Topological Phase Transition in Sn Single Layer from Stanene to Beta-Sn

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Two-dimensional topological insulators (2D TIs) are prized for unique electronic properties, especially in spintronics. These materials feature spin-polarized, disorder-resistant edge states. In contrast, topological nodal line semimetals (TNLSM) exhibit a distinct one-dimensional ring of degeneracy protected by topology, resilient to disorder. However, 2D TNLSMs lack protected boundary modes, posing experimental challenges. β-Sn, a metallic allotrope with a superconducting temperature of 3.72 K, emerges as a potential topological superconductor for hosting Majorana fermions in quantum computing. In this work, we successfully prepared single layers of α-Sn(111) and β-Sn(001) on a Cu(111) substrate, employing scanning tunneling microscopy (STM), angle-resolved photoemission spectroscopy (ARPES), and Density Functional Theory (DFT) calculations. The electronic structure of β-Sn(001) undergoes a topological transition from 2D topological insulator α-Sn to 2D topological nodal line semimetal β-Sn, presenting two coexisting nodal lines. This realization in a single 2D material is unprecedented. Additionally, unexpected freestanding-like electronic structures of β-Sn/Cu(111) were observed, highlighting ultrathin β-Sn(001) films' potential for exploring the electronic properties of 2D topological nodal line semimetals and topological superconductors in the 2D limit, such as few-layer superconducting β-Sn in lateral contact with topological nodal line single-layer β-Sn.