Spatially Resolved Inhomogeneous Ferromagnetism in (Ga,Mn)As Diluted Magnetic Semiconductors

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The spin of the carriers has so far played a minor role in semiconductor devices mainly because the semiconductors used for industrial applications, such as Si and GaAs, are nonmagnetic. On the other hand, the enhanced spin-related phenomena have been realized in diluted magnetic semiconductors (DMS) to offer applications known as spintronics. Discovery of ferromagnetism (FM) in the canonical DMS - GaMnAs films which have the benefit of being compatible with GaAs technology - has led to intense studies of the FM in these materials for spintronics applications.

Although there is an emerging consensus that the FM in DMS originates from the interaction between itinerant carriers and localized magnetic moments, the microscopic theory of FM in these materials is the subject of considerable debate [1]. Theoretical models encounter major difficulties caused by the absence of experimental data on the distribution of the magnetic field in DMS on the nanometer scale because so far the FM properties of DMS have been studied mainly using traditional macroscopic integral techniques unable to produce spatially resolved information.

Here we present direct experimental evidence for the inhomogeneous nature of the FM state in GaMnAs DMS. Using low energy positive muons as a local magnetic probe we are able to resolve spatial inhomogeneity of the magnetic field in the thin film: although homogeneous above Tc, DMS clearly consists of ferromagnetic and paramagnetic regions of the comparable volumes in the FM state.

[1] T. Jungwirth et al., Rev. Mod. Phys. 78 (2006) 809.