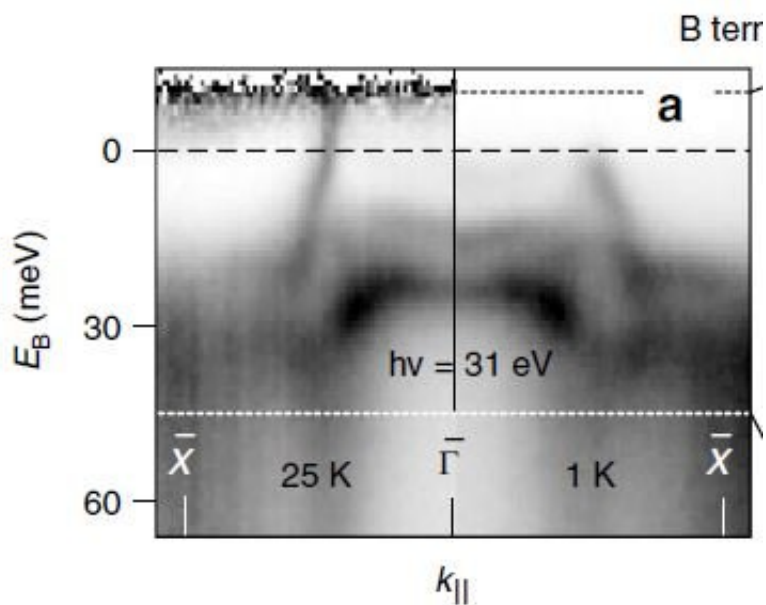


40-year controversy in solid-state physics resolved

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Electrons with differing energies are emitted along various crystal axes in the interior of the sample as well as from the surface. These can be measured with the angular-resolved photoemission station (ARPES) at BESSY II. Left image shows the sample temperature at 25 K, right at only 1 K. The energy distribution of the conducting and valence band electrons can be derived from these data. The surface remains conductive at very low temperature (1 K). Credit: HZB

An international team at BESSY II headed by Prof. Oliver Rader has shown that the puzzling properties of samarium hexaboride do not stem from the material being a topological insulator, as was previously

proposed. Theoretical and initial experimental work had indicated that this material, which becomes a Kondo insulator at very low temperatures, also possessed the properties of a topological insulator. The team has now published a compelling alternative explanation in *Nature Communications*.

Samarium hexaboride is a dark solid with metallic properties at room temperature. It hosts Samarium, an element with several electrons confined to localized f orbitals in which they interact strongly with one another. The lower the temperature, the more apparent these interactions become. SmB₆ becomes what is known as a Kondo insulator, named after Jun Kondo, who first explained this quantum effect.

About 40 years ago, physicists observed that SmB₆ still retained remnant conductivity at temperatures below 4 kelvin, the cause of which had remained unclear until today. After the discovery of the [topological-insulator](#) class of materials around 12 years ago, hypotheses grew insistent that SmB₆ could be a topological insulator as well as being Kondo [insulator](#), which might explain the conductivity anomaly at a very fundamental level, since this causes particular conductive states at the surface. Initial experiments actually pointed toward this.

Now, an international team headed by Prof. Oliver Rader has investigated especially good samples of SmB₆ at BESSY II. The samples, grown by collaborating partners in Ukraine, were cleaved along specific crystal planes and studied with the help of ARPES 13, the unique high-resolution apparatus for angular-resolved photoemission spectroscopy at BESSY II. The physicists were able to achieve the necessary cryotemperatures below 1 kelvin and quite precisely measure the [energy levels](#) of the electron bands with respect to the geometry of the crystal.

First analysis: no topological insulator

Their measurements confirmed the result that electrons on the surface are mobile, but the researchers found evidence that the even number of band transitions observed is irreconcilable with the electrons occupying topological surface states.

In the follow-on experiments, the researchers looked intensively for an alternative explanation of the conductivity that had been demonstrated at the surface. "We were able to show that the gaps between the permitted energy levels of the electrons that opened up due to the Kondo effect were shifted a bit at the surface. As a result, the sample remains conductive only there. This clearly means, however, that the remarkable [surface](#) conductivity is not related to the topology of the system," explains Dr. Emile Rienks who carried out the experiments with doctoral student Peter Hlawenka (HZB and University Potsdam).

The research on topological insulators and other materials that exhibit pronounced quantum effects could lead to new electronic components for energy-efficient information technology. Information might be processed and stored with minimal energy input if we can better understand these materials and thereby control them.

More information: P. Hlawenka et al, Samarium hexaboride is a trivial surface conductor, *Nature Communications* (2018). [DOI: 10.1038/s41467-018-02908-7](https://doi.org/10.1038/s41467-018-02908-7)

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