analytical tools; their atomic structures and electronic energy levels have been well revealed. In general, atomic structures of clean surfaces or adsorbate-covered surfaces are often reconstructed from those of the corresponding bulk to reduce excess energy generated by surface formation, and the reconstructed surfaces have electronic properties different to those of the bulk. For instance, a metallic surface can exist on a semiconducting substrate, and spin-split surface states appear on a non-magnetic substrate. Although the one-atomic-layer thin films still keep free-electron-like metallic properties, the metal layer has a significant interaction with the substrate, implying that the layers would not be the same as the corresponding self-standing layers, if such layers would exist. Nonetheless, these one-atomic-layer decorated surfaces formed on a semiconducting substrate are the first example of surface superconductivity, adding a new item in the list of peculiar surface-localized properties.

The authors present unique superconductors whose contributing electrons are ultimately confined in a two-dimensional space. As physicists have already developed various methods for manipulating surface structures — down to the atomic level with the aid of nanotechnology — intriguing physical phenomena will be explored on these newly discovered systems. ❐

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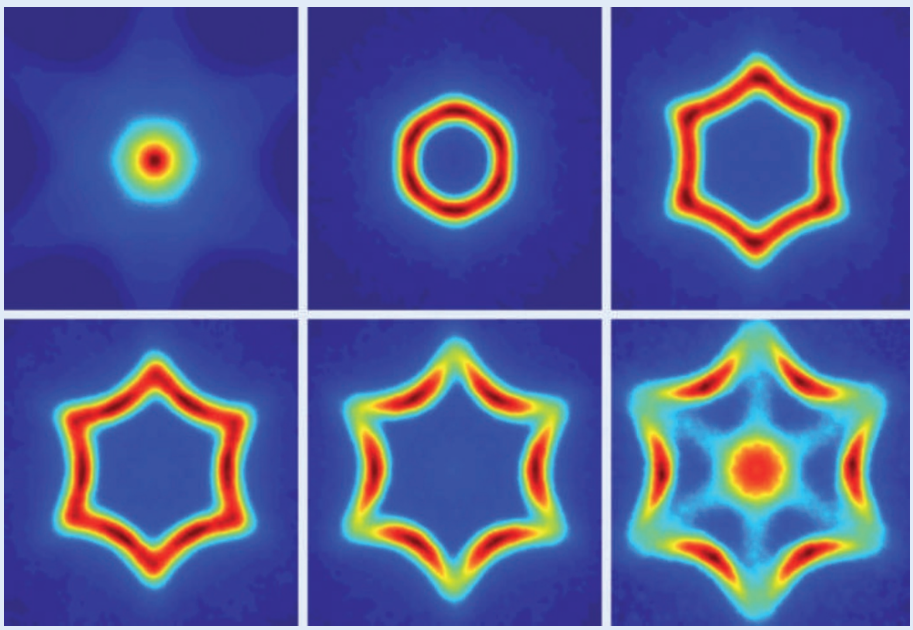
TOPOLOGICAL INSULATORS

A hex on protection

Three-dimensional topological insulators are bulk insulators with charged surface states that are distinct from the bulk. The surface states are gapless (metallic) with linear excitation energy that in three dimensions traces out a cone, as does the Dirac energy spectrum for massless fermions. Robust against perturbations and scattering, such surface states are 'topologically protected' — the surface contains an odd number of 'Dirac cones' as a result of the topological index (Chern number) that characterizes the electronic band structure. Besides being mathematical curiosities, these states are also under consideration for fault-tolerant quantum computation and low-power spintronic devices.

In 2008, Bi_2Te_3 was predicted to be the simplest three-dimensional topological insulator (Q. Xiao-Liang *et al. Phys. Rev. B* **78,** 195424; 2008). Soon thereafter, angle-resolved photoemission spectroscopy experiments on Sn-doped Bi_2Te_3 — doping shifts the bulk states away from the Fermi energy, leaving only the surface states accessible to the charge carriers — confirmed the presence of a single Dirac cone at the centre of the unit cell in momentum space (Y. L. Chen *et al. Science* **325,** 178–181; 2009). The Fermi surface associated with the surface states changes volume with doping concentration and varies from a hexagram at zero doping to a hexagon. Using scanning tunnelling microscopy (STM), Zhanybek Alpichshev and co-workers have now imaged the surface of Bi_2Te_3 and studied the protected nature of the surface states



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(Z. Alpichshev *et al. Phys. Rev. Lett.* **104,** 016401; 2010).

Constant-energy contours of the surface-state bands of pure Bi_2Te_3 are pictured, showing the change from the Dirac point at −330 meV (hexagon; upper left) to 0 meV (hexagram; lower right), where red denotes the occupied states. From about −100 meV, the surface becomes warped. Oscillations resulting from defect-induced interference patterns of electron waves detected by STM abruptly cease below −100 meV: backscattering is suppressed.

So far, these angle-resolved photoemission spectroscopy and STM data are consistent with protected surface states. But the oscillations in STM spectra show a linear energy dependence where Alpichshev *et al.* believe the Fermi surface changes from convex hexagon to concave hexagram. The presence of hexagonal warping may indicate extra scattering channels along 'nesting wave vectors' that connect parts of the Fermi surface together (L. Fu *Phys. Rev. Lett.* **103,** 266801; 2009). Thus surface-band deformations could lead to competing ground states that would otherwise have been forbidden.

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