Graphene and graphene oxide

Graphene was discovered in 2004 by a group of researchers led by Andre Geim and Konstantin Novoselov at the University of Manchester. This is a two-dimensional material where carbon atoms are arranged in a hexagonal structure like honeycomb. Graphene has a thickness of only one monolayer (~ 0.34 nanometre) and is chemically stable under normal conditions in air.

Many graphene layers arranged on top of each other according to a certain pattern create a crystal of graphite. Scientists used graphene as a model for the calculation and determination of the properties of graphite for decades. But no one foresaw that the layer a single atom thick was also really stable. Therefore, mere discovery of graphene has attracted considerable acclaim in the scientific community. The curious way the first samples were prepared also contributed to that. It was a mechanical method of exfoliation of layers of a graphite crystal. And for that, a scotch tape, substrate and a lot of patience was enough.

Currently, chemical vapour deposition is one of the most widely used method for preparation of graphene. A gas which contains carbon (e.g. methane) is to decompose at high temperatures in contact with certain metals which act as a catalyst (e.g. copper). Free carbon atoms are arranged on the surface of the metal to the hexagonal graphene lattice. After copper is dissolved, a graphene layer can be transferred to any substrate as desired. Many "exotic" physical phenomena have been observed in graphene such as Klein's paradox, existence of massless particles with high mobility, quantum Hall effect at room temperature and others.

Studies of electrical transport characteristics of graphene have revealed its great potential for electronics. Operating frequency of transistors made of graphene in the gigahertz region can overcome the speed of most modern computers in the near future. Important applications of graphene are foreseen for chemical sensors that use extremely sensitive changes in conductivity when exposed to various chemical adsorbants. The unique combination of high optical transparency and a large conductivity of graphene layers can be used in a wide range of optoelectronic components such as displays or solar cells.

Another way to prepare graphene is chemical oxidation of graphite powders. Molecules containing oxygen intercalate the graphite layers and bind chemically to them. This process causes the inter-layer distance to increase to the point when a layer is exfoliated from the parent crystal. It is actually a chemical analogue of the original method of mechanical exfoliation. This way, monoatomic layers with lateral dimensions of the order of hundreds of nanometres to micrometres are obtained. The layers are strongly oxidized, so in this case we are talking about graphene oxide.

An interesting feature of graphene oxide (GO) is that the level of its oxidation can be varied by reducing the concentration of oxygen molecules either chemically or by thermal annealing. Changing the concentration of oxide has a significant impact on the electrical transport properties of reduced GO (rGO). In terms of electrical conductivity, fully oxidized graphene behaves as an insulator. The reduction increases the conductivity in many orders of magnitude, and completely reduced GO has properties similar to those of graphene.

The combination of a porous structure (high surface area) and a relatively high conductivity of rGO implies the use of this material for some applications. Electrodes made of rGO in supercapacitors is one of such examples.