Abstract for an Invited Paper
for the MAR05 Meeting of
The American Physical Society

Spatial structure of single and interacting Mn acceptors in GaAs

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Ferromagnetic semiconductors such as $Ga_{1-x}Mn_xAs$ are receiving a lot of attention at the moment because of their application in spintronic devices. However, despite intense study of deep acceptors in III-V semiconductors such as Mn_{Ga}, little information has been obtained on their electronic properties at the atomic scale. Yet the spatial shape of the Mn acceptor state will influence the hole-mediated Mn-Mn coupling and thus all of the magnetic properties of ferromagnetic semiconductors such as $Ga_{1-x}Mn_xAs$. This study presents an experimental and theoretical description of the spatial symmetry of the Mn acceptor wave-function in GaAs. We present measurements of the spatial mapping of the anisotropic wavefunction of a hole localized at a Mn acceptor. To achieve this, we have used the STM tip not only to image the Mn acceptor but also to manipulate its charge state A^0/A^- at room temperature. Within an envelope function effective mass model (EFM) the anisotropy in the acceptor wave-function can be traced to the influence of the cubic symmetry of the GaAs crystal which selects specific d-states that mix into the ground state due to the spin-orbit interaction in the valence band. Comparison with calculations based on a tight-binding model (TBM) for the Mn acceptor structure supports this conclusion. Using the same experimental and theoretical approach we furthermore explored the interaction between Mn acceptors directly by analyzing close Mn-Mn pairs, which were separated by less than 2 nm. We will discuss some implications of these results for Mn delta-doped layers grown on differently oriented growth surfaces.