The 2D spin-helical Dirac quantum metal surfaces of 3D topological insulators (TI) are potentially transformational for spintronics and error-free quantum computing. However, materials quality is a major obstacle: crystalline defects cause scattering of surface state carriers and introduce doping that renders the bulk conductive. Using a two-step Bridgman technique, we grow TI crystals with low bulk carrier densities (~$10^{17}$ cm$^{-3}$) where the Fermi level is within 120 meV of the gap center (top left). These high mobility (>10,000 cm$^2$/Vs) crystals show Hall quantization at the lowest magnetic fields to date (bottom left).

Utilizing a new technique to tune the Fermi level with high-energy electrons, we create magnetically doped TIs with insulating bulk and high-mobility surface states. These materials exhibit the Quantized Anomalous Hall Effect at the highest temperature seen to date (bottom right).

These high quality materials are a platform for tunable interfaces supporting dissipationless transport of charge.