PRESS RELEASE

In topological insulator debate, scientists document materials' high-level surface state stability.

Following scientists' announcement, new class of materials stakes its claim to holding the key to computer technology's future.

Berlin, June 28, 2012

For additional information:

Markus Scholz
Department of Magnetisation Dynamics
Phone: +49 (0)30-8062-12950
markus.scholz@helmholtz-berlin.de

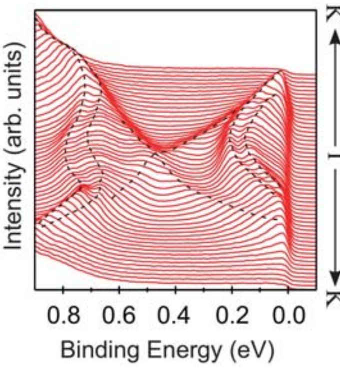
Priv.-Doz. Dr. Oliver Rader
Department of Magnetisation Dynamics
Phone: +49 (0)30-8062-12950
rader@helmholtz-berlin.de

Public Relations
Hannes Schlender

Phone: +49 (0)30-8062-42414
Fax: +49 (0)30-8062-42998
hannes.schlender@helmholtz-berlin.de

Topological insulators are a new, fairly recently discovered class of materials, consisting of an insulating core surrounded by a surface capable of conducting electrical charges. What makes topological insulators unique is their high-level surface state stability. Now, scientists at the Helmholtz Centre Berlin (HZB) have documented topological surface states in bismuth selenide - considered the best-known topological insulator - even when its surface has been iron-coated. Until recently, scientists had assumed that bismuth selenide's stability is lost at its points of contact with a magnetic material. This particular type of interface - between a topological insulator and a ferromagnet – might become key to the computer industry's future ability to develop new storage media. Markus Scholz, a former HZB staff member working in the Department of Magnetization Dynamics, made the discovery as part of his doctoral research - findings that are now being published in the renowned scientific journal *Physical Review Letters* (DOI: 10.1103/PhysRevLett.108.256810).

Topological insulators owe their high-level surface state stability to the fundamental physical principle of time reversal symmetry, according to which physical laws apply even when time is reversed. With respect to electron movement within a solid, time reversal symmetry holds that the laws of nature apply to the same extent regardless of whether an electron is moving from left to right or - following time reversal - from right to left. What is most important is that a state with an upward directed spin must be available to an electron moving in a particular direction, for example from right to left, whereas, by the same token, a state with a downward directed spin - in this case from left to right - has to be available to an electron moving in the opposite direction. As far as topological insulators go, this kind of coupling of the direction of movement to the electron spin is so strong that electrons at the surface are constantly being forced to be available for conductance of electric current. In other words, the conductive surface states are protected.



Spectra of one-third atomic layer iron on bismuth selenide. Bisecting lines indicate the material's surface state. The figure's top and bottom portions are symmetric to each other due to time reversal symmetry, which also protects the point of intersection.

© O. Rader/HZB

In the case of ferromagnetic materials, on the other hand, time reversal symmetry is broken as spin direction is determined by the magnetic North and South poles. If both materials - ferromagnet and topological insulator - are brought into direct physical contact, the break in the ferromagnet's symmetry is expected to transfer to the topological insulator. Until recently, the assumption has been that its surface, too, would thereby become insulating. The HZB team around Markus Scholz has now shown the opposite effect to be true.

"When topological insulators were first discovered, everyone was ecstatic," says Markus Scholz. "Scientists had found a class of materials believed to hold the key to the future of computer technology. Soon, people began to realize that a topologically protected state - like bismuth selenide's surface state - was in fact highly sensitive to magnetic materials, a rather disappointing - and sobering - realization." Because a topological insulator's ability to stabilize its surface state - even when exposed to magnetic materials - is very important if they are to be used in producing computer parts like new storage media.

Now, however, Scholz has declared himself the new materials' knight in shining armor. Using Scotch tape, the scientist initially produced clean-cut broken edges of crystalline bismuth selenide. "From a structural point of view, bismuth selenide is rather two-dimensional," Scholz explains. "Which means that five very tightly bonded atomic layers are followed by a single weak bond. If the tape is pulled off, the crystal tends to fracture at precisely that point." The team then coated the newly created broken edge with an ultra-thin iron film. "Our group has a lot of collective experience producing very clean-cut edges like these ones that meet the highest standards," says Scholz.

Next, the scientists examined the coated crystal surface using angle-resolved photoemission spectroscopy (ARPES), a highly surface-sensitive experimental technique. "Although we are only able to probe the sample's outer one or two atomic layers, in the end we do obtain a highly precise picture of what is currently going on in there," explains Dr. Jaime Sánchez-Barriga, a co-author of the study. The results confirmed that bismuth selenide exhibits its topological surface state even following iron-coating. "As we see it, these discoveries definitely justify future research efforts that would allow us to continue to develop bismuth selenide for application in computer research," argues Sánchez-Barriga. "As such, they could be used in making magnetic transistors, for example."

It looks like the HZB scientists needn't worry as they will, after all, be given the chance to continue their research. The German Research Association just announced that it was in the process of establishing a topological insulator Priority Program with the goal of promoting and supporting 25-30 different research groups. The program is coordinated by Dr. Oliver Rader who also supervised Markus Scholz' doctoral research.

Background:
First postulated back in 2005, topological insulators have since been observed in many different kinds of experiments. The mathematical field of topology deals with quantities that remain constant in the face of continuous change. To illustrate this point, a useful analogy is that of a knot, which can be moved along a rope but not untied, as long as the assumption that the ends are firm holds true. Ropes with knots and those without knots would be considered topologically distinct. Similarly, under certain conditions, electrons can exhibit such topological properties. The firm coupling between an electron's spin and its direction of movement first described in 2005 is an example of such a knot. Whether a magnetic material is actually capable of untying this knot is the active focus of the present research.