Researchers reveal a wide band gap topological insulator

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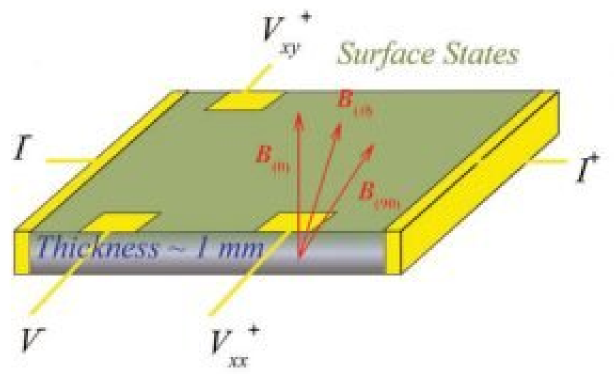


Transport measurement geometry: measuring a freshly cleaved V:BSSTS surface. Credit: FLEET

Since their discovery in 2006, topological insulators have been widely discussed as a promising avenue for energy efficient electronics. Their unique high-mobility edge states have a form of "quantum armor" that protects them from electron-scattering events that would otherwise produce waste heat.

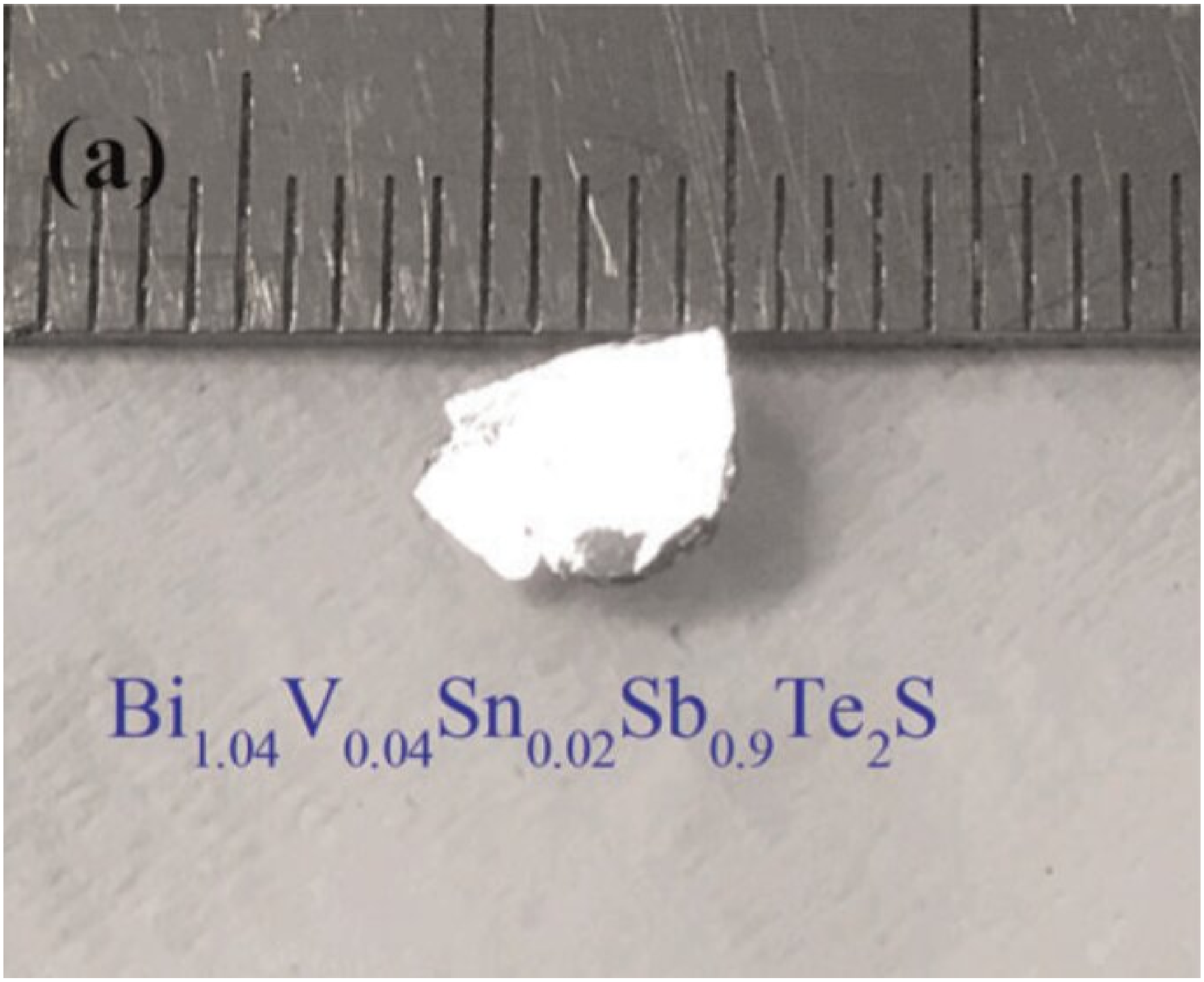
Unfortunately, practical applications of topological insulators have been severely limited by the small electronic bandgaps in most known materials. This means that while they function well at very low temperatures by producing highly mobile surface electrons, at higher temperatures, the bulk electronic states dominate, and these are no better than in other traditional semiconductors.

Now, a team led by Professor Xiaolin Wang (UOW) in collaboration with Michael Fuhrer (Monash), have combined clever chemistry and advanced electronic measurements to develop a new topological insulator with a "wide" bandgap of above 300 meV, which is 12 times larger than the thermal energy of a room temperature system.

The lead author of the study, a Weiyao Zhao, a Ph.D. student at Wollongong explains, "The special aspect of this material is the combination of a wide bandgap, and the existence of a robust surface state."

Previous studies have suggested that substituting sulfur into a Sb_2Te_3 or Bi_2Te_3 topological insulators would result in a larger band gap. However, this is very difficult in practice because the crystal structure becomes unstable owing to the size mismatch of the atoms.

To achieve stability, Zhao used a scheme based on co-substitution of sulfur balanced by a small amount of larger vanadium and tin ions resulting the complex material $Vx{:}Bi_{1.08}\text{-}xSn_{0.02}Sb_{0.9}Te_2S$. Such compounds are sometimes jokingly referred to as "telephone number" compounds by physicist and chemists owing to their long chemical formulas.



Large-scale topological insulator crystal. Credit: FLEET

This compound was the culmination of two years of experimentation by Zhao, who is now in the final year of his Ph.D. at Wollongong.

A key finding was the clear evidence of an increasing band gap that scales with vanadium content. In tandem, using a transport technique based on observing quantum oscillations for magnetic fields at different angles, the team was able to demonstrate that the surface state is active up to the large temperatures of 50 K. This places the material on par with the best known topological insulators.

With the large intrinsic band gap there are strong prospects for further increasing the operational temperatures through reducing defect concentrations and deploying nanofabrication techniques.

Prof. Wang said "We are able to observe the robust topological 2-D surface state at temperature as high as 50K in magnetic fields up to 14 Tesla on large-size topological insulator crystals. This is remarkable, as large 3-D topological insulating crystals can be used as new class of substrate to host novel quantum states such as Majorana fermions and other spin-dependent effects."

This development fits with the theme of enabling technology within FLEET that aims to develop materials that can operate at high temperature to replace silicon in computing technologies.

The paper, "Quantum oscillations of robust topological surface states up to 50 K in thick bulk-insulating topological insulator," was published in *npj Quantum Materials*.

More information: Weiyao Zhao et al. Quantum oscillations of robust topological surface states up to 50 K in thick bulk-insulating topological insulator, *npj Quantum Materials* (2019). DOI: 10.1038/s41535-019-0195-7

Provided by FLEET