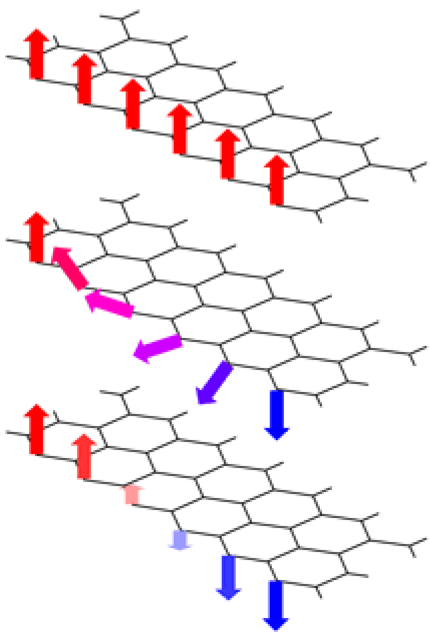
Graphene holds promise for spintronics



Electron spins have been predicted to align along the so-called zigzag edges of graphene (top). In reality, this perfect order is strongly affected by thermal excitations, thus imposing strict limitations on graphene-based spintronic devices. Researchers study theoretically the general types of spin disorder (middle and bottom) in order establish these limitations. Image credit: Oleg V. Yazyev, EPFL.

Graphene is a nanomaterial combining very simple atomic structure with intriguingly complex and largely unexplored physics. Since its first isolation about four years ago researchers suggested a large number of applications for this material in anticipation of future technological revolutions. In particular, graphene is considered as a potential candidate for replacing silicon in future electronic devices. Theoretical physicists from the Swiss Federal Institute of Technology in Lausanne (EPFL) and Radboud University of Nijmegen (The Netherlands) performed a virtual crash-test of graphene as a material for future spintronic devices, possible components of future computers. The material successfully passed the test, although, with some reservations. The results have been published in the February 1, 2008, issue of *Physical Review Letters*.

Current technology uses the charge of electrons to operate information in electronic devices. As an alternative, one can use intrinsic spin of electrons for this purpose. Electronic devices making use of electron spin are now called spintronic devices. Several types of such devices have already found their market-place in high-capacity hard drives and in recently introduced non-volatile magnetic random access memory (MRAM). Further replacement of charge-based devices by the spintronic components promises faster computers consuming less energy.

While spintronics requires magnetic materials, graphene is non-magnetic itself. However, when a single graphene layer is cut properly, e.g. using lithographic techniques widely used in the current semiconductor technology, electron spins are theoretically predicted to align at the edges of graphene. This amazing property of graphene has attracted considerable attention giving rise to new designs of spintronic devices proposed by theoretical researchers.

However, there is a gap between the theoretical models and the real prototypes of such devices. The problem lies in the fact that such edge spins form a truly one-dimensional system. It is known that one-dimensional systems are very sensitive thermal disorder destroying the perfect arrangement of spins. Strictly speaking, a one-dimensional magnet cannot maintain the perfect alignment of magnetic moments at any temperature above absolute zero. Such entropy-driven behavior is in sharp contrast to bulk materials (such as iron) which are able to keep the perfect order of electron spins below certain temperature (Curie temperature). This allows using such materials as permanent magnets, important constituents of modern technology. At graphene edges the order on spins can exist only within a certain range which, in effect, limits the dimensions of spintronic devices.

Researchers from Switzerland and Netherlands performed computer-time-demanding first principles calculations in order establish the range of magnetic order at graphene edges. At room temperature, this range, the spin correlation length, was found to be around 1 nanometer which limits device dimensions to several nanometers. This result may first look rather disappointing since it is about one order of magnitude below the length scales of the present-day semiconductor manufacturing processes. Nevertheless, graphene performs better than any other material when it comes to one-dimension and room temperature. In other words, graphene is the best on the nanoscale.

"We are very optimistic about these results", says Oleg Yazyev, postdoctoral researcher at the Swiss Federal Institute of Technology. "One can now devise different ways of increasing the spin correlation length at graphene edges. For instance, we are now looking for an appropriate chemical modification of graphene edges in order to further extend the length-scale limits. This is only beginning of an interesting direction of research".

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[web-link: http://link.aps.org/abstract/PRL/v100/e047209]

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