# Twisting and stacking double carbon layers

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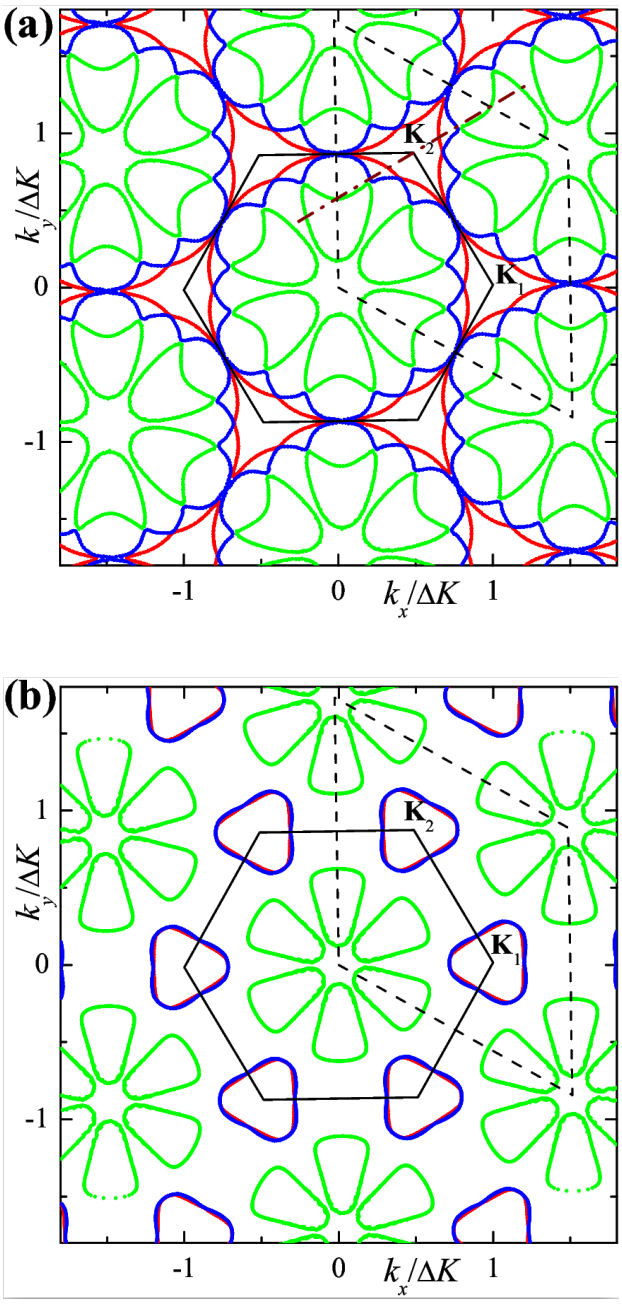


The name 'graphene' is given to a very thin form of carbon: specifically, a single layer of carbon atoms arranged in an hexagonal honeycomb-type lattice. Graphene research took off seriously in 2004 when single wafers were isolated for the first time. At about that time, scientists began to realise that graphene composed of two carbon layers (bilayer graphene) could be at least as interesting as single-layer graphene. Indeed, a growing number of researchers, both theorists and experimentalists, are now actively studying this form.

Since the early 2000s, several thousand papers have been published in this vibrant area of condensed-matter research. It is not easy to navigate this sea of information. An international team of researchers recently published a review in *Physics Reports* that should help newcomers make sense of the field.

Not all bilayer graphene systems are born equal: placing one layer on top of the other in different ways gives rise to non-equivalent forms. The most common varieties are AB-stacking (Bernal stacking), which is the most often studied; AA-stacking; and the twisted bilayer. Initially, the interest in Bernal stacking was driven by the theoretical possibility of opening a controllable electron band gap with a transverse electric field. This field-sensitive gap was first proposed theoretically and then observed using an assortment of experimental tools. Our ability to control this non-negligible semiconducting gap suggests that the AB-bilayer might be useful in electronic applications and for photo-detection. This review discusses collective “many-body” effects in an AB-bilayer; the low-temperature, ordered phase of the system is of particular interest.

AA-bilayer graphene has been much less studied than Bernal stacked graphene. This system is interesting, however, because it possesses an almost ideal nesting of its Fermi surface (Fermi line). This implies that at low temperatures the bilayer freezes into a nesting-driven density-wave phase (most likely a spin-density wave). Theory predicts that this phase may evolve into a spatially inhomogeneous phase or a half-metallic phase when it is doped, before converting into a normal metal at sufficiently high doping. Unfortunately, so far, experimental work on this phase has been limited, so it has not yet been possible to prove the various theoretical predictions about AA-bilayer graphene experimentally.

The third type of stacked graphene is known as twisted bilayer graphene: it occurs when the top layer is slightly rotated with respect to the bottom layer. In other words, the crystallographic axes of the top layer are not parallel to those of the bottom layer, but related by a small twist angle. This system's single-electron properties have been studied quite actively, both experimentally and theoretically. For example, researchers discovered that the Fermi velocity of the electrons becomes very small if the twist is small. In recent publications, experimentalists demonstrated two different many-body effects for twisted bilayer graphene (the Mott insulator effect at one doping, and superconductivity at a different doping). They speculated that this may be due to the interplay of the interactions with this small Fermi velocity. Regardless of the exact answer, these findings are opening up a completely new area of research into twisted bilayer graphene.

**Article details:**

Rozhkov A., Sboychakov A., Rakhmanov A., Nori F.: "Electronic properties of graphene-based bilayer systems," *Physics Reports* (2016)


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