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Single-ion magnetic moments in semiconductors

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The ability to manipulate single spins in a solid-state environment provides a new pathway to study the fundamental physics of magnetism and may lead to the development of nanoscale spin-based quantum devices. Single magnetic ions bound with valence holes in semiconductors are a good candidate for building scalable quantum spin systems that can be directly integrated into conventional charge-based electronics. The highly extended hole wave function is susceptible to external non-magnetic control fields, such as electric or strain fields. The spin-orbit coupling between the orbital and spin character of the bound hole state permits indirect manipulation of the spin states of the magnetic ions. It is also possible to make use of the spin-dependent local density of states to probe the spin state of individual magnetic ions. I will discuss our theoretical understanding on the anisotropic shape of the bound hole states and the resulting anisotropic magnetic interaction. The hole wave function can be significantly altered by a strain field, which in turn influences the magnetic interaction. The magnetic interaction is found to be sensitive to the local changes in the hole binding energy as well. Our results pave the way for electrical manipulation of single ion spins in semiconductors and also shed light on bulk magnetic properties of very dilute magnetic semiconductors.