Topological transistor

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Quantum spin Hall insulators form a class of materials that are insulating in the bulk, but have conducting edge states. As topological protection prevents backscattering in such states, spin and charge transport should occur without dissipation, which could be used to create low-power devices. Xiaofeng Qian and co-workers have now proposed a transistor that operates by switching the topological behaviour of these materials on and off.

Two-dimensional transition metal dichalcogenides consist of three layers, which can be stacked in a number of ways. Using first-principles calculations, Qian *et al.* predicted that for one particular type of stacking, a range of these materials should be quantum spin Hall insulators. They also predicted that moderate electric fields would transform them into ordinary insulators, destroying the edge states.

This electric-field-induced topological phase transition could be used to create transistors: in an 'on' state, current would flow without dissipation through edge states, whereas applying an electric field would turn the device 'off' as there would be no conducting channels. The current could then be increased simply by adding more layers. This proposed device is termed a van der Waals heterostructured topological field effect transistor. *LF*

Distant dust bunnies

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Imagine trying to study Saturn while the sun is shining. Such is the problem facing researchers who are actively looking for exoplanets around distant stars, as those stars always outshine any orbiting planets or surrounding dust. Instead, sophisticated interferometry techniques must null out the light from the star. Bertrand Mennesson and his team used exactly this technique to analyse forty-seven stars, about half with cool dust and half without.

And not all dust is the same. Most of the known exoplanets lie in cool dust well away from their host stars, thus making them easier to find. The challenge now lies in finding smaller Earth-like exoplanets in the warm 'habitable' zone nearer to the central star, but this warm (room temperature) dust makes such planets more difficult to resolve. The study using the twin Keck telescopes is the first to show that many stars with cool dust also have an inner region of obscuring warm dust. Those with too much dust are to be avoided when trying to find new exoplanets. However, these are the very systems most likely to have Earth-like planets. It's a fine balance. *MC*

Beard watching

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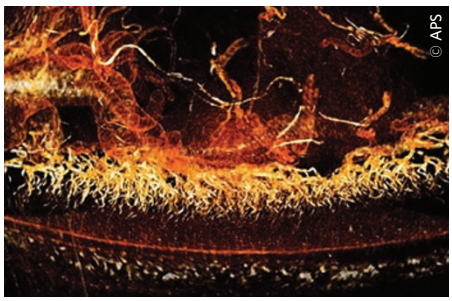
Graphene crystals usually don't come with neat, straight edges. Rather, a graphene edge is a mix of armchair, zigzag or reconstructed-zigzag fragments — the latter resulting from two carbon atoms forming a pentagon with three neighbouring atoms of a zigzag edge. Kuang He and colleagues have now observed a fourth edge type known as 'bearded edges': dangling carbon–carbon bonds protruding from a zigzag edge, which were previously predicted to be unstable.

The authors performed aberration-corrected transmission electron microscopy experiments on 'bulk' graphene and graphene nanoribbons. In both cases, all four edge types were observed. By analysing images recorded at successive time steps, He *et al.* were able to reconstruct the edge dynamics. They found that the electron beam induced structural transformations like bond formation and breaking — or atom loss. The dangling bonds forming the bearded edges were found to lie slightly out of the graphene, an observation corroborated by density-functional-theory calculations.

Edge types directly influence electronic properties, so a bearded graphene edge is expected to result in a peculiar band structure. Indeed, it is known that for photonic crystals with the same beard structure, a novel type of edge state arises, associated with a highly dispersed, nearly flat band. *BV*

Little lanterns

Phys. Rev. Lett. (in the press)



Fireflies light up summer nights using bioluminescence — a mechanism that is well understood from a biochemical point of view, requiring both light-emitting luciferin and oxygen. But how do fireflies control their oxygen supply, and modify it to fuel flashing in addition to other biological functions? Without a microscopic map of their respiratory system, it has been difficult to give a definitive answer. Yueh-Lin Tsai and colleagues used X-ray imaging to study the details of the firefly tracheal system and discovered how the oxygen flow is switched on and off.

Using high-resolution images (pictured), Tsai *et al.* identified the smallest branches of the trachea — the roughly hundred-nanometre-long tracheoles — that are densely packed with mitochondria, which are organelles supplying energy to the cell. They estimated the oxygen diffusion rates and concluded that during flashing, the activity of the mitochondria is reduced (most probably by the release of nitric oxide) and thus the oxygen flux needed for bioluminescence is increased. The firefly lantern seems to be optimized for light emission: the flashing mechanism is very efficient, consuming considerably less energy than flying. *IG*

Protection mechanism

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Much of the excitement surrounding graphene and the wider class of so-called Dirac materials arises from their unusual electronic structure, in which low-energy electrons effectively mimic the motion of relativistic high-energy particles known as Dirac fermions. A notable recent addition to this family has been that of three-dimensional Dirac semimetals, bulk 'analogues' of graphene that have been realized in materials such as Na_3Bi and Cd_3As_2.

The wide variety of phenomena associated with graphene is well known, and it is natural to ask if the physics of three-dimensional Dirac semimetals is equally rich. In fact, Cd_3As_2 has been studied for decades because of its high carrier mobility, but without a clear understanding of its full band structure. Recent theoretical studies also predict several novel transport properties.

Tian Liang and colleagues now report an unexpected characteristic of Cd_3As_2. In addition to a giant magnetoresistance, they observed a suppression of the backscattering of electrons in zero magnetic field, which resulted in an exceptional mobility rivalling the record values measured in epitaxially-grown semiconductors. They attributed this to a topological protection mechanism inherent to the system's band structure, which suggests further surprises may be just around the corner. *AT*

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