

Abstract

The goals of this project are to develop (i) highly-perfect, three-dimensional (3D) Dirac materials with extremely high carrier mobilities using molecular beam epitaxy and (ii) heterostructure engineering approaches that achieve unprecedented control over their unique electronic states. The ultimate objective is a new class of electronic materials and devices that are based on controlling unique nontrivial topological electronic states. Using approaches such as strain, electrostatic confinement, and symmetry engineering, as well as fine-tuning of the Fermi level using electric field effect and modulation doping, we will achieve unprecedented control over the unique electronic states of 3D Dirac materials. These give rise to unique phenomena such as spin-Hall effects, chiral excitations, chiral magnetic currents, unusually large magnetoresistances, topological protection against scattering, and true Fermi arcs, which cannot be found in any other materials class. Using heterostructure engineering, which is completely new to the field of 3D Dirac materials, we will tune between different 3D topological states, such as Weyl semimetal, topological insulator, and quadratic band touching. The control achieved using these approaches will enable entirely new opportunities and device paradigms for spintronics, quantum computing, sensors, chiral, and high-speed electronics.