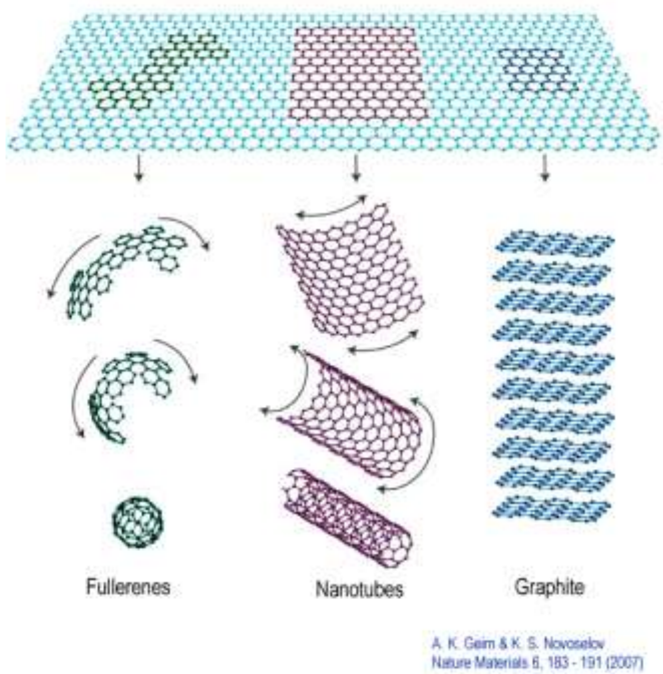
# Novel materials of carbon

Graphite and diamond are the two well known allotropic forms of carbon, with markedly different physical properties. Diamond is a large-gap semiconductor, due to the $sp^3$ bonding scheme of carbon atoms in the crystal structure. Graphite consists of parallel *graphene* sheets, each consisting of a two dimensional (2D) $sp^2$ bonded honeycomb lattice of carbon atoms. A single graphene sheet was long predicted to be a zero-gap semiconductor, but the interlayer interactions turn graphite into a semi-metal. The discovery of a new solid phase of carbon, solid $C_{60}$, in 1990 had opened the way to an entire new class of materials. As a byproduct of fullerene research, *carbon nanotubes* were later identified, from which novel nanostructures originated. The invention of an efficient materials production method has facilitated the study of understanding the fundamental properties of these novel forms of carbon. The typical end products of vaporization of graphite include a range of stable *fullerenes* ($C_{60}$, $C_{70}$, and up), *single* and *multi-walled carbon nanotubes*, which are the subject of intensive research due to their fascinating physical properties and their potential integration in future technology, the most challenging applications currently pursued being nanoelectronics and nanotechnology. The field was delivered a further jolt in 2004, when Geim and co-workers at Manchester University first isolated single-layer graphene samples from graphite, whose extended honeycomb network is the basic building block of important carbon allotropes; it can be stacked to form 3D graphite, rolled to form 1D nanotubes, and wrapped to form 0D fullerenes. Long-range $\pi$-conjugation in graphene yields extraordinary thermal, mechanical, and electrical properties, which have been long the subject of many theoretical studies but only after the isolation of graphene layers became an amazing area for experimental research and development. The Nobel Prize in Physics 2010 was awarded jointly to Andre Geim and Konstantin Novoselov *"for ground breaking experiments regarding the two-dimensional material graphene*", which has been one of the most important events in condensed matter physics over the last years.




Our current research is focused on the superconducting, metallic and insulated states of these novel nanostructured materials, mostly fullerenes, carbon nanotubes and graphene.
*Fullerides* belong to the research area of strongly correlated electron systems and their electronic, magnetic and crystal structures allow them to display novel aspects of contemporary condensed matter physics. The insulating molecular fullerene solid becomes superconducting upon addition of 3 alkali ions per molecule ($M_3C_{60}$). Fullerene solids display quasi-one-dimensional polymeric $C_{60}$ structures formed by alkali fullerides $MC_{60}$ (M=K, Rb, Cs), which exhibit a metal-insulator transition at low temperatures.
*Carbon nanotubes* can be envisioned as single hexagonal graphite layers rolled into long, seamless cylinders a few nanometers in diameter and many microns long. The allowed electron wave functions are no longer those of an infinite two-dimensional system. The rolling operation imposes periodic boundary conditions for propagation around the circumference, which have different consequences on the band structure for different symmetries. As a consequence, carbon nanotubes can be metallic or insulating, the bandgaps in the latter ranging from a few meV to about one eV.

## Recent publications

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