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Spintronics: Semiconductors, Molecules, and Quantum Information Processing

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There is a growing interest in exploiting electronic and nuclear spins in semiconductor nanostructures for the manipulation and storage of information in emergent technologies based upon spintronics and quantum logic. Such schemes offer qualitatively new scientific and technological opportunities by combining elements of standard electronics with spin-dependent interactions between electrons, nuclei, electric and magnetic fields. Here we provide an overview of recent developments in the field through a discussion of temporally- and spatially-resolved magneto-optical measurements, initially designed for probing local moment dynamics in magnetically doped semiconductor nanostructures. We demonstrate new electrical schemes for the local generation and manipulation of spins in conventional semiconductor heterostructures, thereby providing a compelling proof-of-concept that quantum spin information can be controlled within high-speed electrical circuits. Furthermore, we discuss a different experimental approach that enables the molecular wiring and assembly of colloidal semiconductor nanostructures to engineer hybrid systems for room temperature coherent spin transport. These experiments explore electronic, photonic, and magnetic control of spin in a variety of nanostructures, and show significant steps towards spin-based quantum information processing in the solid state.