Spin-Selective Tunneling in Deep Donor States of Interstitial Mn Impurity in GaAs Quantum Well

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The interstitial site, Mn_i, in bulk GaAs, is known to act as a double donor whereby the d-level transitions (0/+) and (+/2+) are calculated and are found to lie within the GaAs conduction band [1], as expected in saturated bonds in which the 4s electron transfers directly to the d-shell.
The electronic structure of the d-levels of an interstitial manganese impurity, Mn_i, in a GaAs quantum well (QW) is studied. The position of the d-levels is determined by the sum of the Hilbert transforms of the partial density of states projected from the total density of states by the hybridization matrix elements. The differences obtained, compared with the case of bulk GaAs, are due primarily to lowering of its tetrahedral T_d symmetry to a tetragonal D_{2d} symmetry in QW, which lifts the symmetry bans for the hybridization matrix elements. Thus, the hybridization of the d-levels with the states near the bottom of the conduction QW subband becomes nonzero, leading to logarithmic singularities of the mass operator. As a result, we found that the d-levels (+/2+) are shifted downward, below the first subband, due to the strong resonance scattering. Hence, the Mn_i introduces its localized donor states $E_{ie\downarrow}$ and $E_{it_2}\downarrow$ into the energy gap with strong quenching of the crystal field splitting. The wave function in the QW appears to be much more extended than in the bulk case and can be represented as a bonding combination of a localized d-core function and an extended Bloch tail of the s-function.
The donor electron is therefore captured by a *spin-selective* resonance scattering of the deep impurity levels. This spin selectivity is caused by electron scattering of the unfilled 3d shell, the deep levels of which are occupied in accordance with Hund's rule, $Mn^+(3d^6(t_{2\uparrow}^3 e_\uparrow^2, t_{2\downarrow}^1))$. As a result only spin-down electrons can resonantly tunnel through the individual Mn_i localized donor states. Similar to the conventional p-i-n resonant tunneling diode, the polarized tunneling current can be controlled by the bias voltage.
Similar electronic structure is revealed, for the first time, for a donor Mn_i in a GaMnAs/GaAs p-i-n diode using resonant magneto-tunneling spectroscopy [2]. Our theory may explain these observations as well.

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REFERENCES

[1] P. Mahadevan atal, *PRB* 68, 075202 (2003)
[2] O. Makarovsky etal., presented in HMF-17 (2006)