A duo of graphene mimics

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Abstract

Graphene is an allotrope of carbon, with atoms arranged in a single layer on a hexagonal honeycomb lattice. Its discovery (for which the Nobel prize was awarded in 2010) less than a decade ago [1, 2] sparked a frenzy of research into its properties. I will briefly explain why graphene has attracted so much attention.

From a theoretical standpoint, the most interesting feature of graphene is its band structure, which exhibits two inequivalent points, known as *Dirac points*, where the energy bands intersect conically. In the vicinity of these points, the charge carriers behave as massless Dirac fermions, but with the speed of light equal to the Fermi velocity $v_F \sim 10^8$ cm s^{-1}. This allows quantum relativistic phenomena, even those unobservable in high energy physics, to be mimicked and observed on table-top experiments at much lower energies, due to the small value of v_F/c. Graphene also exhibits desirable mechanical properties. It is one of the strongest materials, with a breaking strength over 100 times that of steel. Graphene paper is touted as a future replacement for carbon fiber.

I will then discuss two analogs of graphene which have been recently synthesized. The first [3] utilizes an optical honeycomb lattice to trap ultracold potassium atoms. A graphene-like band structure was reproduced in this system. This optical method of creating the honeycomb lattice is advantageous as it allows more flexibility over a traditional solid state lattice. For instance, by tuning the anisotropy of the lattice, the locations of the Dirac points may be shifted. When the anisotropy reaches a certain limit, the Dirac points merge and annihilate, and evidence supporting the existence of a theoretically predicted topological phase transition was observed.

The second analog [4] was synthesized using individually placed carbon monoxide molecules. By distorting the lattice slightly, the Dirac fermions may be made to acquire mass, or even be made to behave as if influenced by electromagnetic fields, far stronger than those achievable with graphene. When subject to strong pseudo-magnetic fields, a zeroth Landau level was observed, which serves as confirmation of the existence of massless Dirac fermions in honeycomb lattice structures.

References

[1] K. Novoselov, et al, Nature **438**, 197-200 (2005)

[2] Y. Zhang, et al, Nature **438**, 201-204 (2005)

[3] L. Tarruell, et al, Nature **483**, 302-305 (2012)

[4] K. Gomes, et al, Nature **483**, 306-310 (2012)