Quantum Spin Hall States and Topological Phase Transition in Germanene

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We provide experimental evidence of a topological phase transition in the monoelemental quantum spin Hall insulator, germanene. Low low-buckled epitaxial germanene on buffer-layer/Ge_2Pt is a quantum spin Hall insulator with a large bulk gap and robust metallic edges. The topological edge states have distinct dispersion characteristics depending on their termination. Particularly, we observe a pronounced variance in Fermi velocity, with armchair edges exhibiting a velocity higher than zigzag edges by about an order of magnitude. Moreover, we demonstrate that the application of a critical perpendicular electric field closes the topological gap and makes germanene a Dirac semimetal. Increasing the electric field further results in the opening of a trivial gap and the disappearance of the metallic edge states. This electric field-induced switching of the topological state and the sizable gap make germanene suitable for room-temperature topological field-effect transistors, which could revolutionize low-energy electronics.

References

[1] P. Bampoulis et al. Phys. Rev. Lett. 130, 196401 (2023)
[2] H.J.W. Zandvliet, D.J. Klaassen, P. Bampoulis. Phys. Rev. B. *accepted* DOI: 10.1103/PhysRevB.00.005400
[3] B. Weber et al. J. Phys. Mater. 7, 022501 (2024)

Figures

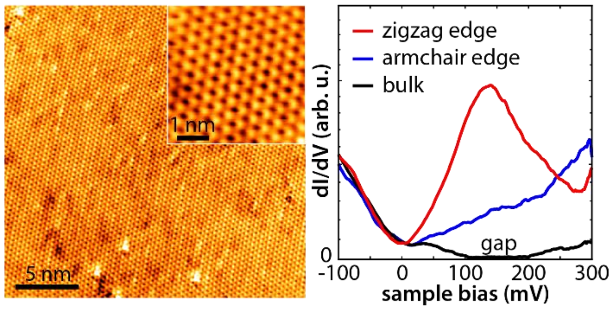

Figure 1: Left: STM image of the hexagonal buckled lattice of germanene, the inset is a zoomed-in image [1]. Right: dI(V)/dV curves taken at a zigzag terminated edge, an armchair terminated edge, and of the bulk [2].

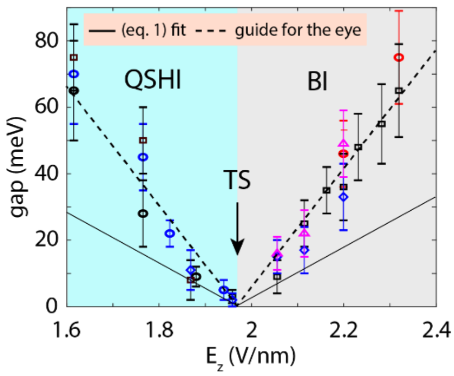

Figure 2: Bandgap size as a function of the electric field. The material transitions from a QSH insulator to a topological semimetal (TS) and finally to a trivial band insulator (BI). Markers indicate the results of multiple experiments [1].

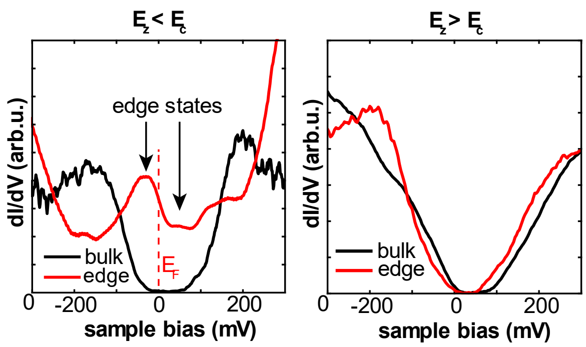

Figure 3: dI(V)/dV taken at low E-field in the QSH insulator state (left), and taken at high E-field in the band insulator state (right) [1].