

## MATERIALS SCIENCE

# Exotic conductors from lab and nature

*Mineral proves to be remarkably clean topological insulator.*

BY ZEEYA MERALI

Silicene's reactivity makes it much harder to produce than graphene. The Nobel prize-winning work on graphene began by peeling sheets from a block of graphite with a piece of sticky tape. Silicene, by contrast, can only be grown in an ultra-high vacuum on top of a material that matches its natural structure (see 'Making silicene').

Crystalline silver has proved to be the best fit because its atomic structure allows it to lock together with silicene's wavy ridges, and the silver's non-reactive surface means that it doesn't pull the silicene apart, Le Lay says. Reversing a technique he honed for depositing silver onto silicon, Le Lay grew the first samples of silicene on silver<sup>1</sup>.

Only two other materials have been found to support silicene up to now. One, zirconium diboride, has the advantage of naturally sucking silicene onto its surface from a block of silicon positioned below<sup>2</sup>. The other, crystalline iridium, was reported as a possibility only in January this year<sup>3</sup>.

Unfortunately, all three of these materials conduct electricity, says Yukiko Yamada-Takamura, a materials scientist at the Japan Advanced Institute of Science and Technology in Nomi. The bulky conductors mask silicene's delicate electrical properties, making it impossible to check whether the theoretical predictions of strange quantum effects are correct.

To see if silicene performs as expected, experimentalists will have to find a semiconducting or insulating surface on which to grow it. Better still would be to develop a technique to create free-standing sheets of silicene, Yamada-Takamura says. It's not entirely clear how that would be done, but given the increasingly competitive nature of the field, she says, "I will not tell you even if I had an idea."

As Peeters isn't racing to grow silicene himself, he's more willing to speculate. He thinks that sandwiching silicene between two sheets of another material, such as graphene, could stabilize it and prevent it from reacting with the outside world.

"I think if it will be used, it will be used in sandwich form, because that's the way in which you can stabilize it," he says. The outer sheets "can be any material; it really depends on what you want to do with it".

Despite its troubles, silicene's future looks bright. It has been included as part of Europe's massive graphene programme, and is catching on in the United States, Le Lay says.

The talks on it at the March meeting are likely to be more popular than they were two years ago, but Le Lay won't be there to find out. He's too busy giving seminars at departments everywhere from Hawaii to Austria to Japan. "It's crazy," he says. "But it's good!" ■

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2. Fleurence, A. *et al. Phys. Rev. Lett.* **108**, 245501 (2012).
3. Meng, L. *et al. Nano Lett.* **13**, 685–690 (2013).

They say that it's what's on the inside that counts. But that is not true for topological insulators — exotic materials that conduct electricity only along their surfaces. A team of physicists has now demonstrated this property in a naturally occurring mineral<sup>1</sup>, and another group has synthesized the first two-dimensional topological insulator that conducts at room temperature<sup>2</sup>.

Having a broader range of such materials could boost researchers' efforts to build spintronic devices — in which currents are driven by an intrinsic property of electrons called spin, rather than by voltages. The materials could also help the design of quantum computers that would use spin to encode information.

Predicted to exist in 2005 (ref. 3), topological insulators that work at low temperatures were first synthesized from heavy elements in 2008 (ref. 4). Their odd conducting abilities arise because each electron's spin becomes coupled to its motion. This relationship compels each electron to circle around a specific spot, preventing them from moving through the bulk material, which means that they cannot conduct electricity. But at the material's edge, the electrons do not have enough space for this circling motion; instead, they are forced to hop along the surface in semi-circular jumps, enabling conduction.

The thin conducting layer of a topological insulator makes it relatively easy for physicists to manipulate the spin current. "Topological insulators raise the possibility of building spintronic devices that use electron spin, rather than charge," says Pascal Gehring, a solid-state physicist at the Max Planck Institute for Solid State Research in Stuttgart, Germany, and a co-author of the mineral study. Spins can be rotated quickly without expending much energy, so spintronic devices should be more efficient than their electronic counterparts, in which energy is required to change charges, he adds.

Physicists attempting to construct quantum computers that would outperform the best current machines are also interested in encoding information in electron spins. In theory, it is difficult to corrupt spin values in a topological insulator. That is because, to flip the spin value accidentally, you would have to

knock the system hard enough to cause the electron to make a complete U-turn.

In search of materials that display these properties, Gehring and his colleagues examined a natural sample of kawazulite, which contains bismuth, tellurium, selenium and sulphur, found at a former gold mine in the Czech Republic. Lab-made samples of kawazulite have already been shown to be topological insulators, but no one had checked for the property in natural samples.

The team cleaved off single crystalline sheets 0.7 millimetres wide and applied the standard test for a topological insulator: photoelectron spectroscopy. This involves measuring the properties of electrons dislodged when ultraviolet light is fired at a material's surface. Their results<sup>1</sup> confirm that the electrons' energy and momentum distribution matches predictions for a topological insulator.

Feng Liu, a materials scientist at the University of Utah in Salt Lake City, notes that the team's natural sample contains fewer structural defects than its lab-made counterparts, reducing unwanted conduction in the bulk. "It may turn out to be cheaper to use a natural supply of topological insulators," says Liu.

Even in the lab, topological insulators require less exotic conditions than had been thought. Jeroen van den Brink, a physicist at the Leibniz Institute for Solid State and Materials Research in Dresden, Germany, and his colleagues stacked bismuth-containing sheets with a honeycomb structure like that of graphene. The result is a bulk material that acts as topological insulator at room temperature<sup>2</sup>.

The next step should be to find organic materials that act as topological insulators, says Liu. His team recently proposed a design for such a compound<sup>5</sup>, and says that another group has synthesized a candidate structure. "Ultimately, these will be these cheapest and most versatile materials to work with." ■

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