Epitaxially engineered quantum materials for quantum technologies: interfacing topology, magnetism, and superconductivity

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Quantum materials that interface magnetism, topology, and superconductivity are attractive for emerging quantum information technologies. We provide an overview of the opportunities presented by the epitaxial growth of diverse quantum materials using molecular beam epitaxy (MBE) and chemical vapor deposition (CVD). We discuss MBE-grown Dirac semimetal heterostructures [1-3] and ferromagnetic topological insulators interfaced with ferromagnetism [4], motivated by the effects of broken time-reversal symmetry on transport in topological states. We then show how epitaxially engineered heterostructures can lead to emergent superconductivity that coexists with topological order and ferromagnetism [5]. Finally, we investigate superconductivity in CVD-grown doped diamond films for potential applications in quantum technologies [6]. Supported by the Penn State 2DCC-MIP (NSF DMR-2039351), Penn State MRSEC (NSF DMR-2011839), and Q-NEXT, a DOE National Quantum Information Science Research Center.

References

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Figures

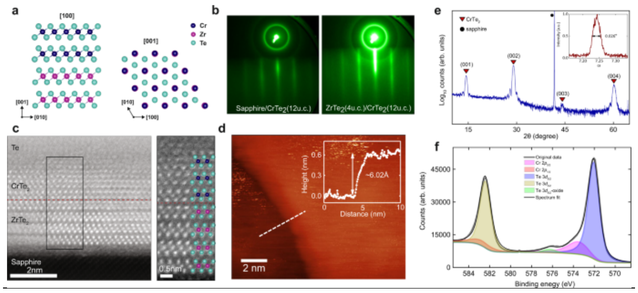

Figure 1: Example of the MBE growth and characterization of a hybrid Dirac semimetal ($ZrTe_2$)/2D ferromagnet ($CrTe_2$) heterostructure. The panels show (a) schematic crystal structure, (b) RHEED, (c) XRD, (d) TEM, (e) scanning tunnelling topography, and (f) x-ray photoelectron spectroscopy. Figure reprinted from Ref. [1].

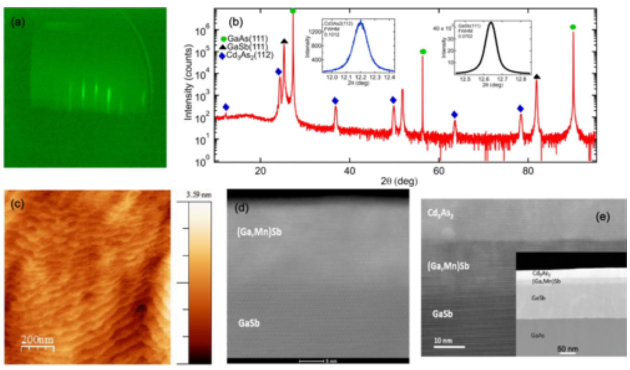

Figure 2: Example of the MBE growth and extensive characterization of a hybrid Dirac semimetal/ferromagnetic semiconductor heterostructure aimed at breaking time-reversal symmetry. The panels show (a) reflection high energy electron diffraction (RHEED), (b) x-ray diffraction (XRD), (c) atomic force microscopy (AFM), and (d), (e) transmission electron microscopy (TEM). Figure reprinted from Ref. [3].