Topological Phase Transition from 1D Edge States to 0D End States in Germanene Nanoribbons

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Investigating topological phases and their transitions is crucial for discovering new quantum states and advancing topological device technology. The transitions between distinct topological phases, especially from two-dimensional (2D) to one-dimensional (1D) systems, remain largely unexplored and poorly understood. In this study, we synthesized germanene nanoribbons, which are 2D topological insulators [1], featuring zigzag terminations, large topological gaps (100-150 meV), and metallic edge states. These nanoribbons enable the packing of a dense array of parallel 1D topological edge states. By systematically varying the nanoribbon width, we monitored the evolution of their topological characteristics, pinpointing a transition to a 1D topological insulator phase below a critical width of about 2 nm. This transition is marked by the vanishing of the 1D edge states and the emergence of distinct zero-dimensional (0D) end states. We obtain theoretically and experimentally that the 0D topological behavior of (thin) Germanene nanoribbons is rich and complex. The topological phase depends in a non-monotonic way on ribbon width, spin-orbit coupling, staggered mass, and termination.

References

[1] P. Bampoulis et al. Phys. Rev. Lett. 130, (2023) 196401

Figures

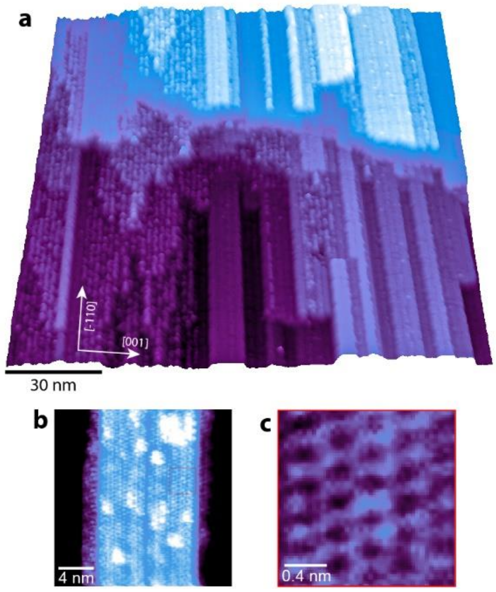

Figure 1: (a) Large-scale STM image of germanene nanoribbons grown on the Ge_3Pt substrate. **(b)** Detailed view of a germanene nanoribbon. **(c)** Close-up of the area marked by the red square in (b), highlighting the honeycomb lattice structure of germanene.

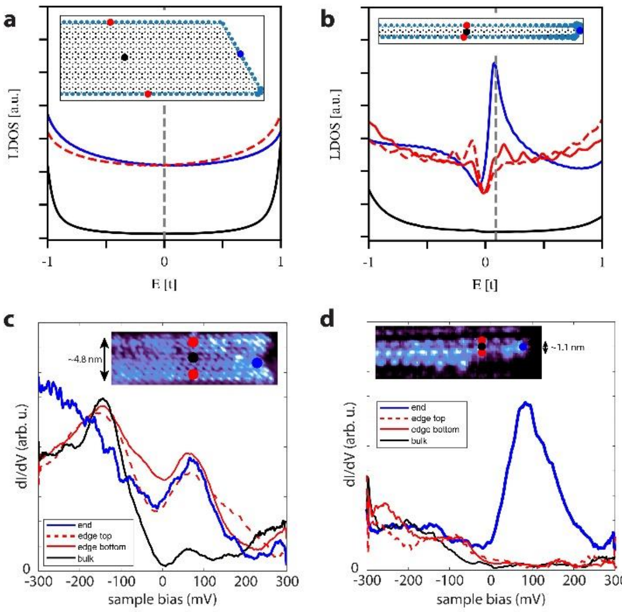

Figure 2: LDOS calculations for a wide **(a)** and a narrow **(b)** nanoribbon showing a transition to 0D end states. Experimental dI(V)/dV spectra comparing a wide **(c)** and narrow **(d)** nanoribbon, showing the vanishing of edge states and emergence of pronounced end states as the nanoribbon width decreases.