Realization of a one-dimensional topological insulator in ultrathin germanene nanoribbons

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Realizing a one-dimensional (1D) topological insulator and identifying the lower-dimensional limit of two-dimensional (2D) behavior are crucial steps toward developing high-density quantum state networks, advancing topological quantum computing, and exploring dimensionality effects in topological materials. Although 2D topological insulators have been experimentally realized, their lower dimensional limit and 1D counterparts remain elusive. Here, we fabricated and characterized arrays of zigzag-terminated germanene nanoribbons, a 2D topological insulator with a large topological bulk gap. The electronic properties of these nanoribbons strongly depend on their width, with topological edge states persisting down to a critical width (~2 nm), defining the limit of 2D topology. Below this threshold, contrary to the tenfold way classification, we observe zero-dimensional (0D) states localized at the ends of the ultrathin nanoribbons. These end states, topologically protected by time-reversal and mirror symmetries, indicate the realization of a 1D topological insulator with strong spin-orbit coupling.

References

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Figures

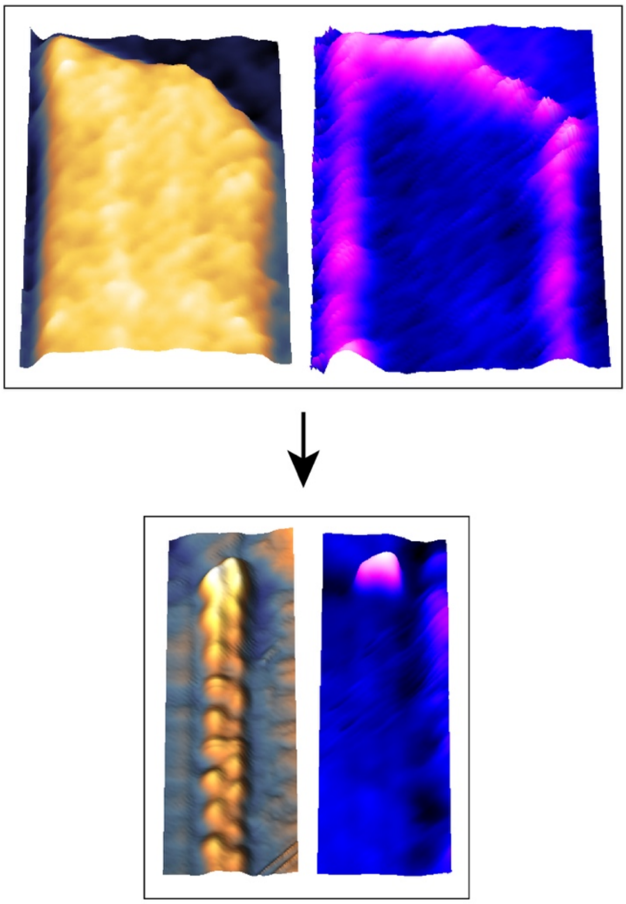

Figure 1: Top: topography (left) and in-gap local density of states (right) of a wide germanene nanoribbon. Quantum spin Hall (QSH) edge states can be observed along the edges of the ribbon from the increased local density of states. Bottom: same but for an ultrathin (~2 nm wide) germanene nanoribbon. Here, the QSH states are absent, and an end-localized state can be seen, marking the transition to an one-dimensional topological insulator.