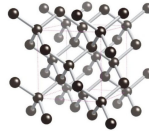
National Research Institute "MEPhI"

Carbon allotropes

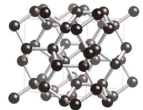
Allotropy is the property of some chemical elements to exist in several different geometries (known as *allotropes*) in the same physical phase.



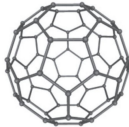
graphite



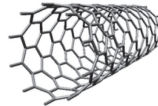
diamond



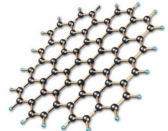
BC8



fullerene



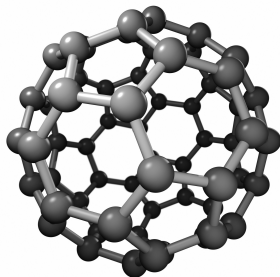
nanotube



graphene

The Buckyball

- ▶ The Buckminsterfullerene (named after inventor Richard Buckminster Fuller) was one of the first nanoparticles to be discovered (1985)
- ▶ Number of atoms: 20 to over 100; the most common type (C₆₀) contains 60 carbon atoms
- ▶ Modifying a buckyball by adding or replacing an atom in order to change the properties of the buckyball is called **functionalization**

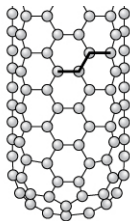


Uses

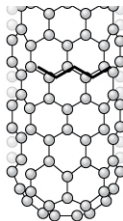
- ▶ **Armor.** Hard as diamonds, buckyballs are potentially useful within armor
- ▶ **Medicine.** Functionalized buckyballs can be made soluble by body cells, and hence find the following medical applications:
 - ▶ As antioxidants, because of their ability to absorb electrons in free radicals
 - ▶ In targeted drug delivery. The buckyball encases a minute dose of a particular drug. By controlling the functionalization of the buckyball the drug remains encased until the buckyball reaches the site where the drug is required. The buckyball then releases it
- ▶ **Fiber optics.** Because of their perfect spherical shape, buckyballs are able to transmit light

The nanotube

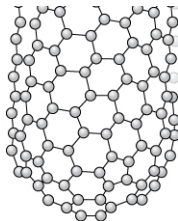
- ▶ Diameter < 1 nm
- ▶ A few nano- up to a millimeter in length
- ▶ Symmetry: armchair, zig-zag, chiral
- ▶ Single/multiple wall CNTs
- ▶ Compared to steel:
 - ▶ $100 \times$ more difficult to tear apart
 - ▶ $5 \times$ as elastic
 - ▶ a quarter density
- ▶ High thermal conductivity
- ▶ Metallic/semi-conductive contingent on symmetry



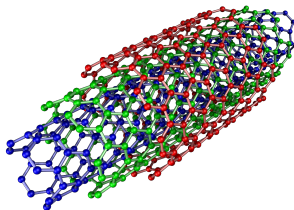
Armchair



Zigzag



Chiral



Uses

1. **Medicine:** functionalization, as well as their natural fluorescence, enable the use of CNTs as chemical sensors; they have also been shown to fuse well with bone, which could be used to diminish the implant rejection rate
2. **Conductive plastics:** CNTs are the best known conductive fillers because of their high aspect ratio
3. **Energy storage:** good battery electrodes due to high surface area ($\sim 1000 \text{ m}^2/\text{g}$), good electrical conductivity, and linear geometry; the high surface area and thermal conductivity also make them useful as electrode catalysts in fuel cells
4. **Molecular electronics:** their geometry, electrical conductivity, and the ability to be precisely derived, make CNTs invaluable connectors between switches at the nanoscale; their properties as semiconductors also make them usable as switches themselves

The nanobud

A nanobud is a nanotube with a fullerene ball attached to it.

