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Investigation of Ferromagnetic Semiconductors through Depth Resolved Spin Resonance Techniques

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Technologically, a semiconductor which is also a ferromagnet has exciting potential for spintronic applications, where logic and memory operations could in principle be integrated on a single device. Artificial heterostructures based on such ferromagnets show immense promise, in particular for the injection of polarised spins into a semiconducting substrate. From a fundamental perspective, understanding ferromagnetism in a novel material which is also a semiconductor is an important challenge. Although no consensus on the mechanism has yet been reached, it is now established that the interaction between the magnetic atoms in prototypical systems like the III-V semiconducting materials Ga1−xMnxAs/GaAs or EuO1-x/doped Si is induced by charge carriers in the semiconductor host. Large changes in the electronic structure occur as the temperature is reduced through the Curie temperature, caused by an exchange splitting of the conduction band in the ferromagnetic state.
The unusual interplay between magnetism and transport properties opens up the interesting and potentially technologically useful possibility of modulating magnetic behaviour by controlling the charge carrier properties, through doping, applied electric fields or photoexcitation. These heterostructures may be produced in thin film form using non-equilibrium techniques such as molecular beam epitaxy. Investigations using local probes which are sensitive to magnetic structure on a nanometre lengthscale are therefore invaluable. I will discuss our recent studies of the internal magnetic field distribution and spin fluctuations in these model materials for spintronic devices using depth resolved Low Energy mu-SR and beta-detected Nuclear Magnetic Resonance (beta-NMR), complementary spin resonance techniques.

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