Ultrahigh Electron Mobility in a Dirac semimetal

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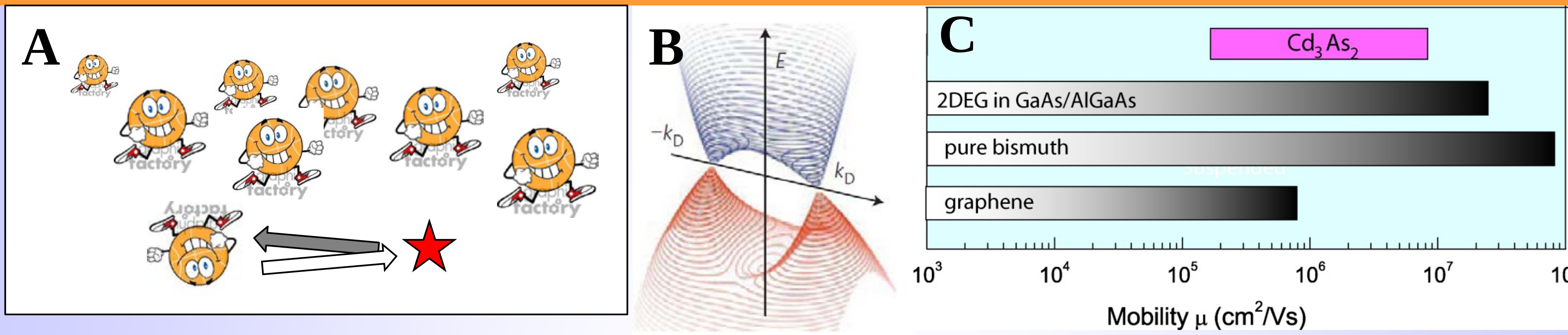

Figure (A) Back scattering of electrons degrades mobility. (B) Schematic of the dispersion of the bulk Dirac states in Cd_3As_2. (C) Comparison of the mobilities (at 4 K) in Cd_3As_2 , the 2DEG in GaAs/AlGaAs quantum wells, in pure bismuth and graphene.

What limits the conductivity in a metal? 60 years after the Bloch-Wilson theory of solids, research is still uncovering surprises. The key quantity is the electron mobility, which measures the current carried per electron. In the conventional picture, the mobility at 4 Kelvin is limited only by impurity scattering (Panel A). Progress in purification over the decades has resulted in mobilities as high as 30 million cm^2/Vs in the 2D electron gas (2DEG) in GaAs-AlGaAs quantum wells, 90 million cm^2/Vs in ultrapure bismuth, and 1 million cm^2/Vs in suspended graphene (Panel C).

Research on topological phases of matter sheds new light on this question. In topological insulators (e.g. Bi_2Se_3), the quantum properties at the surface can enhance the mobility by "protecting" the electrons against back-scattering events, which reverse their momentum (Panel A). Recently, strong interest has focused on a new class of materials called Dirac semimetals, which are 3D analogs of graphene (Fig. B). A group at Princeton reports [1] mobilities in Cd_3As_2 (9 million cm^2/Vs) comparable to those seen in GaAs-AlGaAs and Bi, even though the Cd_3As_2 crystals show significant disorder. Although the mechanism that shields the electrons from back scattering in Cd_3As_2 is still not understood, the experiments show that it is rapidly suppressed when a magnetic field is applied. The research may lead to future applications in ultralow-dissipation electronics.

1. T. Liang et al., "Ultrahigh mobility and giant magnetoresistance in a Dirac semimetal, Cd_3As_2," *Nature Materials*, Nov. 24 2014, doi: 10.1038/NMAT4143

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