Novel topological crystalline insulator shows mass appeal

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Disrupting the symmetrical structure of a solid-state topological crystalline insulator creates mass in previously mass-less electrons and imparts an unexpected level of control in this nascent class of materials, an international team of researchers reports in the current edition of *Science Express*.

The researchers not only confirmed several theoretical predictions about topological crystalline insulators (TCIs), but made a significant experimental leap forward that revealed even more details about the crystal structure and electronic behavior of these newly identified materials, according to Boston College Associate Professor of Physics Vidya Madhavan, one of the lead authors of the report.

The findings could pave the way for engineering the electronic properties of TCI surfaces towards novel functionalities at the nanoscale.

"There is a lot of rich physics here that's waiting to be explored," said Madhavan. "We've opened the door to better understanding topological crystalline insulators and the potential of these materials."

Confirmed within the past few years, topological insulators possess interiors that behave like insulators, blocking the flow of electrons. Yet externally, they contain conducting states where electrons can move freely across their surfaces. A few years ago, physicists first posited the existence of TCIs, a new class of topological materials where conducting surface electrons are theorized to obey fundamental quantum laws set by the crystalline structure of the interior.

Starting with a TCI consisting of lead and selenium, researchers sought to disrupt its structural symmetry by provoking, or doping, the material through the addition of tin, Madhavan said. The subsequent disruption had a dramatic effect on mass-less "Dirac" electrons that are present within the material and behave as relativistic particles. The manipulation added mass to some of these electrons, which took their places side-by-side with the Dirac electrons, a startling result in a solid-state material, Madhavan said.

The new massive electrons were measured topologically through scanning tunneling microscopy and electrically through spectroscopy, the researchers report.

The analysis revealed the Dirac point, which is the defining characteristic of the TCI, said Madhavan. Furthermore, the researchers found that varying the amount of tin imparted a measure of control over the material's properties, fulfilling yet another theoretical prediction.

Madhavan said the results confirmed the TCI's exotic band structure, a measure of the energy a surface electron may or may not possess within a solid. At the same time, the fundamental properties of the TCI remained accessible.

Moreover, observing and controlling Dirac electrons in TCIs paves the way for investigating relativistic physics in solid state systems: physics which was previously accessible only in the experiments of high-energy physics where particles are accelerated to speeds close to light.

In addition, the experiments revealed two distinct regimes of fermiology, an energy boundary used to make determinations about the properties of metals and semiconductors.

More information: "Observation of Dirac Node Formation and Mass Acquisition in a Topological Crystalline Insulator" *Science Express*, 2013.

Provided by Boston College