Spin orbital reorientation transitions induced by magnetic field

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Motivation: SRT like effect

Here we report on a new effect similar to the spin reorientation transition (SRT) that takes place at two magnetic fields of B_{SORT1} and B_{SORT2}.

The effect is observed in the magnetization curves of small Mn^{3+} magnetic clusters in the wurtzite GaN (being in a paramagnetic state) calculated using crystal field model approach.

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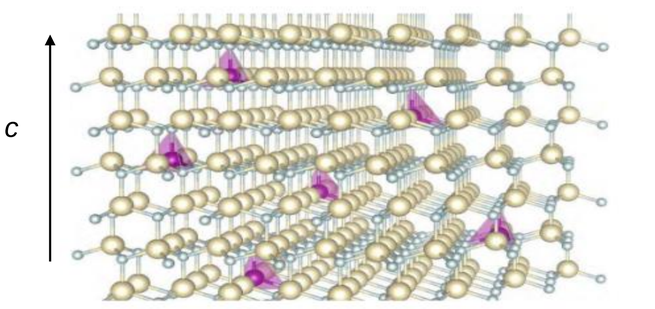
Conclusions

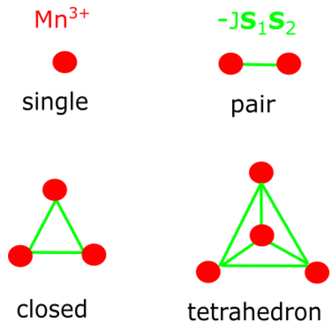
The observed effect arises from the interplay of the crystalline environment and the spin–orbit coupling λ**SL**, therefore we name it spin orbital reorientation transition (SORT)

The value of B_{SORT1} depends on the crystal field model parameters and the number of ions *N* in a given cluster, whereas B_{SORT2} is controlled mostly by the magnitude of the spin-orbit coupling λ.

The explanation of SORT is given in terms of the spin M_S and orbital momentum M_L contributions to the total magnetization $M = M_S + M_L$.

Dilute magnetic semiconductor

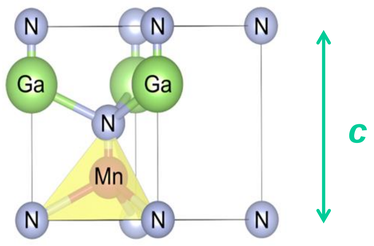




(Ga,Mn)N

Crystal field model

Crystal field model for Mn^{3+} ion in GaN: spin and orbital momentum *S* = 2 and *L* = 2, respectively

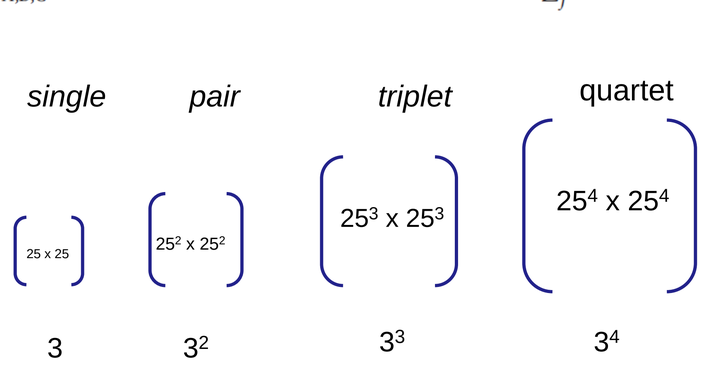


$$H_S(j) = H_{CF} + H_{JT}(j) + H_{TR} + H_{SO} + H_B$$

Tetrahedral crystal field — Jahn-Teller splitting — Trigonal distortion — Spin-orbit coupling — Zeeman splitting

j = A, B, C

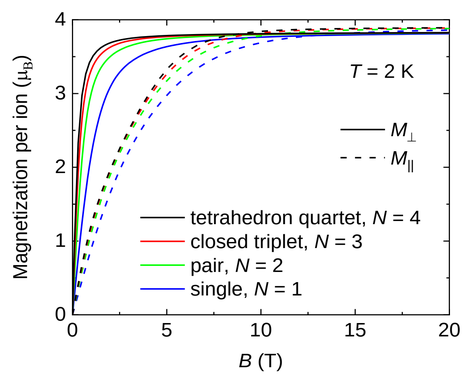
$$\langle \mathbf{M} \rangle = Z^{-1} \sum_{j=A,B,C} Z_j \mathbf{M}^j, \qquad \mathbf{M}^j = \frac{-\sum_{k=1}^{W} \langle \varphi_k^j | g_L \hat{\mathbf{L}} + g_S \hat{\mathbf{S}} | \varphi_k^j \rangle \exp(-E_k^j/(k_B T))}{Z_j};$$

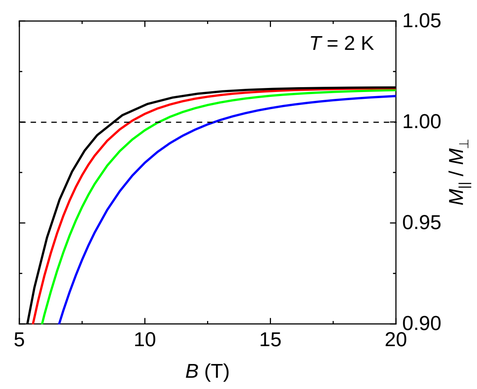


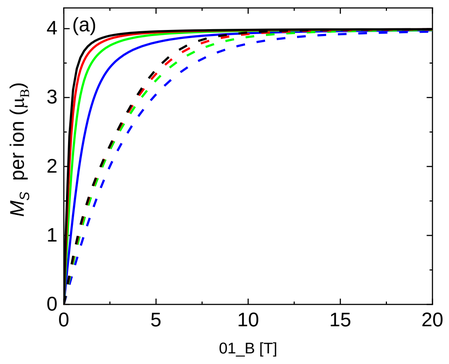
Jahn-Teller configurations

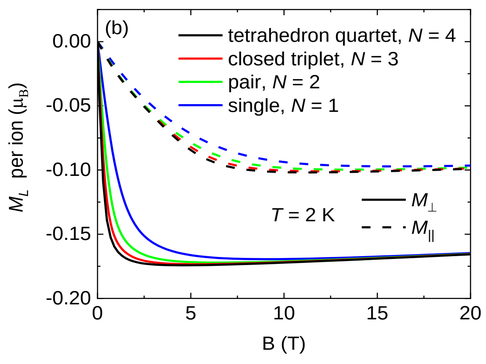
Eigenfunctions and eigenvalues are obtained by a numerical diagonalization of the full (25 × 25), (25² × 25²), (25³ × 25³), (25⁴ × 25⁴) *Hamiltonian matrix, for a single ion, pair, triplet or* quartet, respectively.

First spin orbital reorientation transition



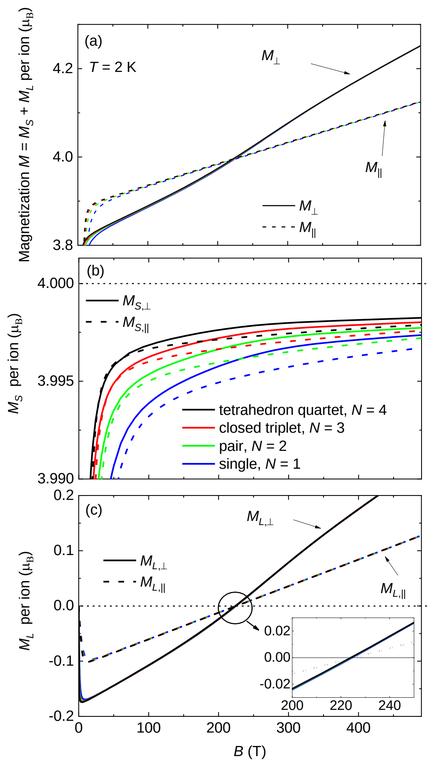


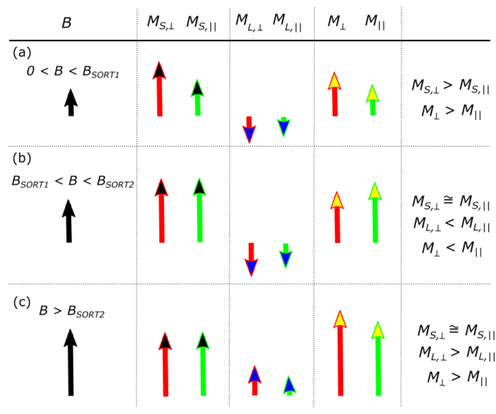




The spin M_S (a) and orbital momentum M_L (b) contributions (per one ion) to the total magnetization $M = M_S + M_L$.

Second spin orbital reorientation transition





Schematic explanation of the observed spin reorientation like transitions.

Red and green arrows denote the magnetizations M_S, M_L and $M = M_S + M_L$ calculated for the magnetic field applied perpendicular and parallel to the **c** axis of GaN respectively. (a) The magnetic anisotropy (MA) is controlled by the dominant spin component M_S. Antiparallel alignment of M_S and M_L is due to the presence of spin-orbit interaction λ**LS** with λ > 0. (b) and (c) In the spin saturation regime with $M_{S,\perp} = M_{S,||} = 4$ μB per ion, MA depends on values of the orbital contribution M_L to the total magnetization M. (c) A very strong magnetic field B overcomes the influence of the spin-orbit interaction what results in the reversal of M_L and the occurrence of the second spin reorientation like transition.

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