Quantum spin Hall states and topological phase transition in germanene

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The realization of the topological field-effect transistor requires an electric field-induced transition from a topological state with dissipationless conductive channels ('On') to a trivial insulator state ('Off'). Monoelemental and buckled quantum spin Hall insulators with large topological band gaps are ideal candidates to investigate topological phase transitions[1-3]. We provide compelling experimental evidence that low-buckled epitaxial germanene [4] is a quantum spin Hall insulator with a bulk gap and robust metallic edge states. The low-buckled structure of germanene allows for topological phase transitions to take place. Upon the application of a critical transversal electric field, the topological gap closes and germanene becomes a Dirac semimetal. Increasing the electric field further results in the opening of a trivial gap and the disappearance of the edge states. This reversible electric field-induced switching of the topological state, shown in Figure 1, and the sizeable gap make germanene suitable for room temperature topological field-effect transistors, which could revolutionize low-energy electronics and spintronics.

References

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Figures

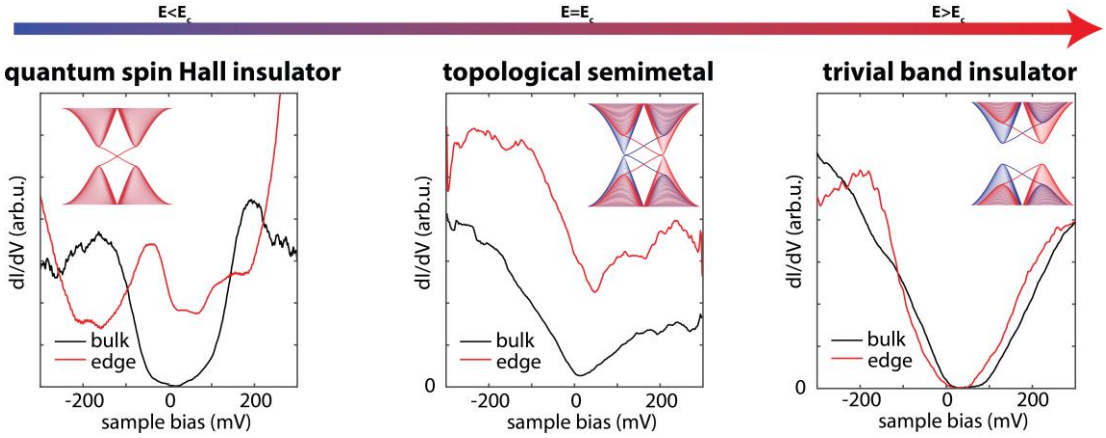

Figure 1. Scanning tunneling spectroscopy (dI(V)/dV) recorded at the bulk (black) and step edge (red) of germanene for increasing electric fields (from left to right). Left: dI(V)/dV spectra recorded at the bulk and the step edge of germanene for an electric field below the critical field to close the topological gap of germanene (E_c=1.95 V/nm). Inset: the topological insulator band structure. Middle: dI(V)/dV spectra recorded at the bulk and the step edge of germanene for an electric field of about 1.95 V/nm, showing the V-shaped density of states of germanene for this field. Inset: the topological semimetal band structure. Right: dI(V)/dV spectra recorded at the bulk and the step edge of germanene for an electric field of about 2.32 V/nm, showing the trivial gap in germanene. Inset: the trivial band insulator band structure.