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Julius Edgar Lilienfeld Prize Talk: Quantum spintronics: abandoning perfection for new technologies[1]

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There is a growing interest in exploiting the quantum properties of electronic and nuclear spins for the manipulation and storage of information in the solid state. Such schemes offer qualitatively new scientific and technological opportunities by leveraging elements of standard electronics to precisely control coherent interactions between electrons, nuclei, and electromagnetic fields. We provide an overview of the field, including a discussion of temporally- and spatially-resolved magneto-optical measurements designed for probing local moment dynamics in electrically and magnetically doped semiconductor nanostructures. These early studies provided a surprising proof-of-concept that quantum spin states can be created and controlled with high-speed optoelectronic techniques. However, as electronic structures approach the atomic scale, small amounts of disorder begin to have outsized negative effects. An intriguing solution to this conundrum is emerging from recent efforts to embrace semiconductor defects themselves as a route towards quantum machines. Individual defects in carbon-based materials possess an electronic spin state that can be employed as a solid state quantum bit at and above room temperature. Developments at the frontier of this field include gigahertz coherent control, nanofabricated spin arrays, nuclear spin quantum memories, and nanometer-scale sensing. We will describe advances towards quantum information processing driven by both physics and materials science to explore electronic, photonic, and magnetic control of spin.

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