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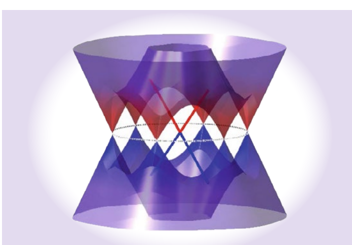
TOPOLOGICAL MATERIALS

One material, dual topology

> We provide a first insight into the intricate coexistence and interaction of two different types of topological surface states

Topological insulators are insulating in the bulk but exhibit symmetry-protected conducting states on their surfaces. As long as the symmetry is not broken, these surface states are immune to various types of disorder that deteriorate the performance of regular conductors. Now, Nurit Avraham, Haim Beidenkopf and collaborators present the first experimental evidence for a dual topological insulator, a material that hosts not one, but two different types of surface states. These results are published in *Nature Materials*.

Dual topological materials can involve a dual protection of surface states ensured by different bulk symmetries, distinct topological surface states coexisting on the same surface, or different topological surface states hosted on different surfaces. This last type of dual topology was predicted to occur in Bi_2TeI. Owing to its symmetries, Bi_2TeI should host a weak topological insulator state (protected by time-reversal symmetry and a discrete translational invariance) on a set of surfaces and a topological crystalline insulator state (protected by mirror symmetry) on a distinct set of surfaces.



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Bi_2TeI is a layered compound, with Bi bilayers sandwiched between two layers of the trivial semiconductor BiTeI; each of these sandwiches is a robust 2D topological insulator, and stacks of 2D topological insulators generally form a weak topological insulator, with surface states on the side surfaces. Bi_2TeI also has mirror symmetry, implying it is a topological crystalline insulator, with surface states on the top and bottom surfaces.

The researchers used scanning tunnelling microscopy to characterize the surface states on different surfaces of Bi_2TeI and their interaction. They cleaved the sample in vacuum, obtaining a surface that comprised many terraces separated by step edges. "In this work we provide comprehensive experimental evidence of a dual topological insulator," summarizes Avraham. "By probing the conductive surface states locally on the material facets, we show that the top surface exhibits crystalline topological surface conductivity, whereas the side facets exhibit weak topological surface states."

On all terraces, independent of whether they are terminated with Bi or with Te atoms, there are robust surface states that disperse linearly with energy. These states are suppressed in the vicinity of step edges. Because topological crystalline insulator states are sensitive to mirror symmetry breaking, such as the one provided by step edges, but not to surface termination, the surface states observed on the terraces are identified as topological crystalline insulator states.

The edges of the terraces can be seen as the 'sides' of the sample; in particular, edges of terraces containing an odd number of Bi bilayers should host the weak topological insulator states. Indeed, at such step edges, 1D conducting channels are revealed and identified as weak topological insulator states. Remarkably, the two types of topological states coexist at the step edges instead of hybridizing, owing to their substantial separation in both momentum and energy.

"Our study goes beyond confirming the dual topological classification of Bi_2TeI as a weak and crystalline topological insulator," explains Beidenkopf. "We provide a first insight into the intricate coexistence and interaction of two different types of topological surface states, which can serve as bedrock for the discovery of new topological phenomena; we plan to take this forward by investigating more exotic topological states of matter, such as higher-order and fragile topological insulators, which were recently predicted to be also realized in Bi_2TeI."

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ORIGINAL ARTICLE Avraham, N. et al. Visualizing coexisting surface states in the weak and crystalline topological insulator Bi_2TeI. *Nat. Mater.* https://doi.org/10.1038/s41563-020-0651-6 (2020)