Covalent bonded bilayers of monoatomic two-dimensional materials: germanene-stanene heterostructures

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Since the discovery of bilayer graphene with unexpected properties, such as "tunable" super-conductive states, great focus has been directed at the world of two-dimensional materials. The significance of such bilayer systems lies in the weak interaction between layers. That allows for a variety of heterostructures to be achieved through layer twisting. Here we propose a new paradigm for the realization of bilayer materials, where covalent bonding replaces the van der Waals interaction between the layers. As a specific example, we consider a bilayer made up of germanene and stanene that is covalently bonded. The nature of the covalent bonds between Ge and Sn atoms is crucial and leads to the realization of a completely novel material with interesting topological properties. Our ab-initio calculations reveal linear Dirac bands with a small gap in the electronic structure. We develop a k·p model that shows that the gap of the covalent bilayer is sensitive to an induced electric polarization. By changing the electric polarization value, the gap can be closed, resulting in degenerate Dirac cones. Thus, an applied electric field can drive the GeSn system from a trivial to a topological insulator. To investigate these theoretical predictions, we fabricate and experimentally characterize a GeSn bilayer. We find, that the measured reflectivity spectrum for such heterostructure deposited on a sapphire substrate decreases by 20 - 25 % at the lowest energies and is in excellent agreement with theoretical calculations. The unique properties and simplicity of the GeSn heterostructure fabrication opens up new routes for novel optoelectronic applications that require enhanced sensitivity and stability.