Abstract

We propose to develop new solid state platforms for full quantum state control by exploiting the interplay between single spin defects and emergent phenomena in two dimensional (2D) systems such as transition metal dichalcogenides (TMDs) and related ultrathin materials (e.g. the high temperature superconductor, single unit cell FeSe). By creating hybrid heterogeneous systems that embed and interface isolated defect spins in host 2D materials with disparate electronic, magnetic and photonic environments, we will pursue the creation, initialization and manipulation of quantum states at the wafer scale. We will take advantage of recently discovered optical methods to 'wire' quantum states with a superconducting 'quantum bus' and control them using photons. Our principal goal is to develop a rigorous fundamental understanding of the underlying phenomena that will enable these functionalities. In contrast to current hybrid solid state quantum technology schemes, this bottom-up method offers a fundamentally new approach with unprecedented advantage: it enables the coherent integration of components based on precise electronic and structural control at the atomic level to create wafer scale quantum entangled technologies built upon a *reconfigurable* architecture and enable a quantum analog to the field programmable gate array.

Our project combines the complementary expertise of the principal investigator, Professor D. D. Awschalom, with collaborators Professor Jiwoong Park at the University of Chicago and Professor N. Samarth at Penn State University. The collaboration involves state-of-the-art laboratories that focus on quantum measurements, including spatio-temporal probes of quantum coherence and entanglement, and advanced materials synthesis, such as molecular beam epitaxy and metal-organic chemical vapor deposition. Our focus on 2D chalcogenides takes advantage of a new national user facility at Penn State, the 2D Crystal Consortium (2DCC), part of the NSF Materials Innovation Platform. We will use these synthesis capabilities to fabricate the materials that are at the foundation of this project.

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