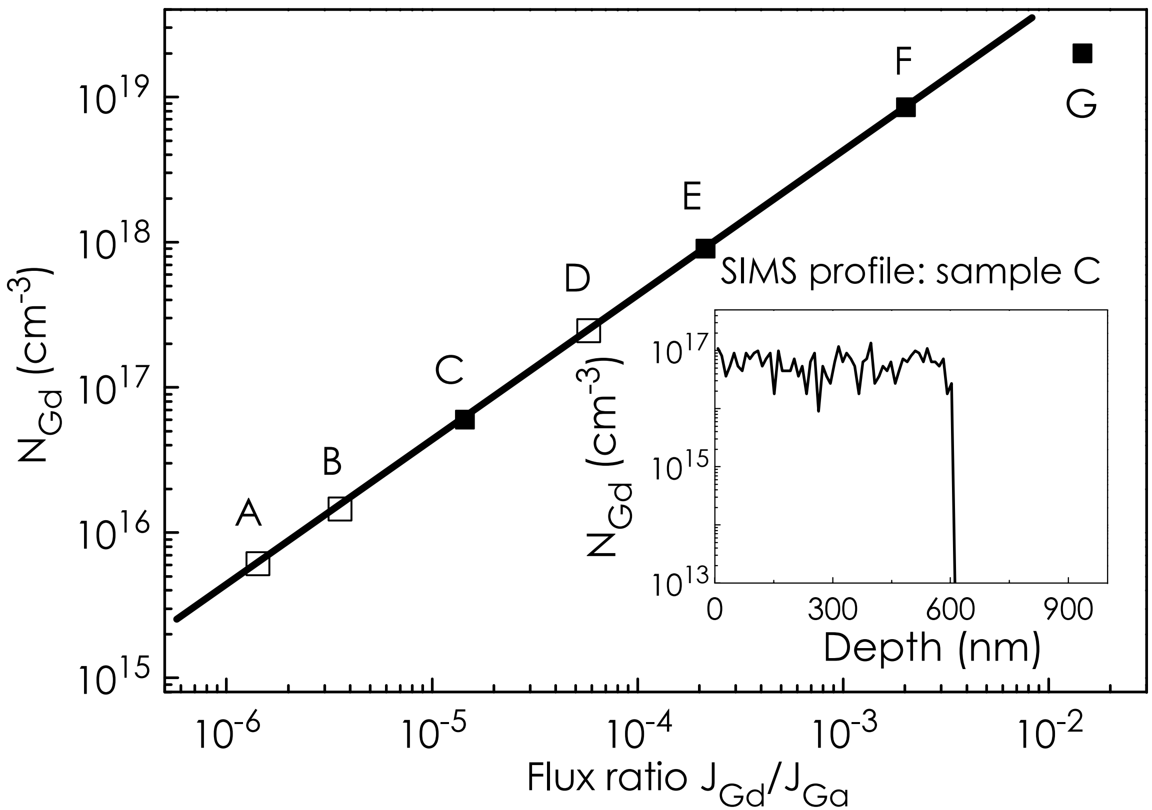
Growth

Reactive (NH3)molecular-beam epitaxy on 6H-SiC(0001) Substrate with Ts = 810° C

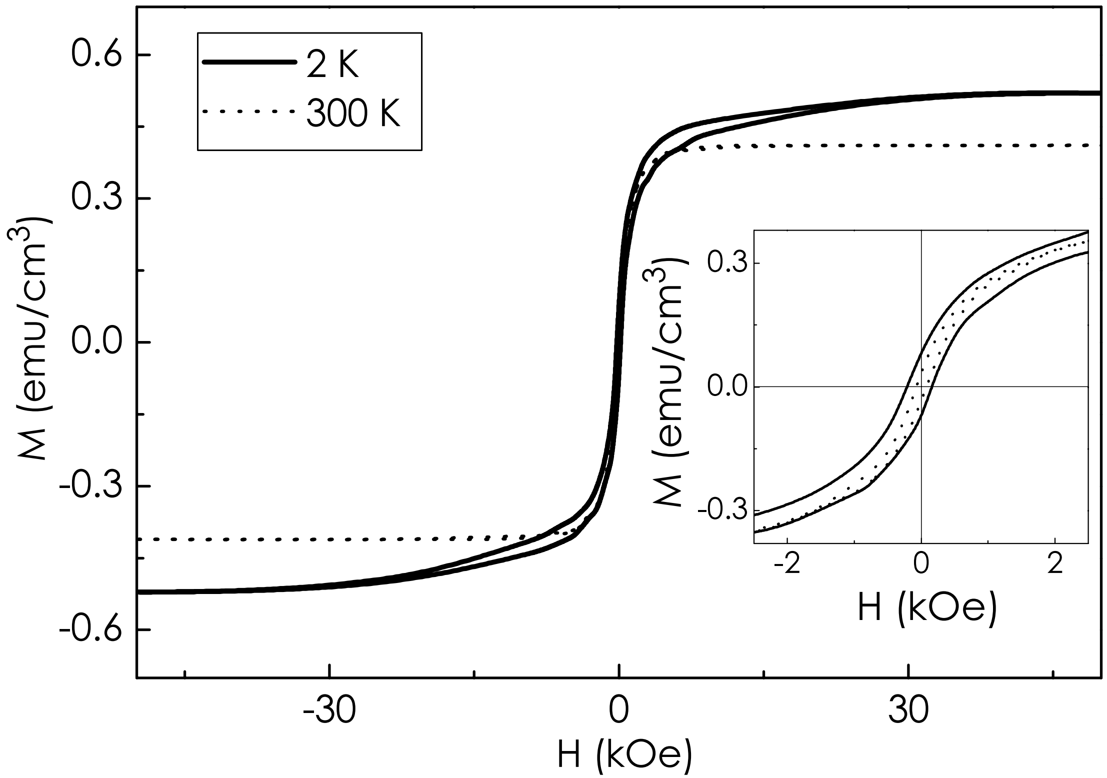


Gd corporation varies linearly with J_{Gd}/J_g

Electrically highly resistive

Magnetic Hysteresis

Sample C ($N_{Gd} \sim 6 \times 10^{16}$ cm^{-3})



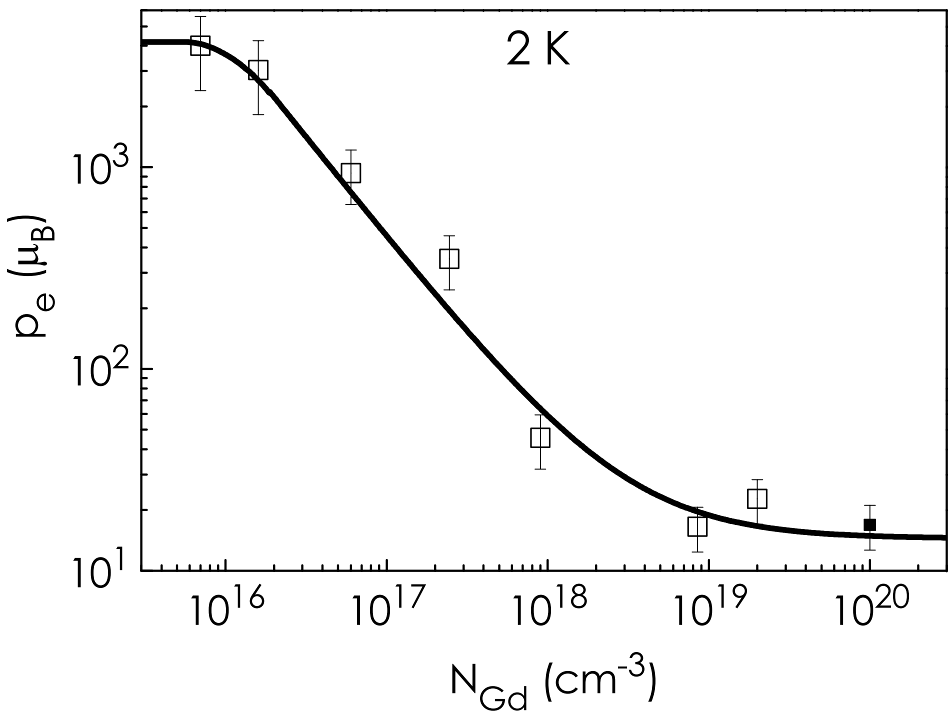
Clear hysteresis at 2 K and 300 K

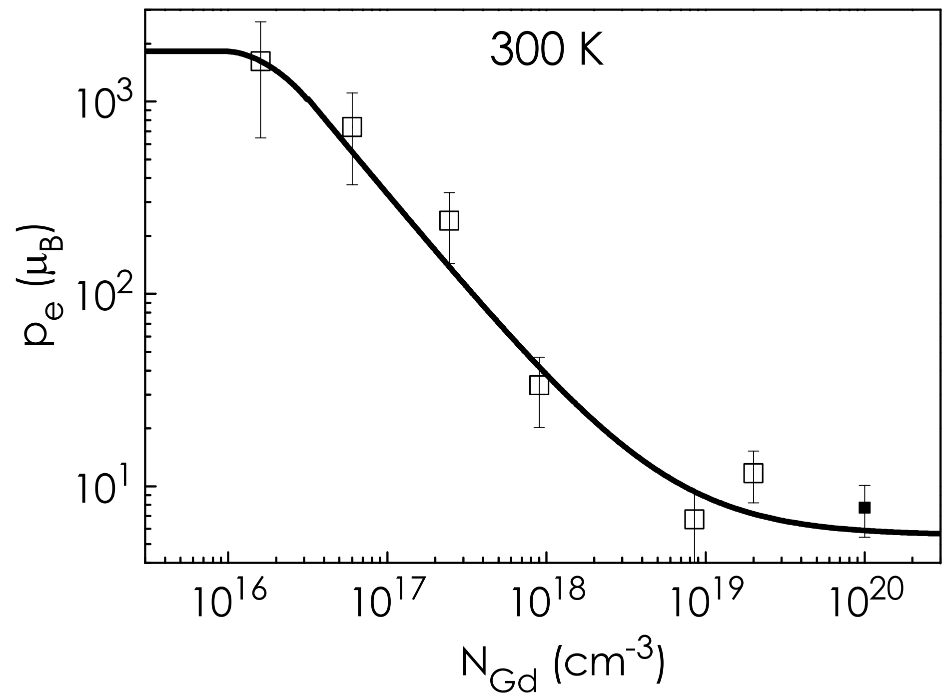
Magnetization saturates at high fields

⇓

Ferromagnetism

Colossal Magnetic Moments





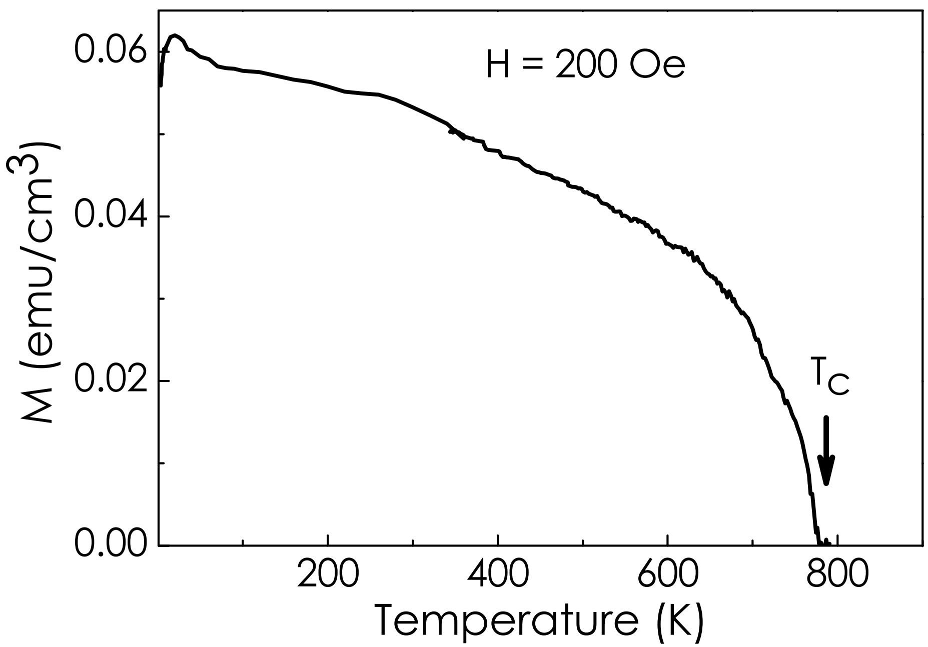
Average moment per Gd atom ⇒ as high as 4000 μ_B

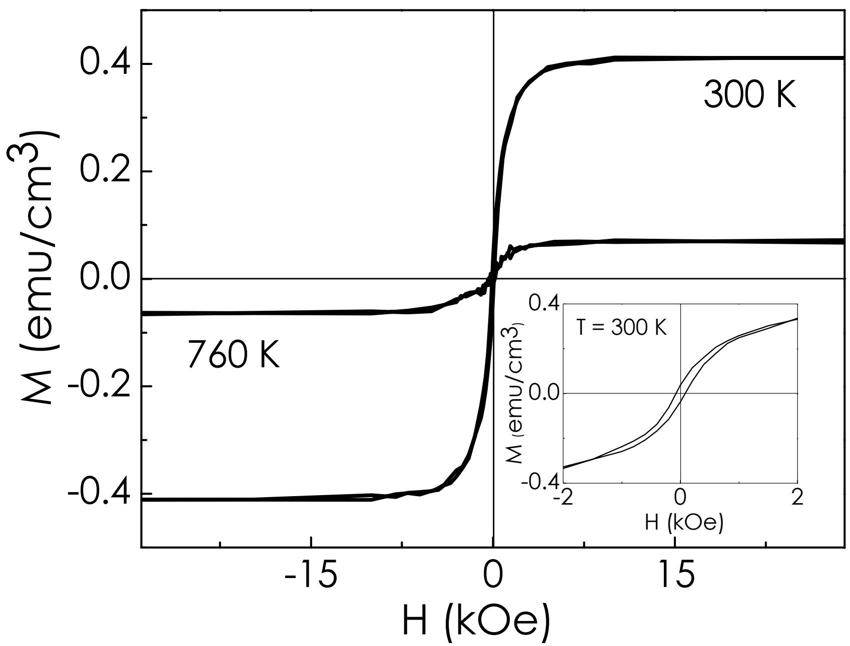
Fit returns

2 K: $p_m = 1.1 \times 10^{-3}$ μ_B, r = 33 nm

300 K: $p_m = 8.4 \times 10^{-4}$ μ_B, r = 25 nm

Magnetic Results: Sample B





Motivation

Search for ferromagnetic (FM) semiconductor with T_C > 300 K
TM doped wide band-gap semiconductors seem to be good candidates

Previous results from (Ga,Mn)N

Homogeneous layer exhibits spin-glass behavior
Ferromagnetism with T_C > 300 K is caused by precipitates (clusters)[1]
Electrically resistive

Previous results from (Ga,Gd)N

Found to be FM with T_C > 300 K[2]

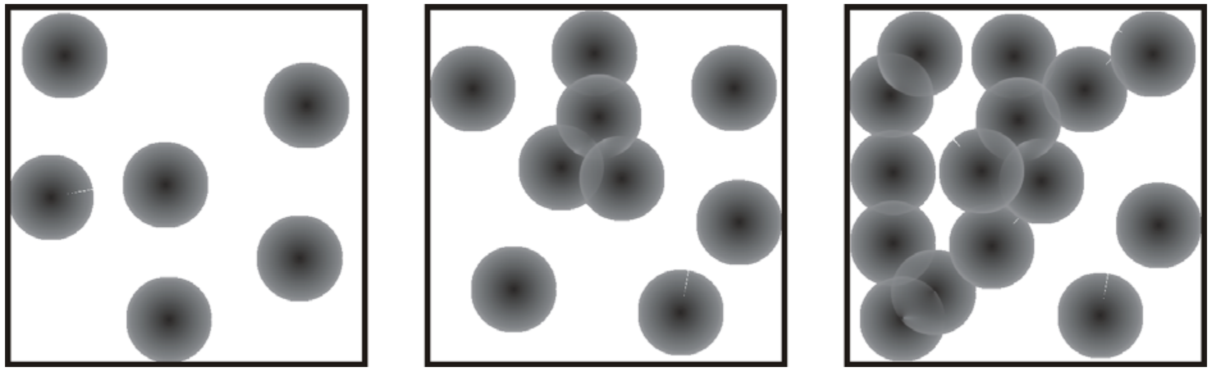
Advantages of Gd

Magnetic moment $8\mu_B$, larger than that of any TM atom
Only rare earth element with both 4*f* and *5d* orbitals partially filled

[1] S. Dhar *et al.,* Appl. Phys. Lett., **82**, 2077 (2003)
[2] N. Teraguchi *et al.,* Sol. State. Commun., **122**, 651 (2002)

Empirical Model

Origin of colossal moment: Gd atoms polarize the matrix



$$p_e = p_{Gd} + p_m \nu N_o/N_{Gd};\ \nu = 1\text{-}\exp(-v N_{Gd})$$

Expected $\Rightarrow$ p_e decreases as N_{Gd} is increased $\Leftarrow$ Experimentally observed

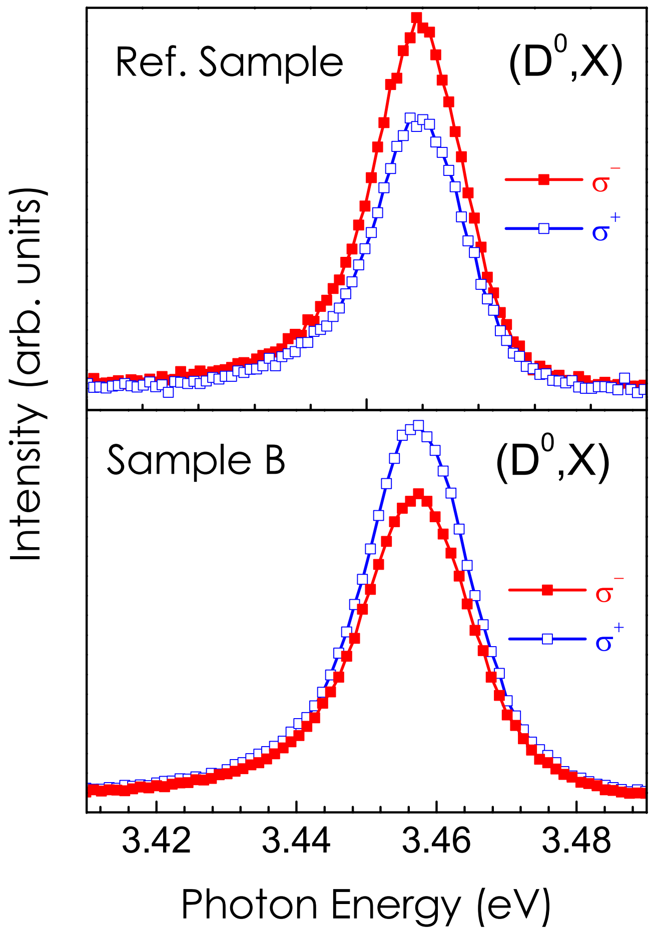
Ferromagnetism: overlap of spheres → ferromagnetic coupling

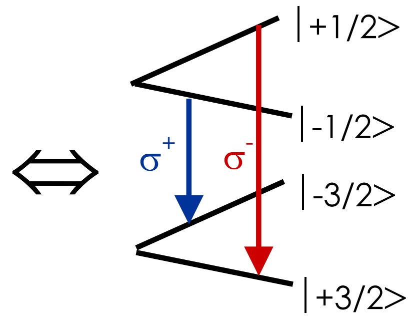
Expected $\Rightarrow$ T_c increases with N_{Gd} $\Leftarrow$ Experimentally observed

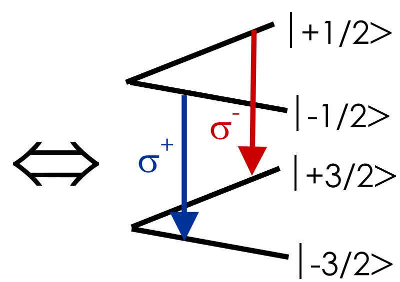
Magneto-Photoluminescence

No magnetic field: PL spectra for all samples dominated by (D°,X) transition
⇒ characteristic for GaN

B = 10 T in Faraday geometry (**B** || c)







Donor responsible for (D°,X): Oxygen concentration ≈ 10^{18} cm^{-3} (SIMS)

Polarization in sample B has opposite sign as compared to the Ref. Sample

Average Gd to (D°,X) distance in B:
≈ 12 nm ⇒ Gd has a long-range influence on the GaN matrix