Low-cost and defect-free graphene

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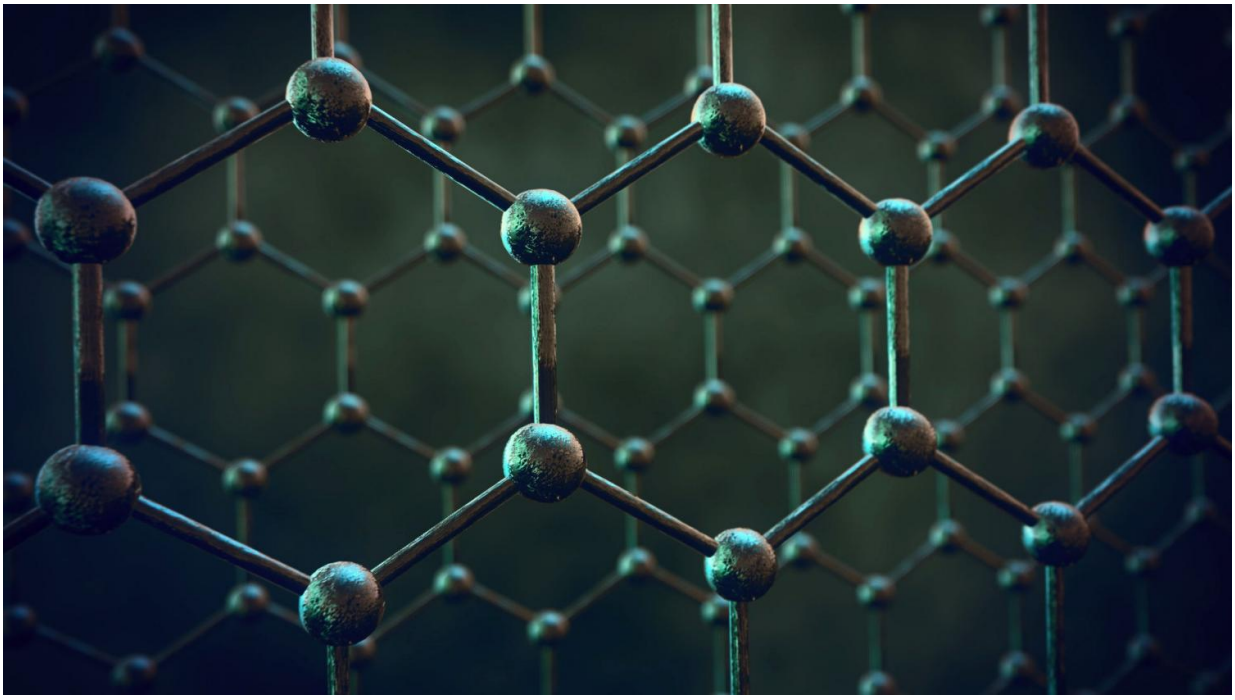

This visualisation shows layers of graphene used for membranes. Credit: University of Manchester

Graphene is one of the most promising new materials. However, researchers across the globe are still looking for a way to produce defect-free graphene at low costs. Chemists at Friedrich-Alexander-Universiät Erlangen-Nürnberg (FAU) have now succeeded in producing defect-free graphene directly from graphite for the first time. They recently published their findings in the journal *Nature Communications*.

Graphene is two dimensional and consists of a single layer of carbon atoms. It is particularly good at conducting electricity and heat, transparent and flexible yet strong. Graphene's unique properties make it suitable for use in a wide range of pioneering technologies, such as in transparent electrodes for flexible displays.

However, the semi-conductor industry will only be able to use graphene successfully once properties such as the size, area and number of defects - which influence its conductivity - can be improved during synthesis. A team of FAU researchers led by Dr. Andreas Hirsch from the Chair of Organic Chemistry II has recently made a crucial break-through in this area. With the help of the additive benzonitrile, they have found a way of producing defect-free graphene directly from a solution. Their method enables the graphene - which is of a higher quality than ever achieved before - to be cut without causing defects and also allows specific electronic properties to be set through the number of charge carriers. Furthermore, their technique is both low-cost and efficient.

A common way of synthesising graphene is through chemical exfoliation of graphite. In this process, metal ions are embedded in graphite, which is made of carbon, resulting in what is known as an intercalation compound. The individual layers of carbon - the graphene - are separated using solvents. The stabilised graphene then has to be separated from the solvent and reoxidised. However, defects in the individual layers of carbon, such as hydration and oxidation of carbon atoms in the lattice, can occur during this process. FAU researchers have now found a solution to this problem. By adding the solvent benzonitrile, the graphene can be removed without any additional functional groups forming - and it remains defect-free.

'This discovery is a break-through for experts in the international field of reductive graphene synthesis,' Professor Hirsch explains. 'Based on this discovery we can expect to see major advancements in terms of the

applications of this type of graphene which is produced using wet chemical exfoliation. An example could be cutting defect-free graphene for semi-conductor or sensor technology.'

Additional benefits

The method devised by FAU researchers has another advantage: the reduced benzonitrile molecule formed during the reaction turns red as long as it does not come into contact with oxygen or water. This change in colour allows the number of charge carriers in the system to be determined easily through absorption measurements. This could previously only be done by measuring voltage and means that graphene and battery researchers now have a new way of measuring the charge state.

More information: Philipp Vecera et al, Solvent-driven electron trapping and mass transport in reduced graphites to access perfect graphene, *Nature Communications* (2016). DOI: 10.1038/ncomms12411

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