Magnetostructural-transition related multifunctionality in martensitic Heuslers

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Outline

Elemental properties of Fe and Mn
Martensitic transformations and Heuslers
Magnetic interactions in martensitic Heuslers

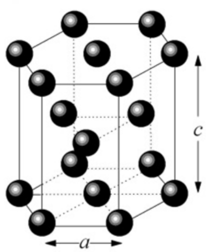
Structure of the transition elements and elements with wrong crystal structures

complex cubic bcc hcp

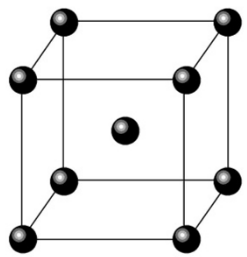
Number of s + d electrons

Period ↓	3	4	5	6	7	8	9	10	11
3d, 4s	Sc	Ti	V	Cr **AF**	[Mn][1] **AF**	[Fe][2] **FM**	[Co][3] **FM**	Ni **FM**	Cu
4d, 5s	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag
5d, 6s	(La)	Hf	Ta	W	Re	Os	Ir	Pt	Au
Structure	hcp	hcp	bcc	bcc	hcp	hcp	fcc	fcc	fcc

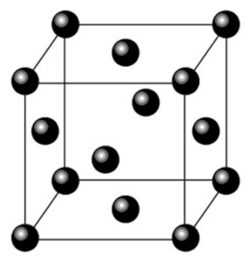
The elements shown in brackets have the "wrong" crystal structure in the ground state.
[1] complex cubic (A12); [2] bcc; [3] hcp
AF: antiferromagnetic; **FM**: ferromagnetic



hcp



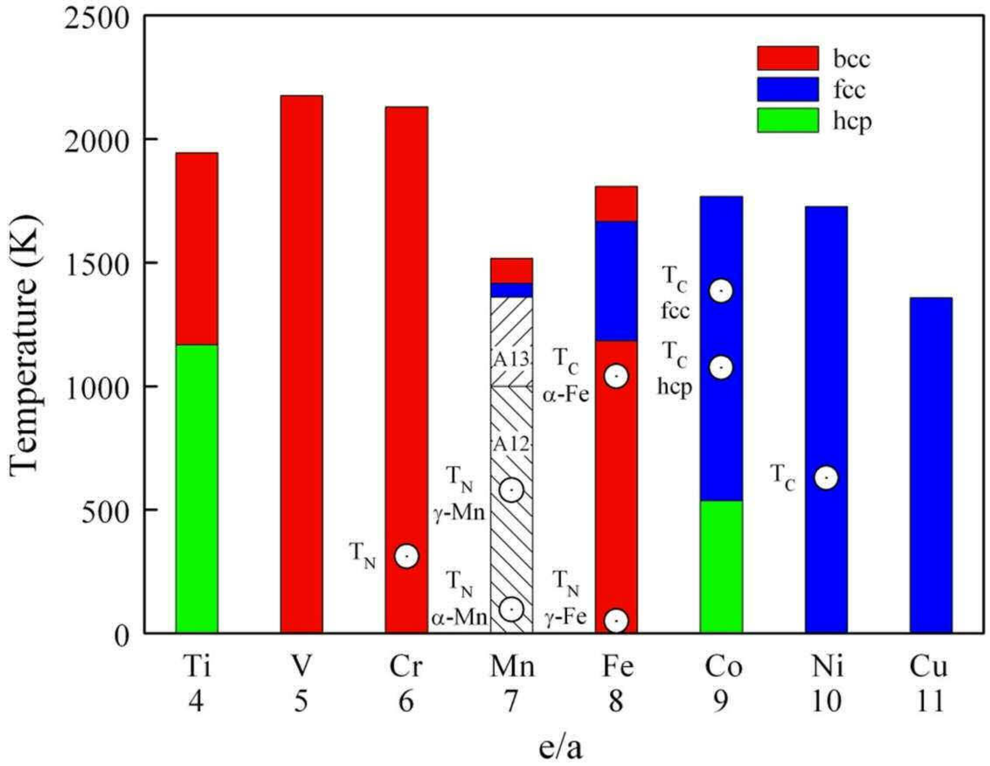
bcc



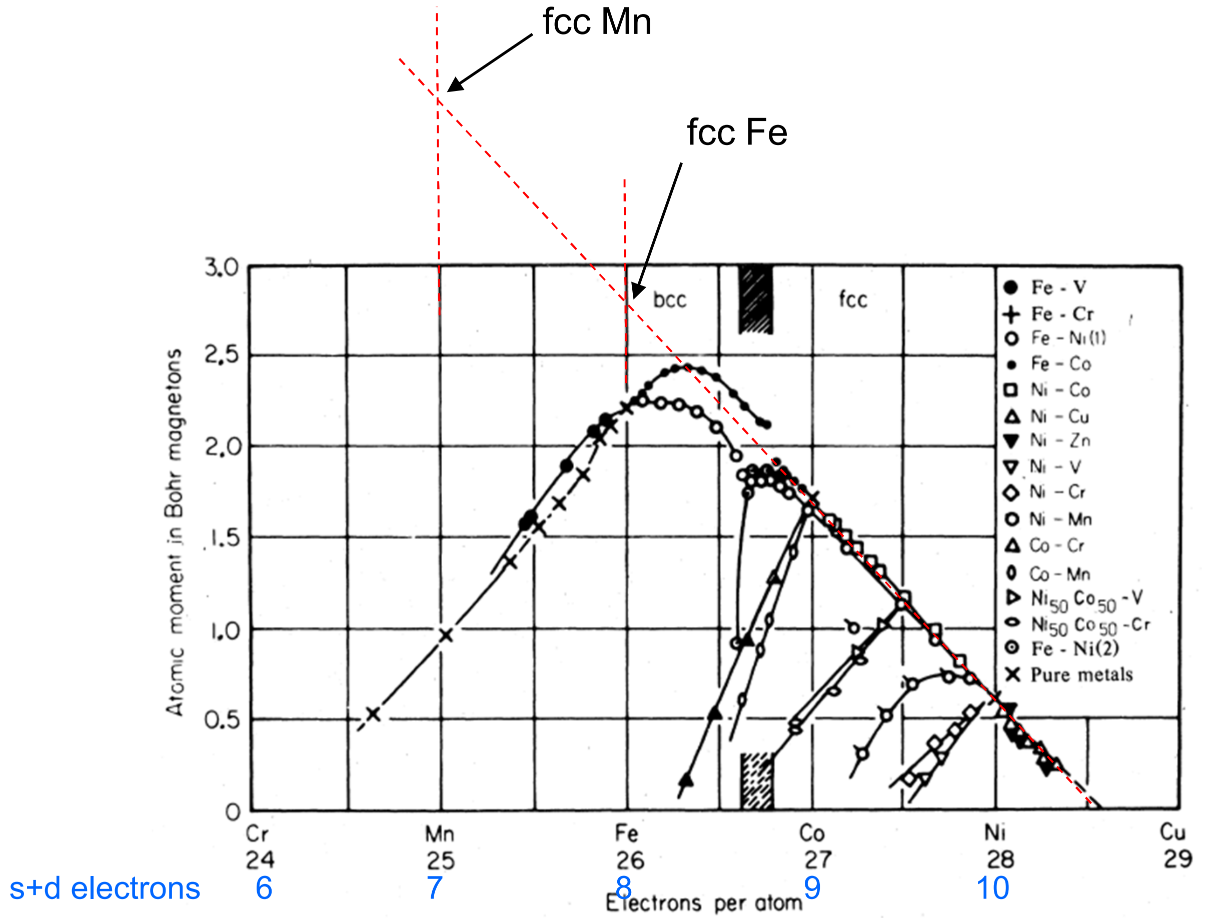
fcc

Allotropy in the 3d elements

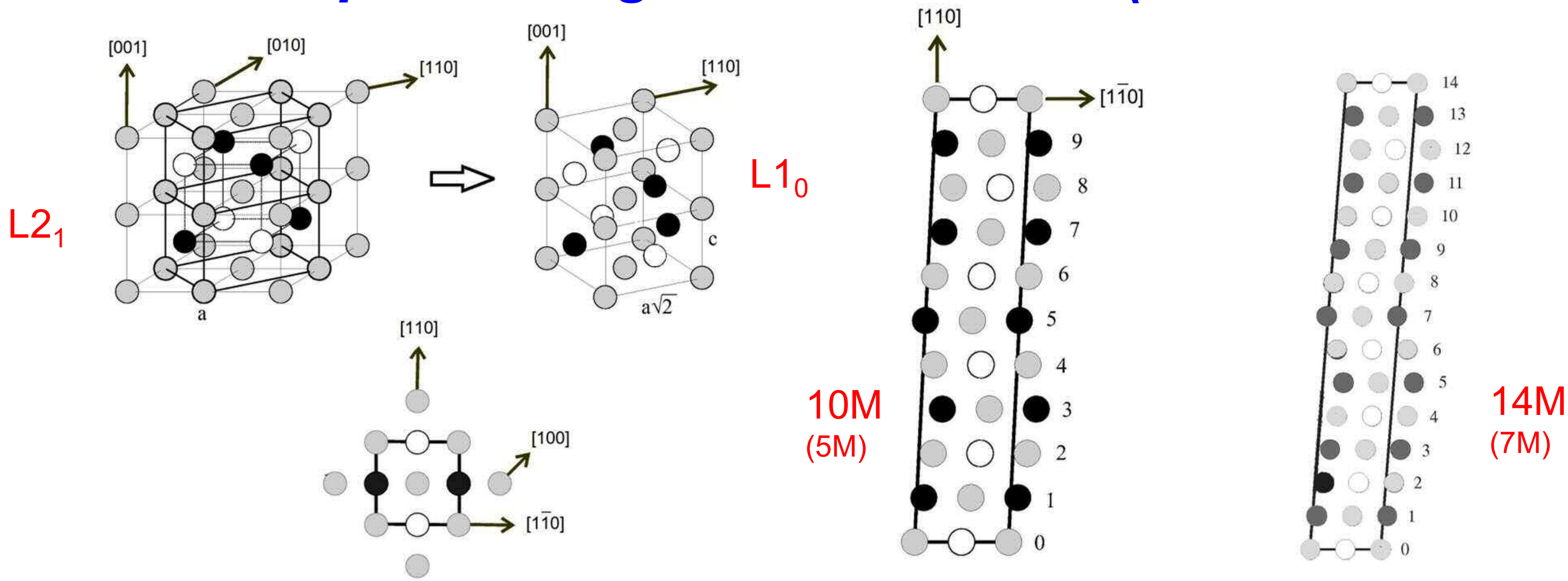
Period ↓	3	4	5	6	7	8	9	10	11
3d, 4s	Sc	Ti	V	Cr **AF**	[Mn][1)] **AF**	[Fe][2)] **FM**	[Co][3)] **FM**	Ni **FM**	Cu
4d, 5s	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag
5d, 6s	(La)	Hf	Ta	W	Re	Os	Ir	Pt	Au
Structure	hcp	hcp	bcc	bcc	hcp	hcp	fcc	fcc	fcc

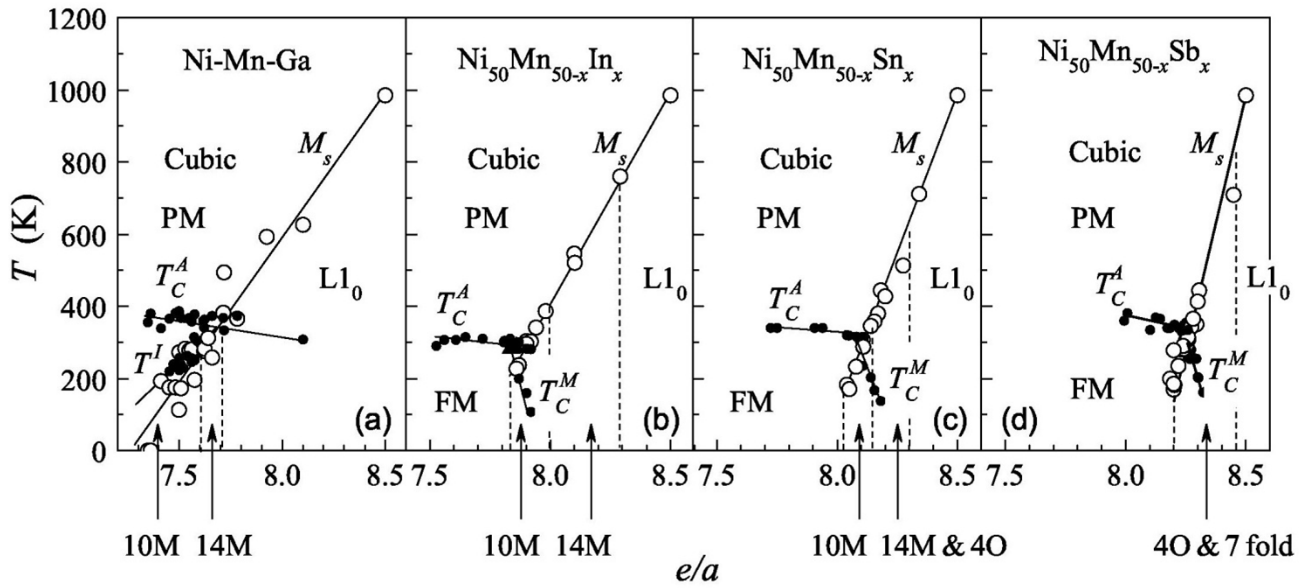


Rigid band model and the Slater-Pauling curve: Valence electron concentration dependence of the magnetic moment



Structure and phase diagrams of Ni-Mn-Z (Z: Ga, In, Sn, Sb)





(e/a):
Concentration weighted number of

s+d (3d elements)
+
s+p (main group)

Some features of Heusler alloys

Heusler alloys

Shape memory (nonmagnetic martensite)

Cu-Ni-Al
Cu-Zn-Al

Magnetic field induced Structural modifications (magnetic martensite)

Ni-Mn-Ga
Co-Mn-Al
Ni-Mn-In

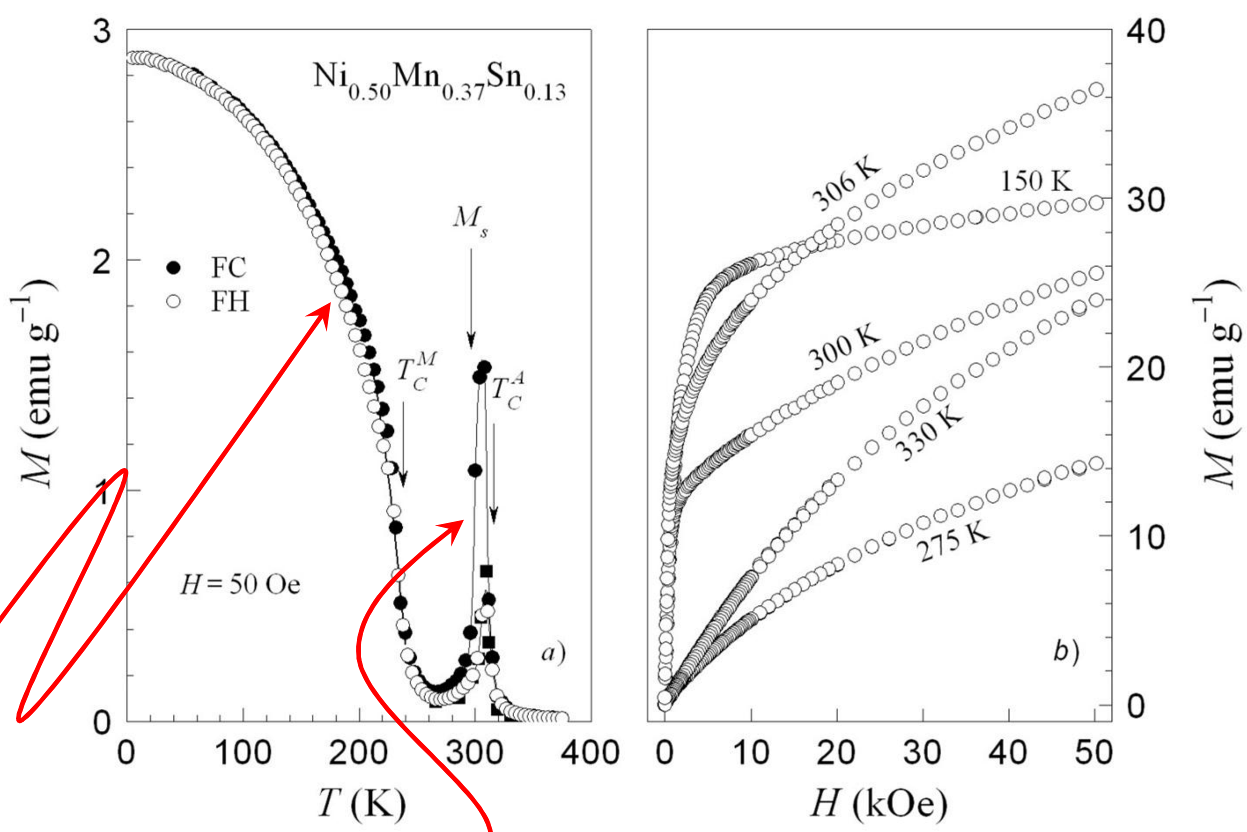
Magnetocaloric effect

Ni-Mn-Ga
Ni-Mn-Sn
Ni-Mn-In

Electron spin polarization

half metallic properties in ferromagnetic Heuslers

The magnetization of Ni-Mn-Z (Z: Ga, In, Sn, Sb)



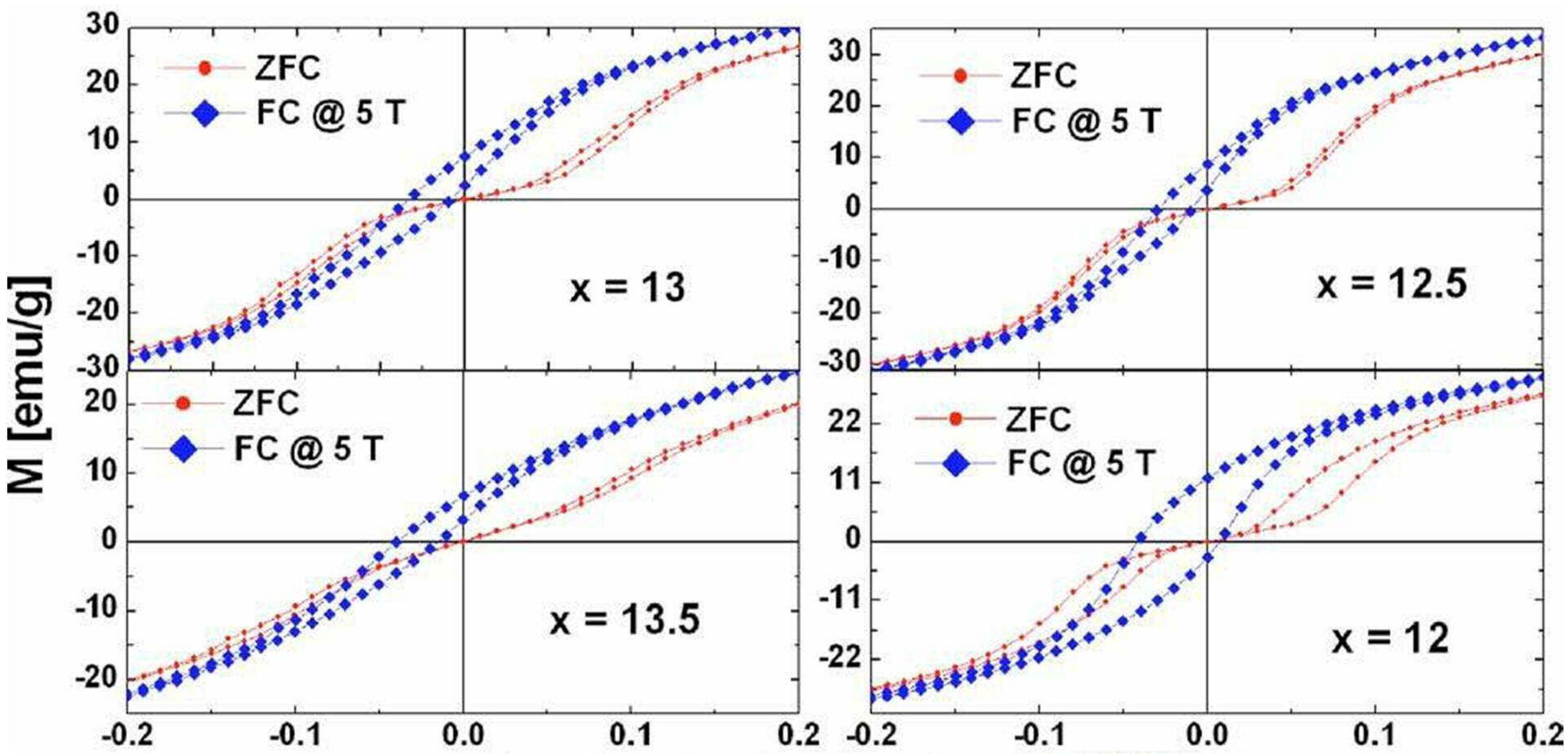
Why is the FM transition smeared over the temperature?

Why does M(T) drop?

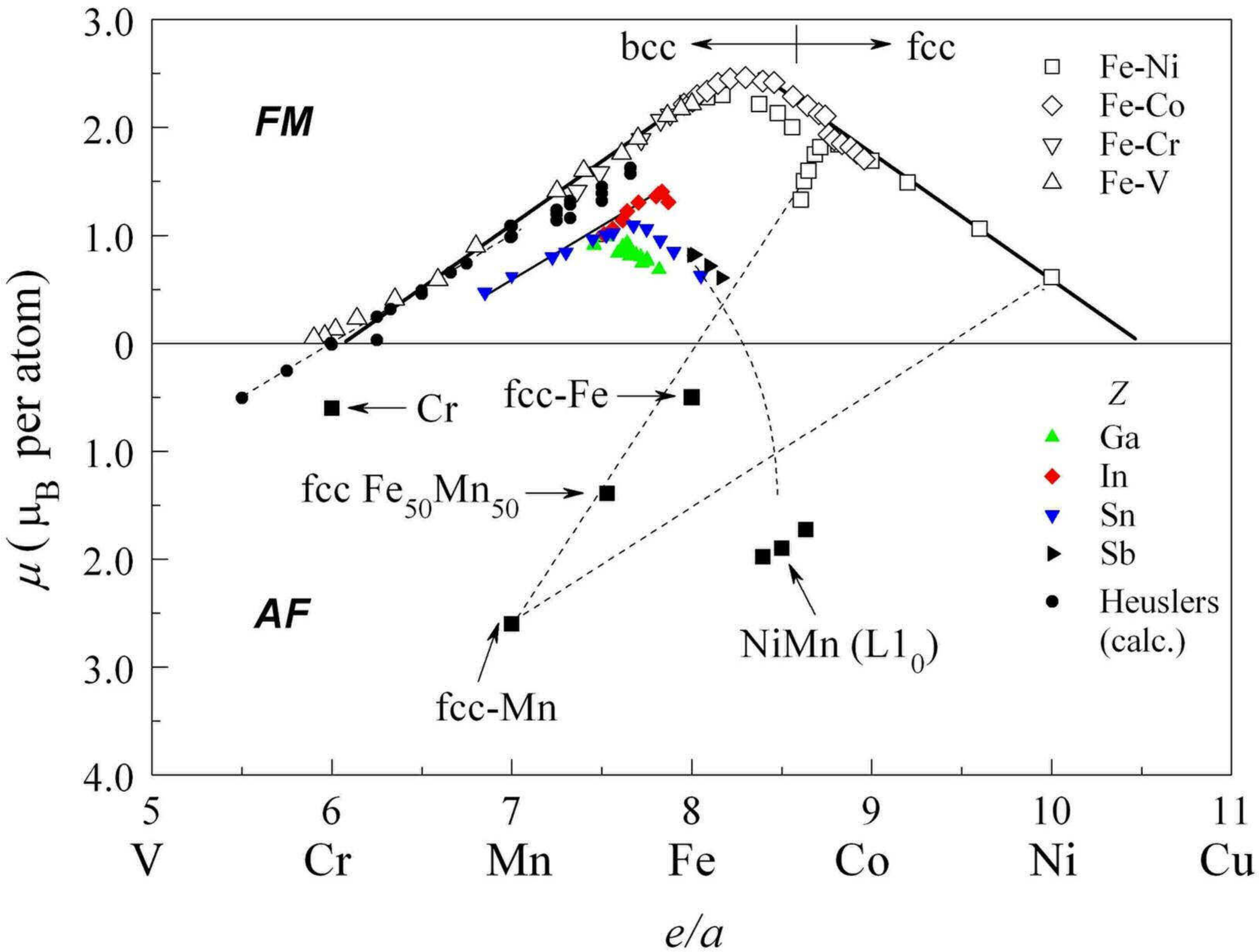
APPLIED PHYSICS LETTERS **91**, 072510 (2007)

Exchange bias behavior in Ni–Mn–Sb Heusler alloys

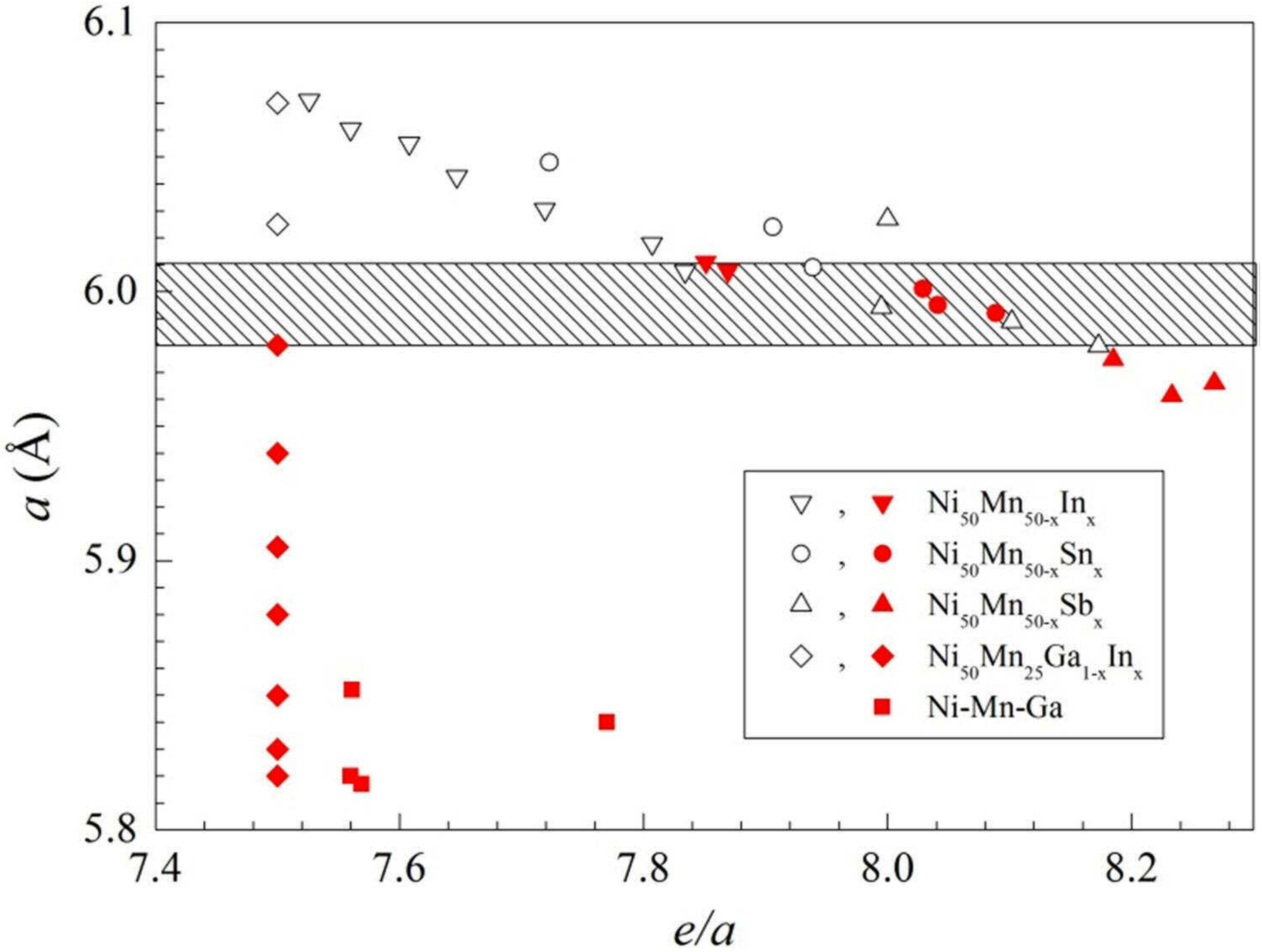
Mahmud Khan,[a)] Igor Dubenko, Shane Stadler, and Naushad Ali
Department of Physics, Southern Illinois University, Carbondale, Illinois 62901



Extended Slater-Pauling curve



Mn-Mn separation and the martensitic transformation in Heuslers

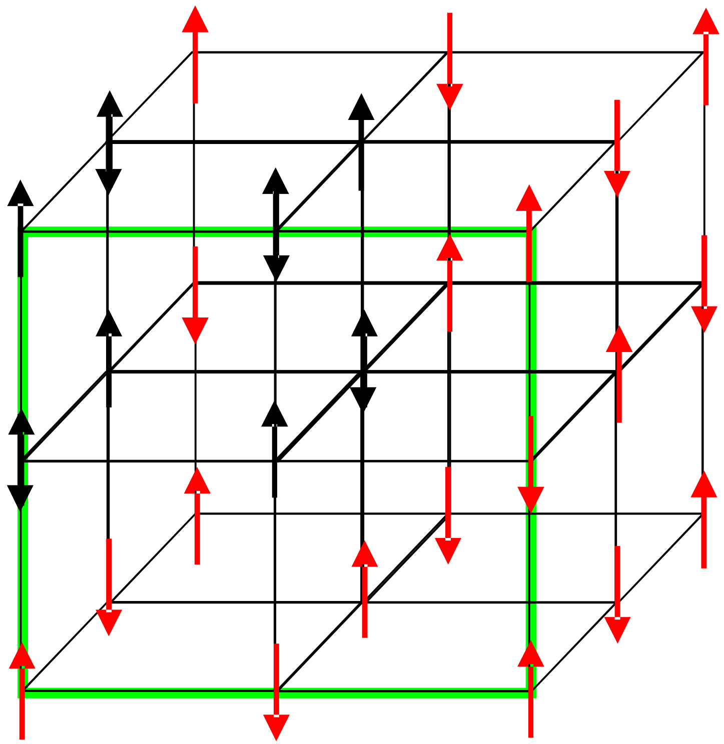


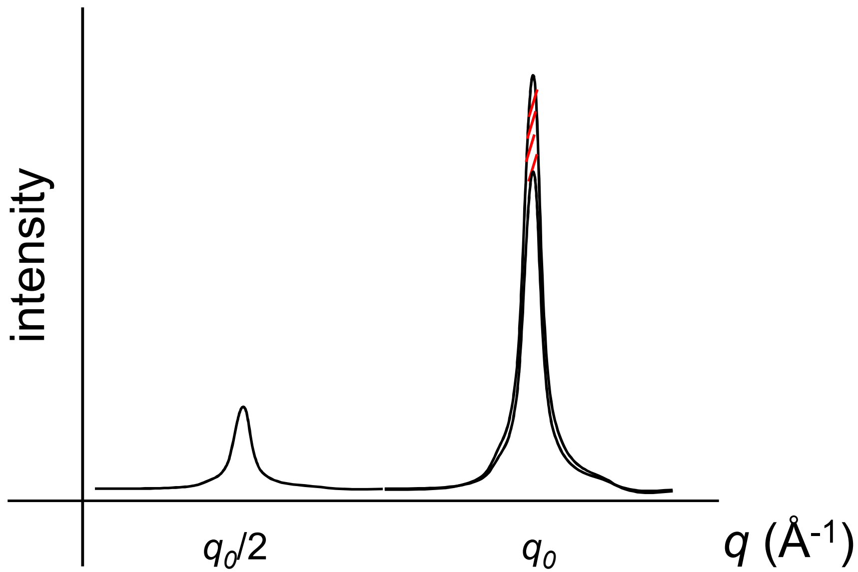
Martensitic transformation takes place for $d_{Mn\text{-}Mn}$ ~ 3 Å:

Is there any relationship between the martensitic transformation and the onset of AF-exchange?

Complementary

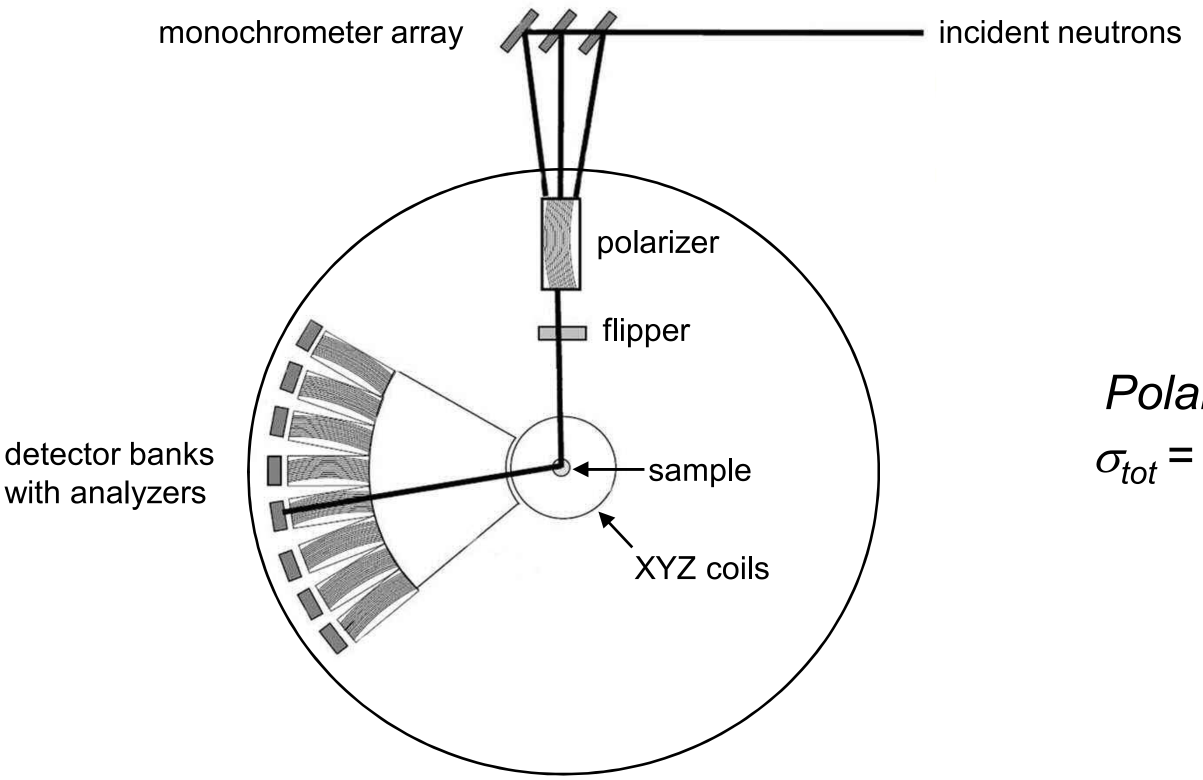
Neutron polarization analysis
Ferromagnetic resonance





$$q = \frac{4\pi \sin\theta}{\lambda}$$

XYZ polarization analysis and neutron depolarization (D7/ILL)

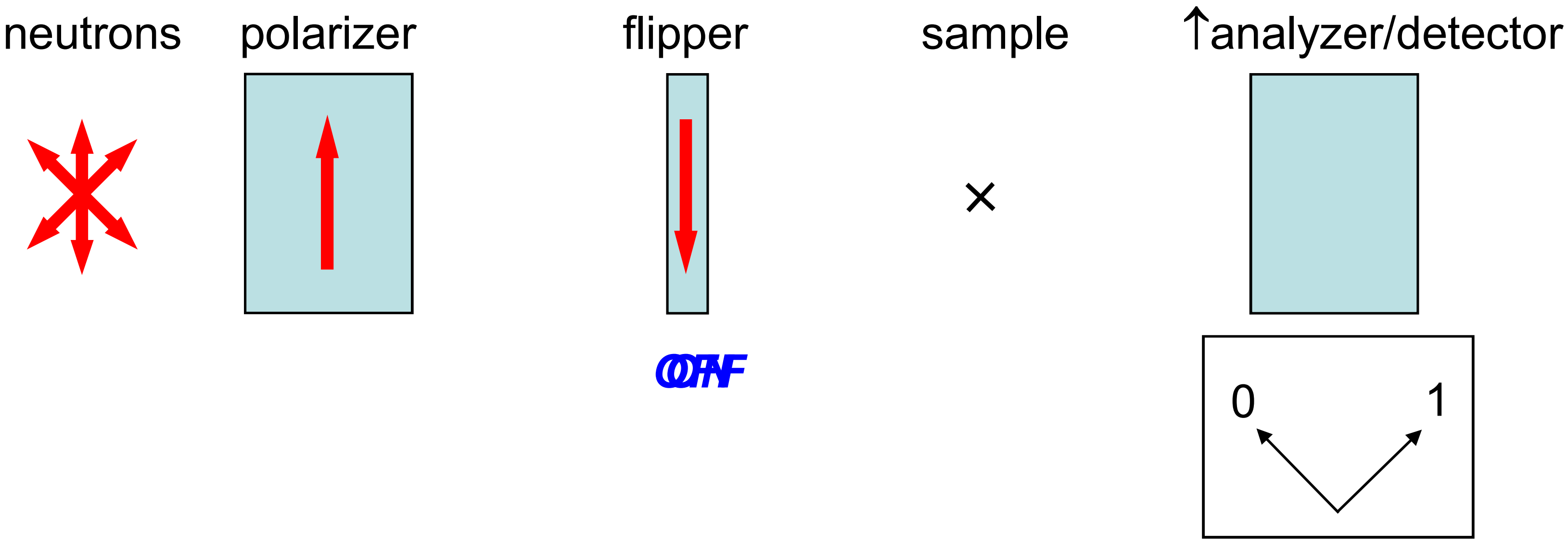


D7

Polarization analysis

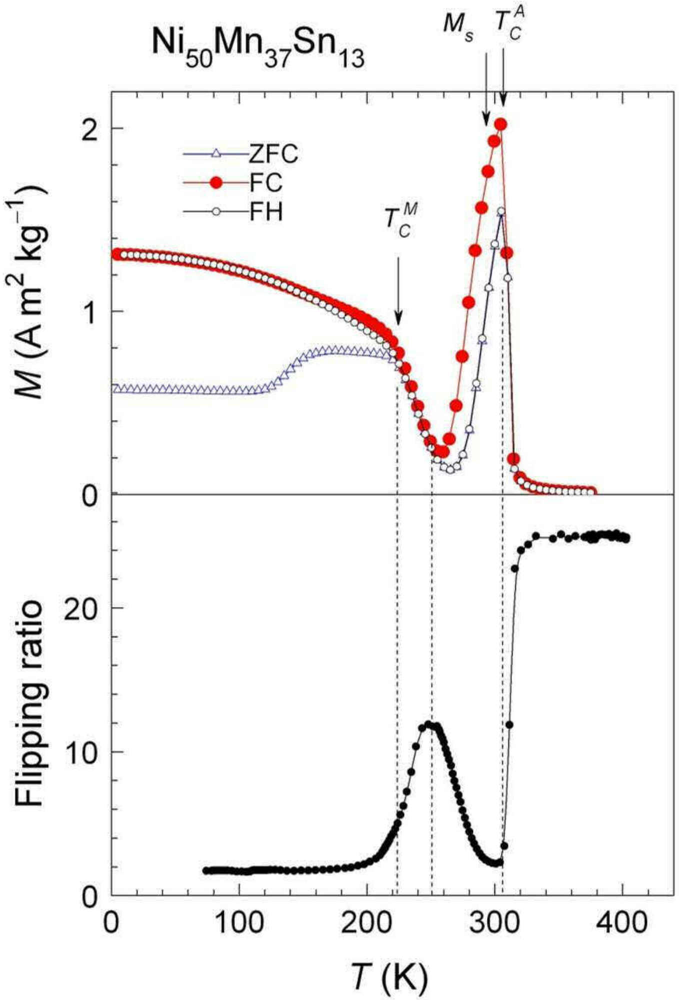
$$\sigma_{tot} = \sigma_{coh} + \sigma_{incoh} + \sigma_{mag}$$

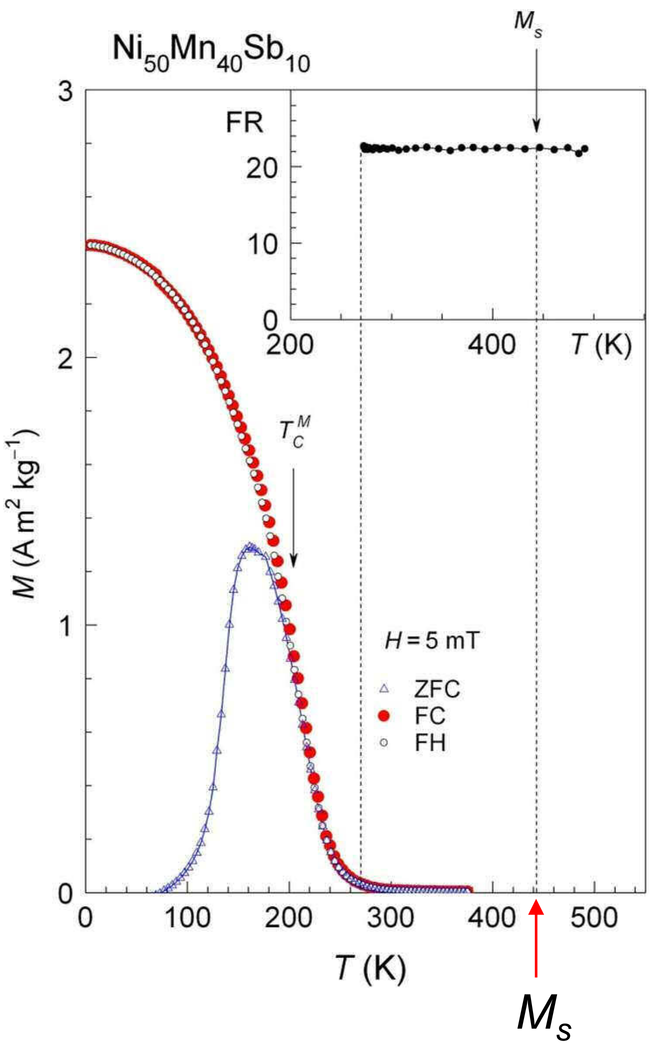
Neutron depolarization and the flipping ratio (R_f)



$$R_f = \frac{1 + n_{\uparrow}}{1 + n_{\downarrow}}$$

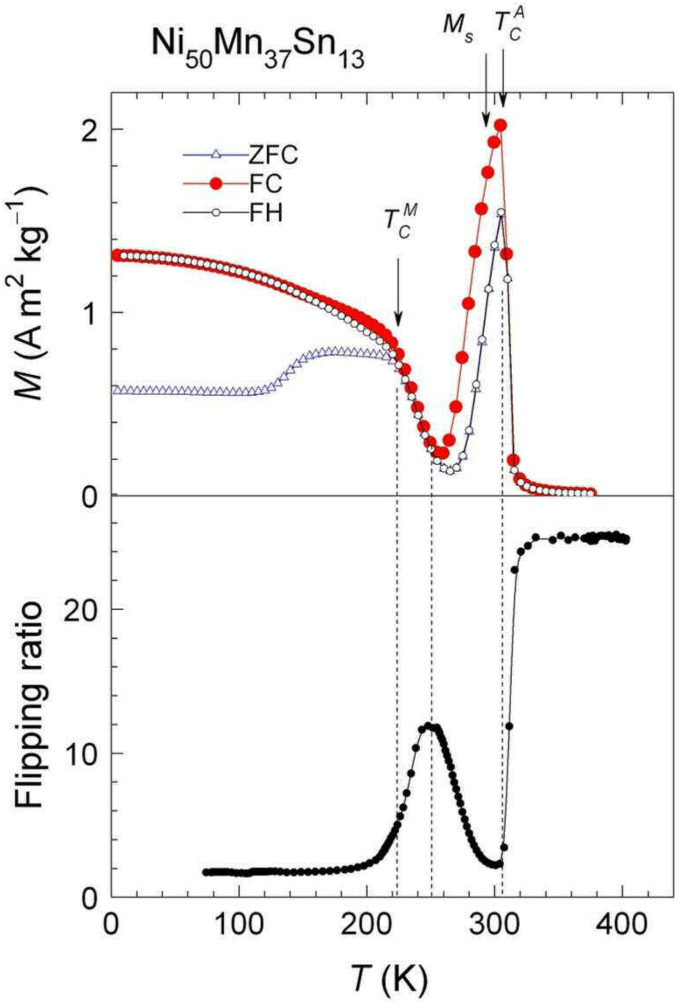
Magnetization and flipping ratio
Ni-Mn-Sn and Ni-Mn-Sb



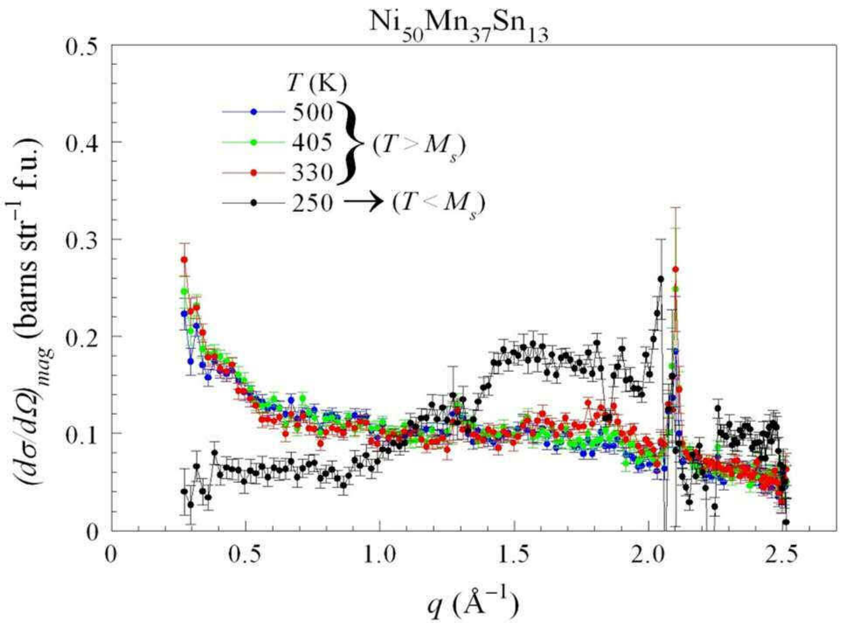


Ni-Mn-Sn: polarization analysis

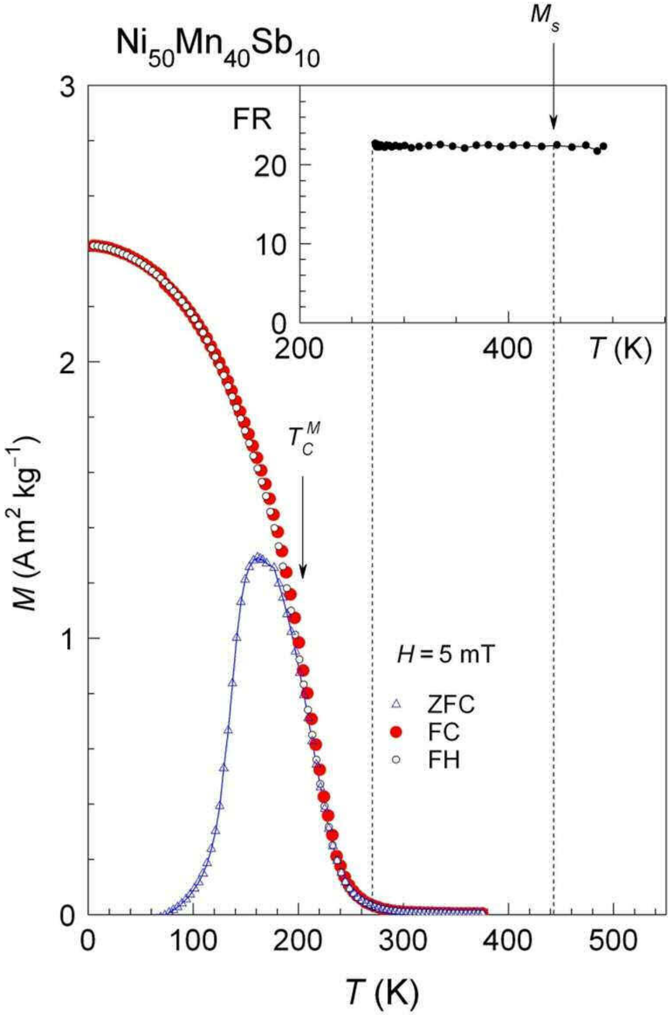
Neutron depolarization

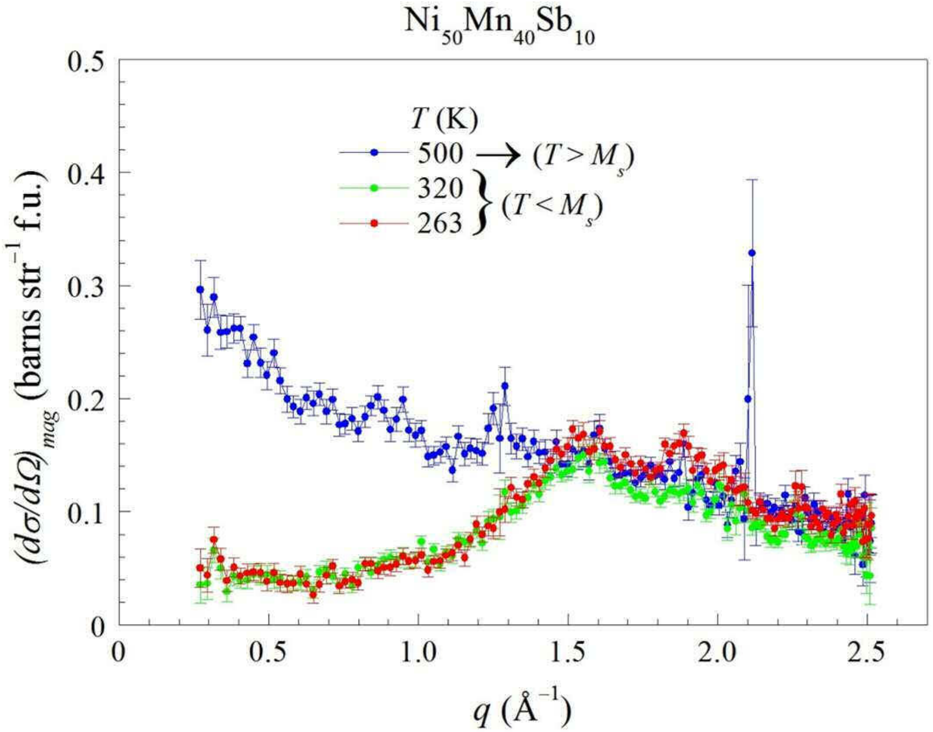


Magnetic scattering



Ni-Mn-Sb: polarization analysis

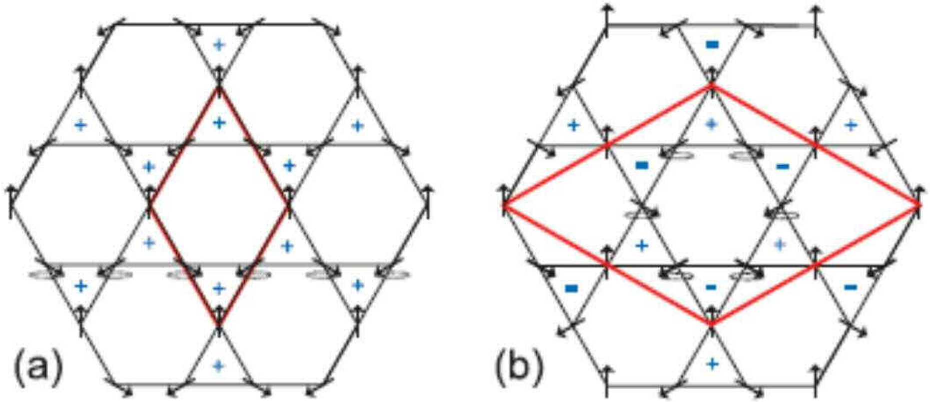




PRL 98, 067201 (2007) PHYSICAL REVIEW LETTERS week ending 9 FEBRUARY 2007

Approaching the Ground State of the Kagomé Antiferromagnet

W. Schweika,[1] M. Valldor,[2,*] and P. Lemmens[2]



Physica B 267–268 (1999) 139–141

Polarized neutron scattering study of the kagome antiferromagnet $SrCr_8Ga_4O_{19}$

C. Mondelli[a,*], K. Andersen[a], H. Mutka[a], C. Payen[b], B. Frick[a]

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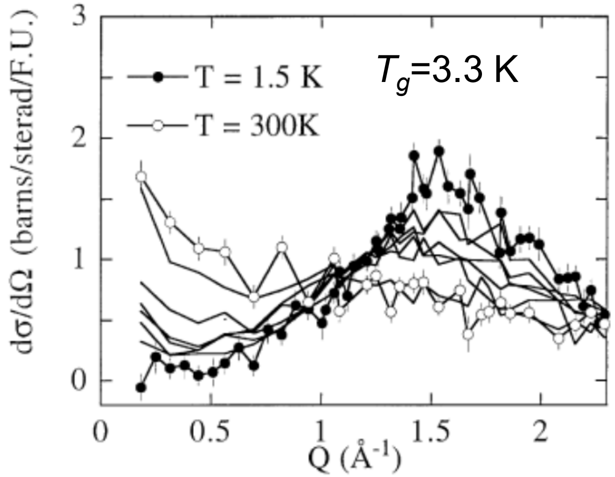
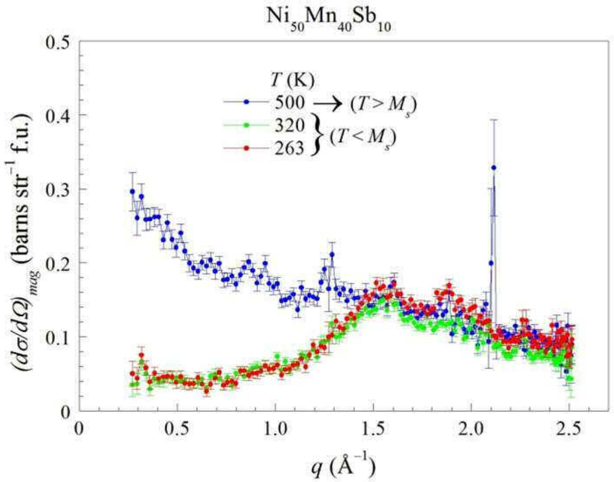
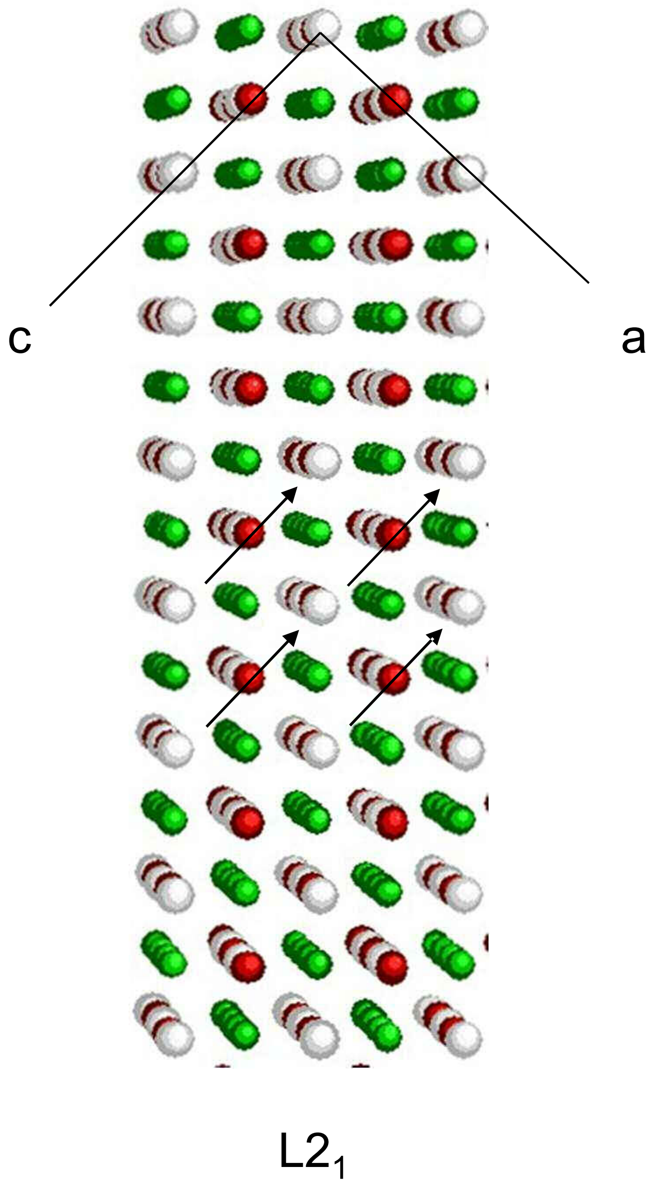
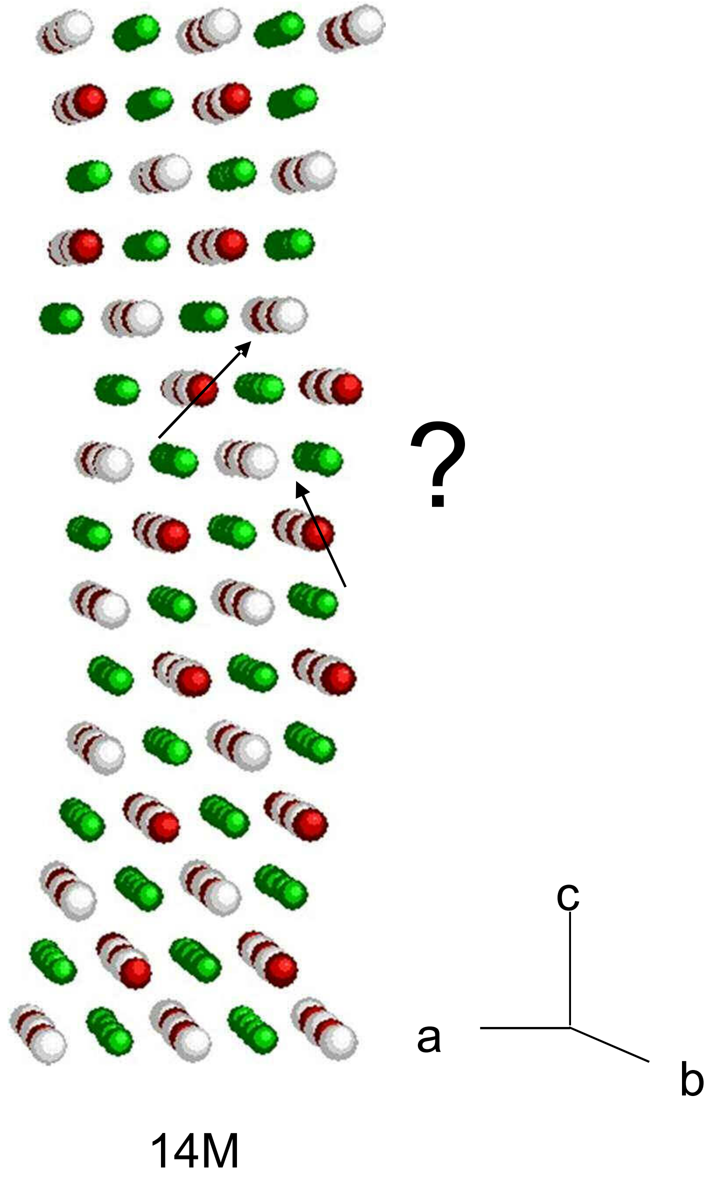
[b]*Institut des Matériaux de Nantes, BP 32229, 44322 Nantes Cedex 3, France*



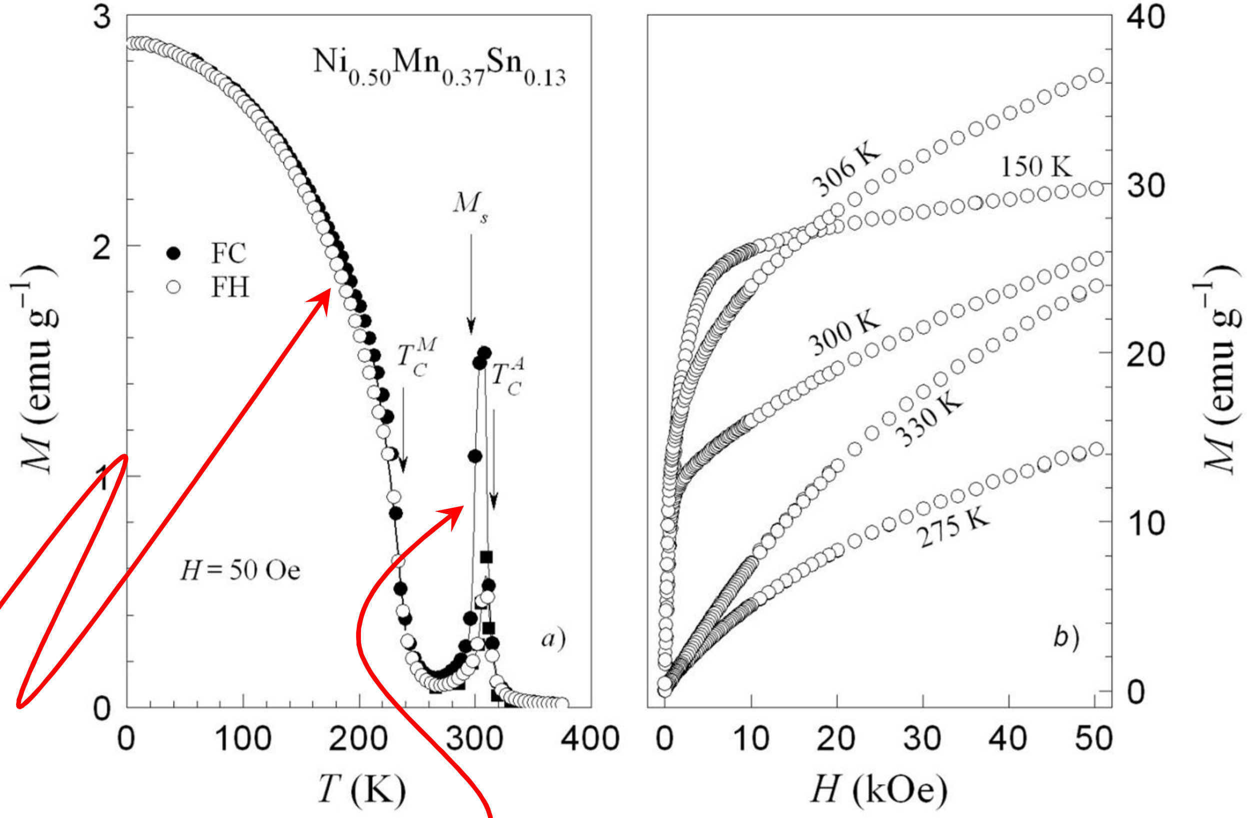


Moment configurations in austenite and martensitie





Summary

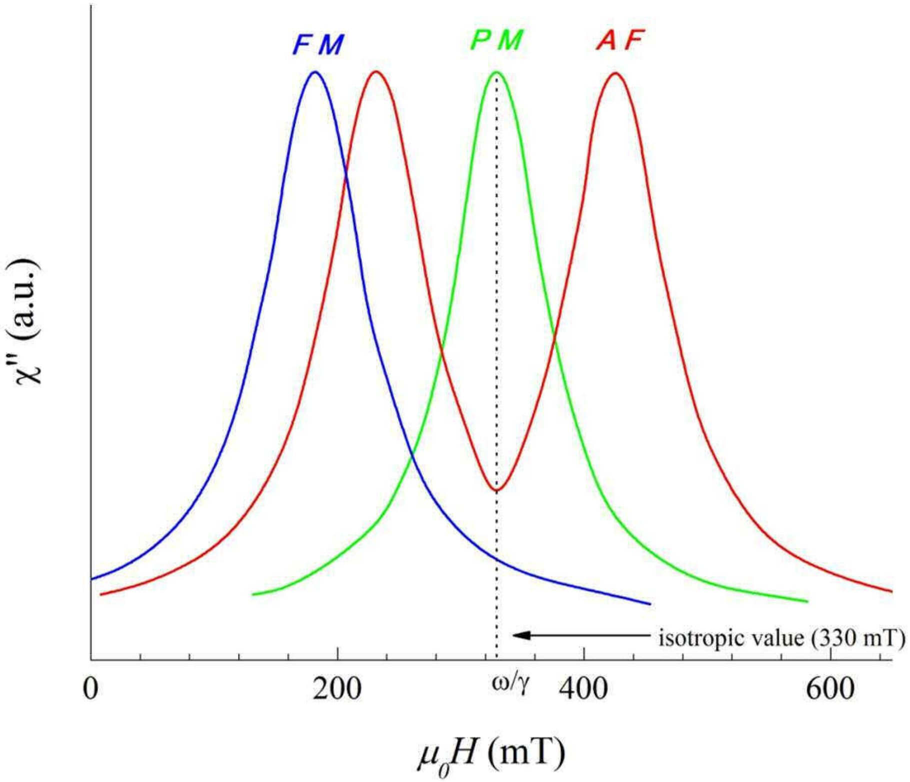


T_C(M) denotes the onset of FM and AF-like ordering

Drop in *M(T) caused by disappearance of FM coupling*

Mn and antiferromagnetism and Ms

Ferromagnetic resonance (FMR)



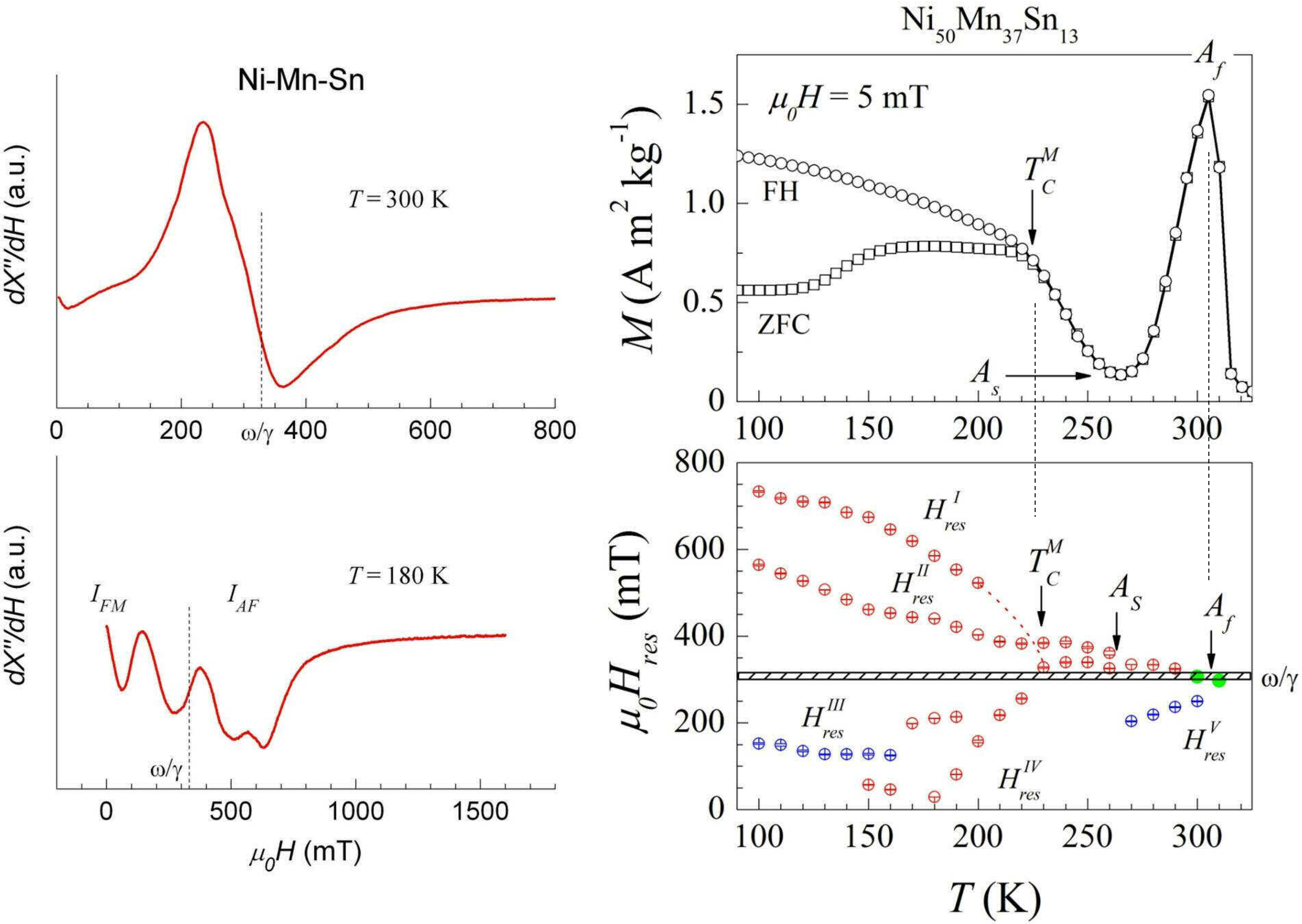
ω: instrument microwave frequency
γ: gyromagnetic ratio

$\mu_0 H_{res} = \omega/\gamma$ → PM

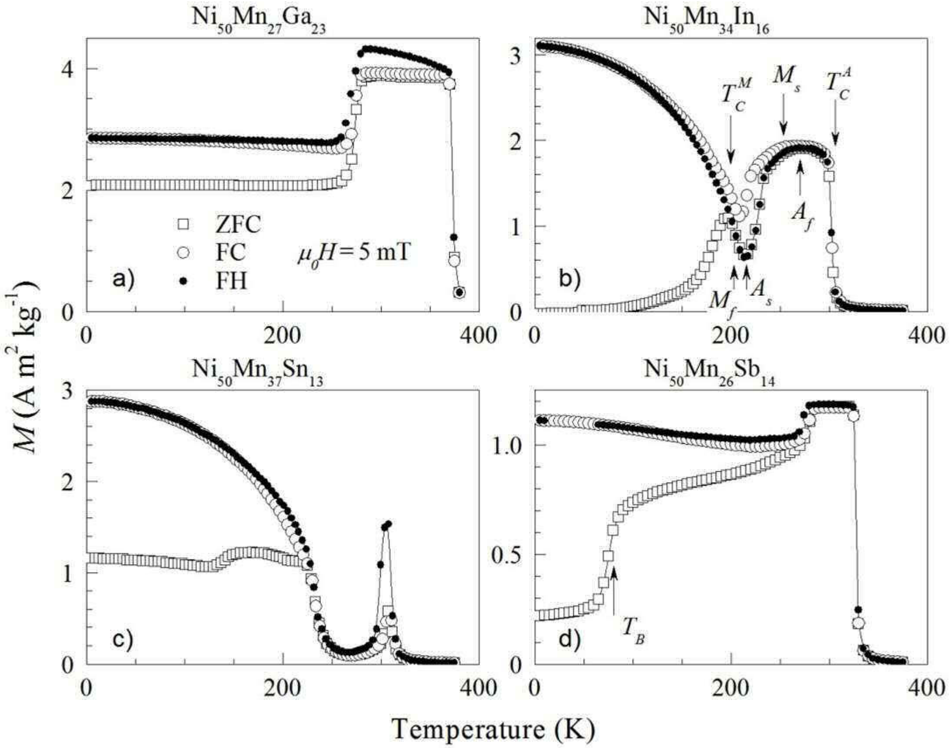
$\mu_0 H_{res} < \omega/\gamma$ → FM $\quad \mu_0 H_{res} = \dfrac{\omega}{\gamma} - \mu_0 H_A$

$\mu_0 H_{res}$ → AF $\quad \mu_0 H_{res} = \dfrac{\omega}{\gamma} \pm \sqrt{\mu_0 H_A (2H_E + H_A)}$

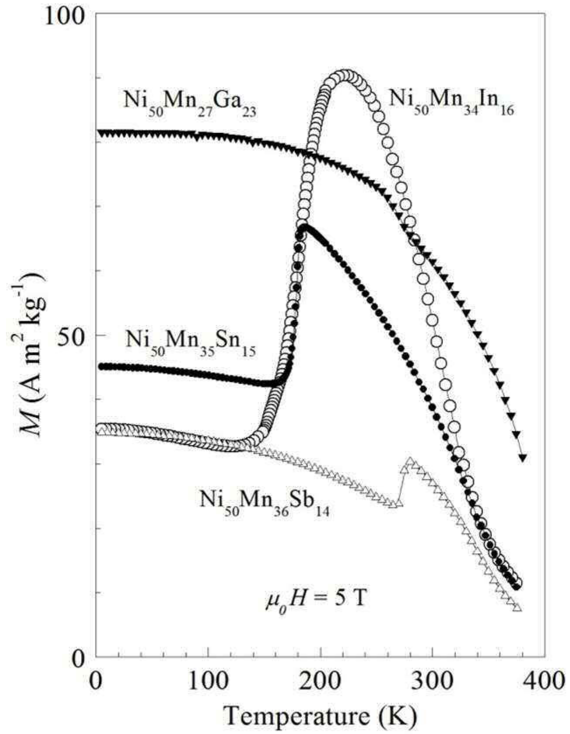
Ferromagnetic resonance



The magnetization of Ni-Mn-Z (Z: Ga, In, Sn, Sb)



M(T) in 5 mT



M(T) in 5 T

Conclusions

FM and AF correlations coexist at $T > M_s$ and beyond T_C^A

FM correlations disappear below M_s but AF short-range correlations persist down to lowest temperatures

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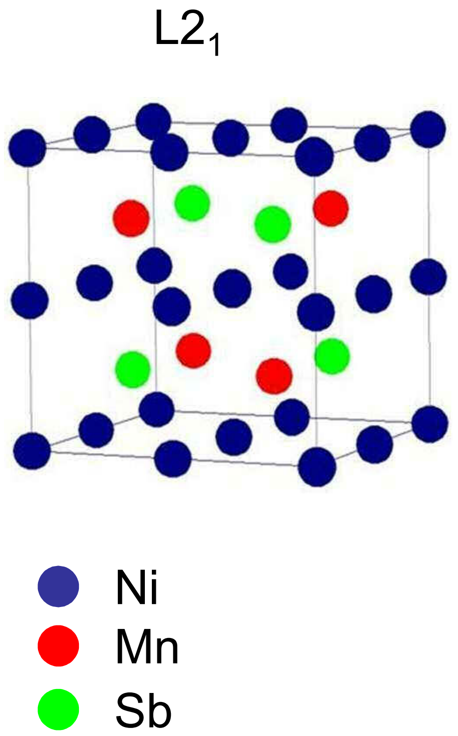
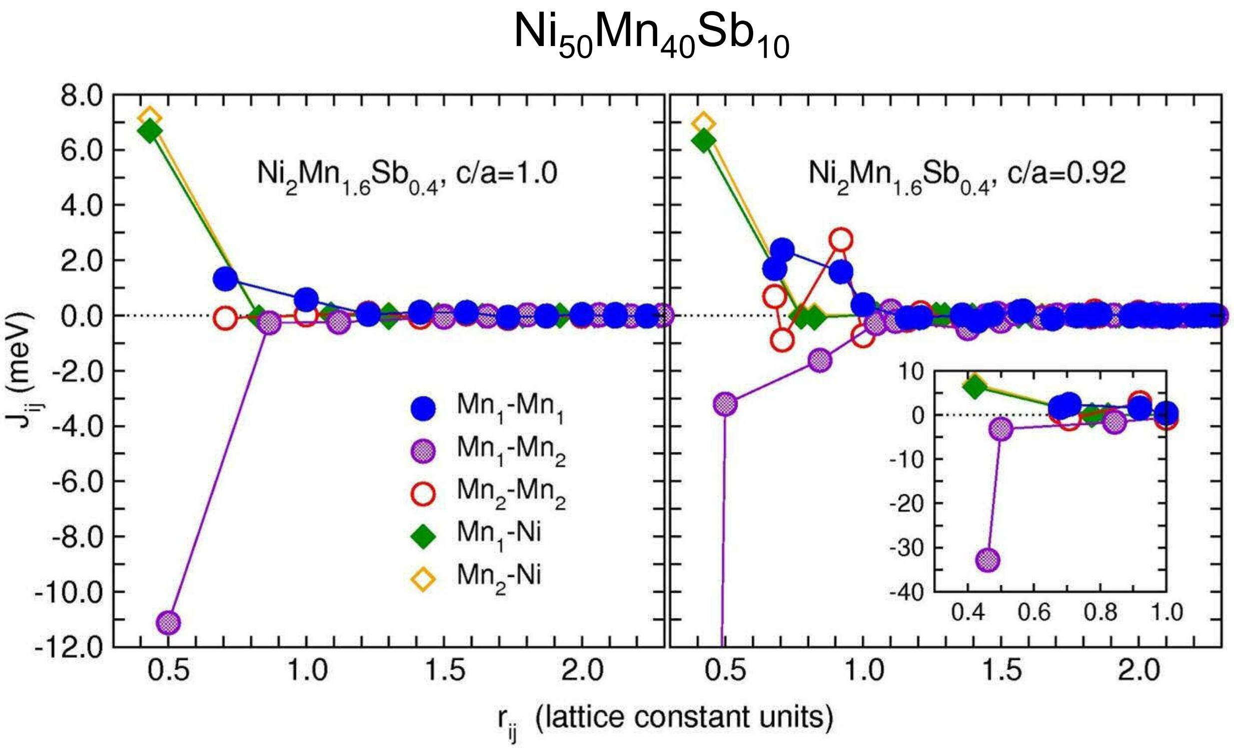
MAGNETIC SHAPE MEMORY
A DFG PRIORITY PROGRAMME

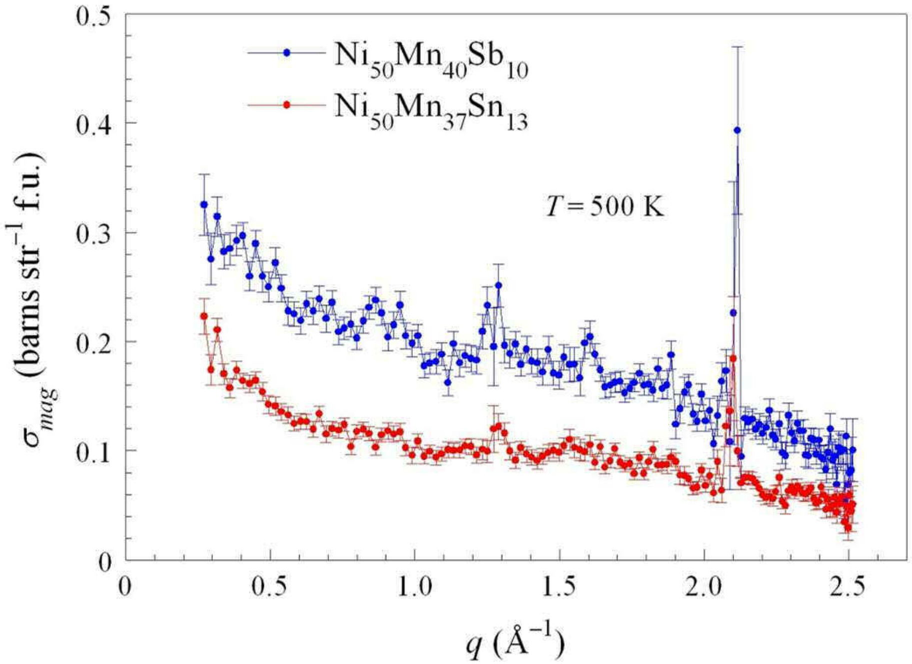
SPP 1239

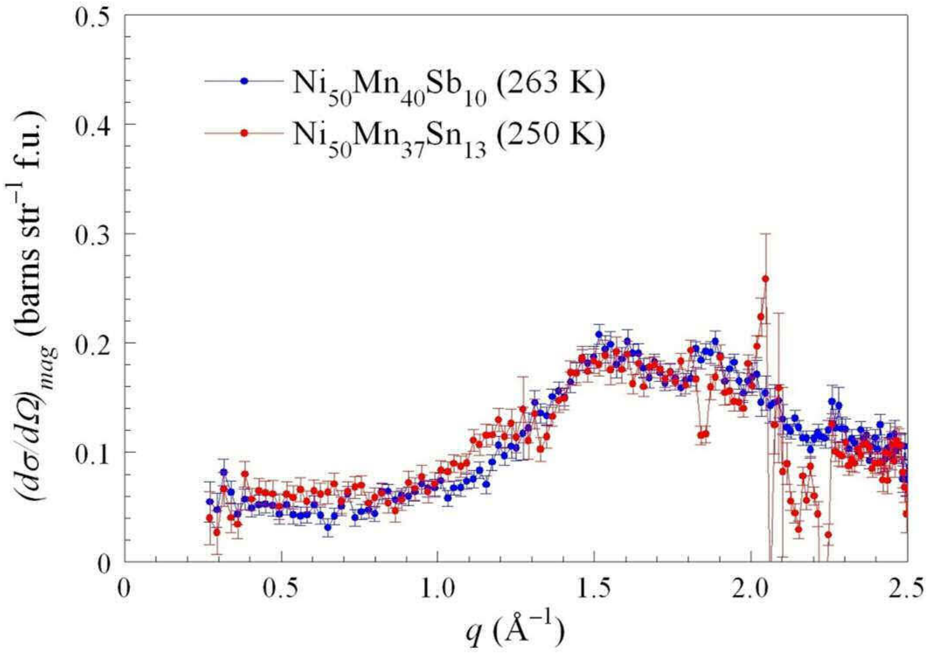
Magnetic exchange constants in Ni-Mn-Sb



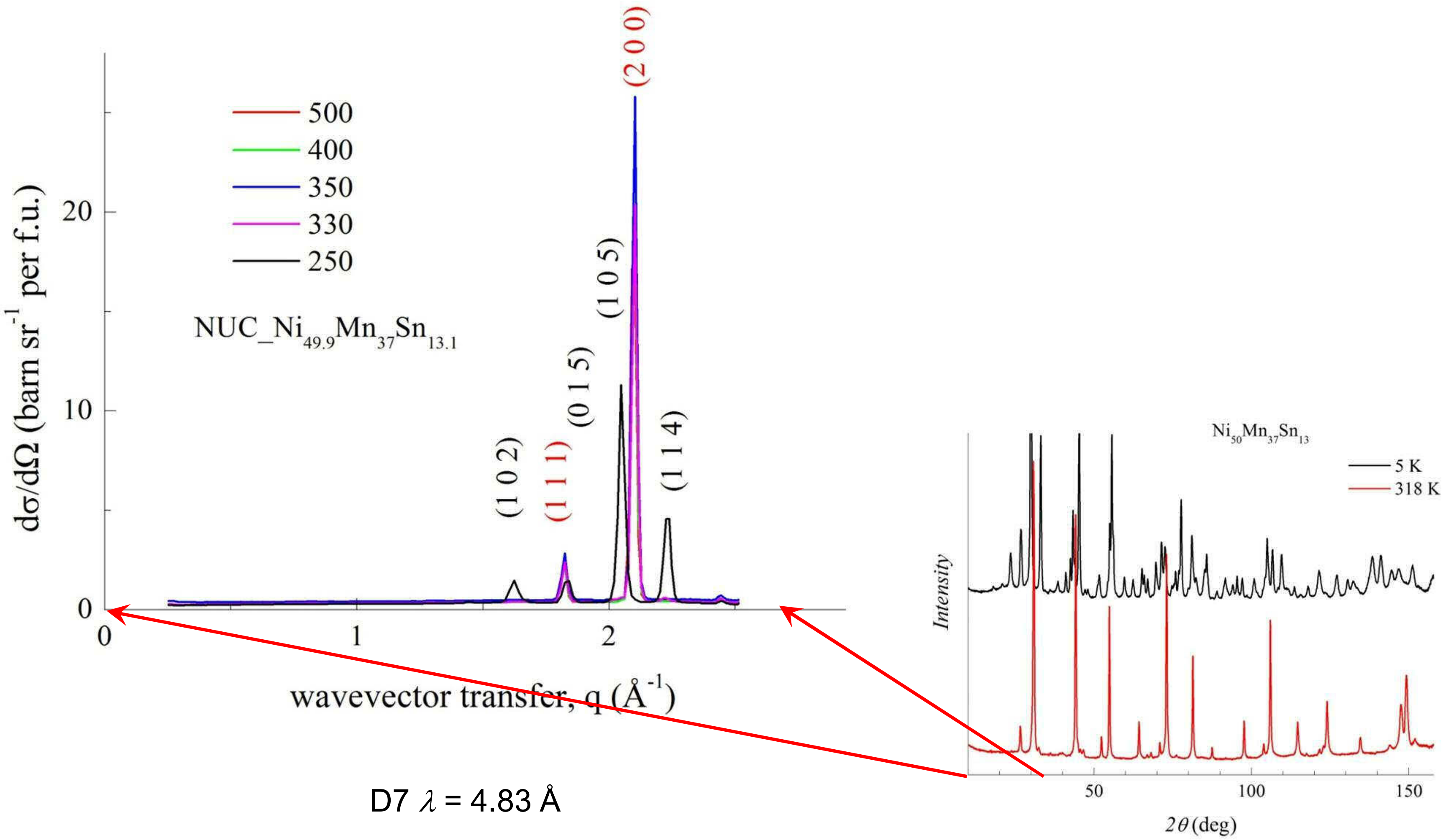


Ni-Mn-Sn and Ni-Mn-Sb (magnetic scattering)





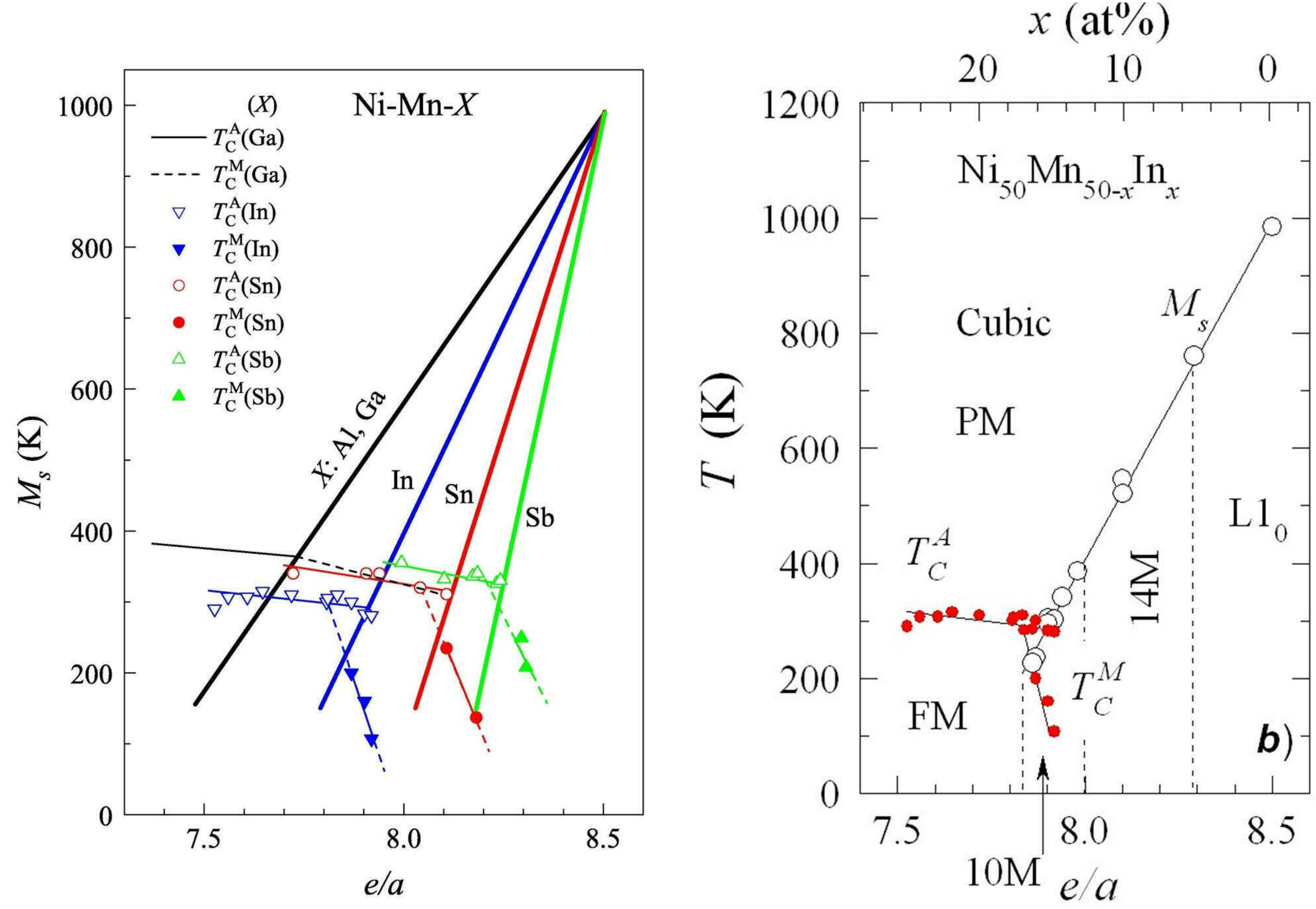
Ni-Mn-Sn (coherent scattering)



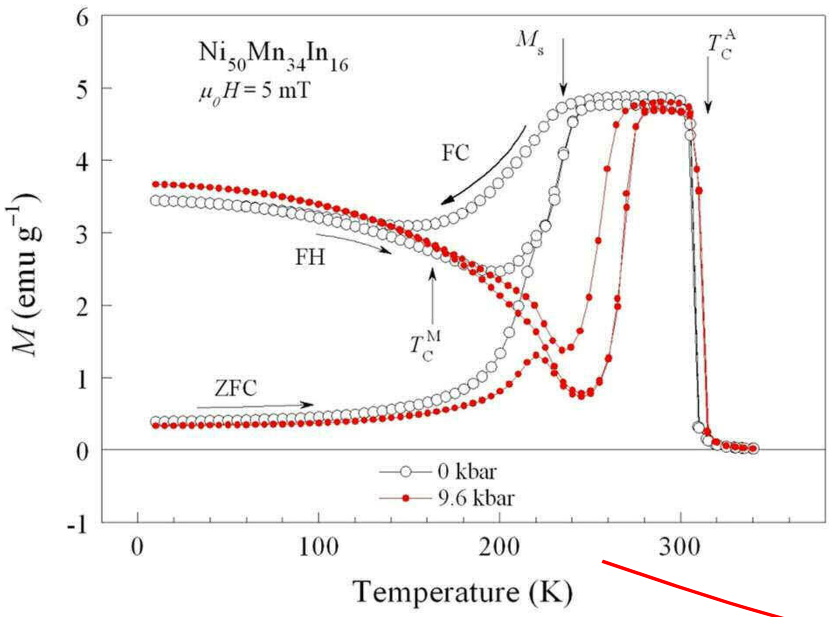
D7 λ = 4.83 Å

D2B λ = 1.594 Å

M_s and T_C as a function of valence electron concentration

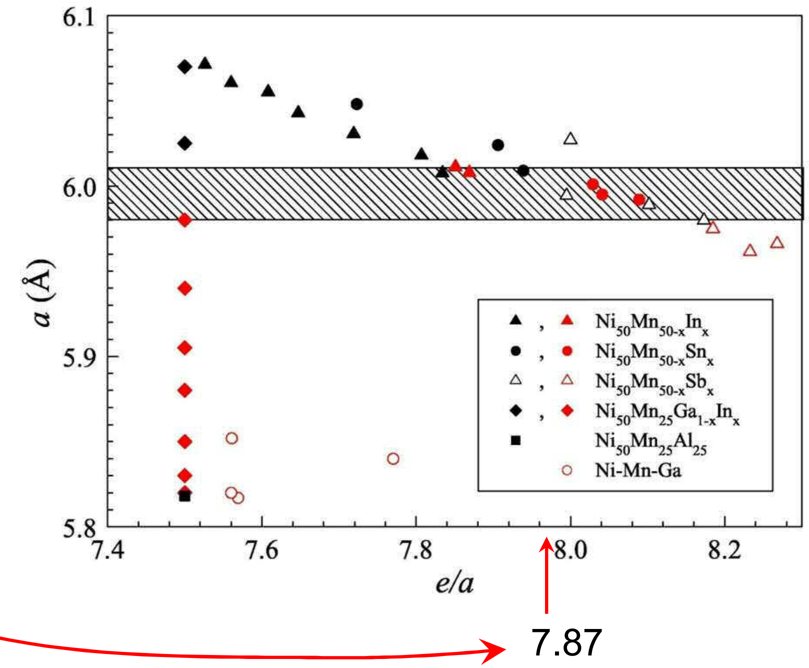


Pressure-dependence of magnetization in Ni-Mn-In



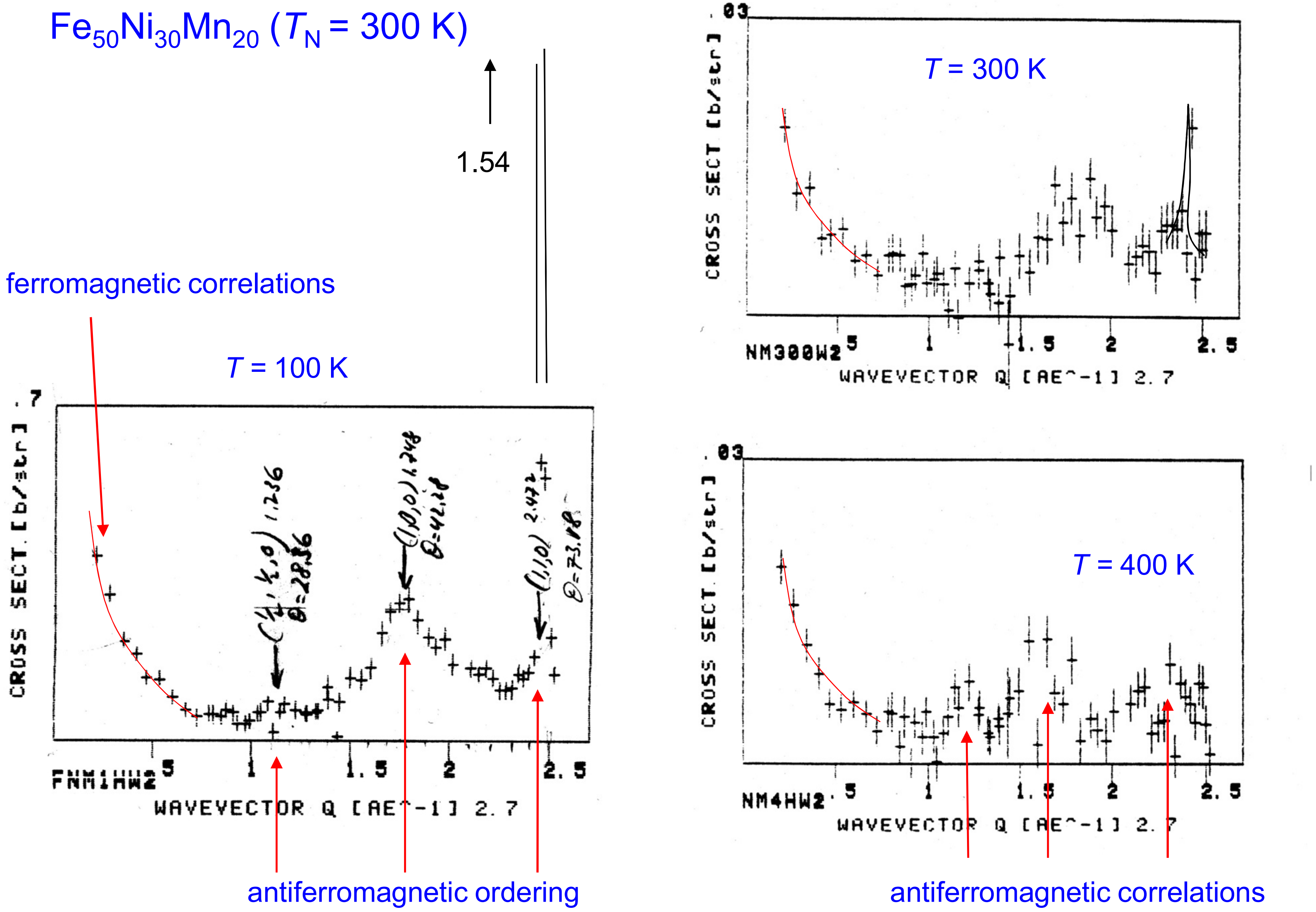
L. Mañosa et al., APL 92, 012515 (2008).

Austenitic state lattice constant at room temperature in Ni-Mn-Z

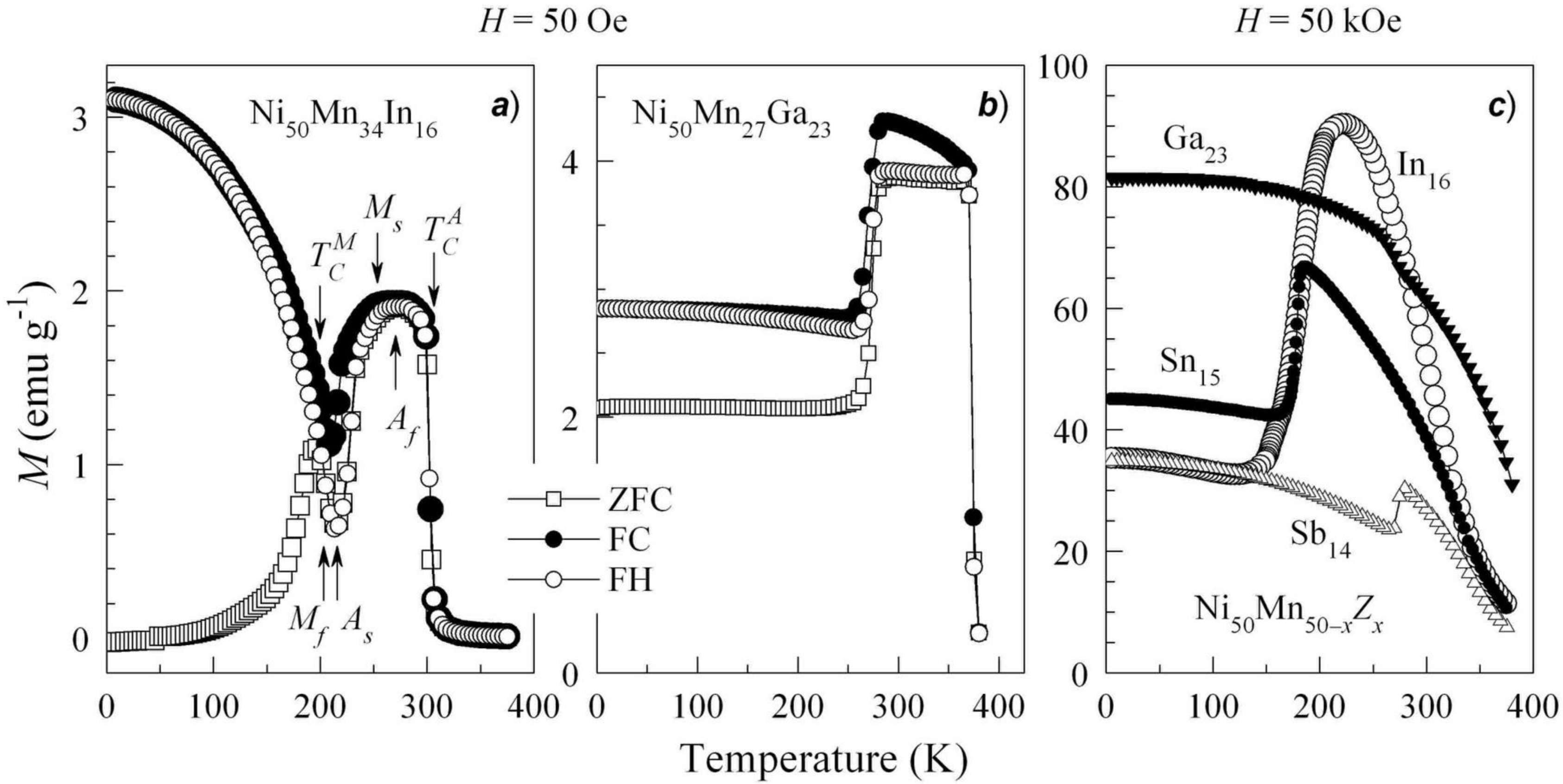


T. Krenke, Thesis (Duisburg, 2007).

Coexisting FM and AF correlations in Fe-Ni-Mn

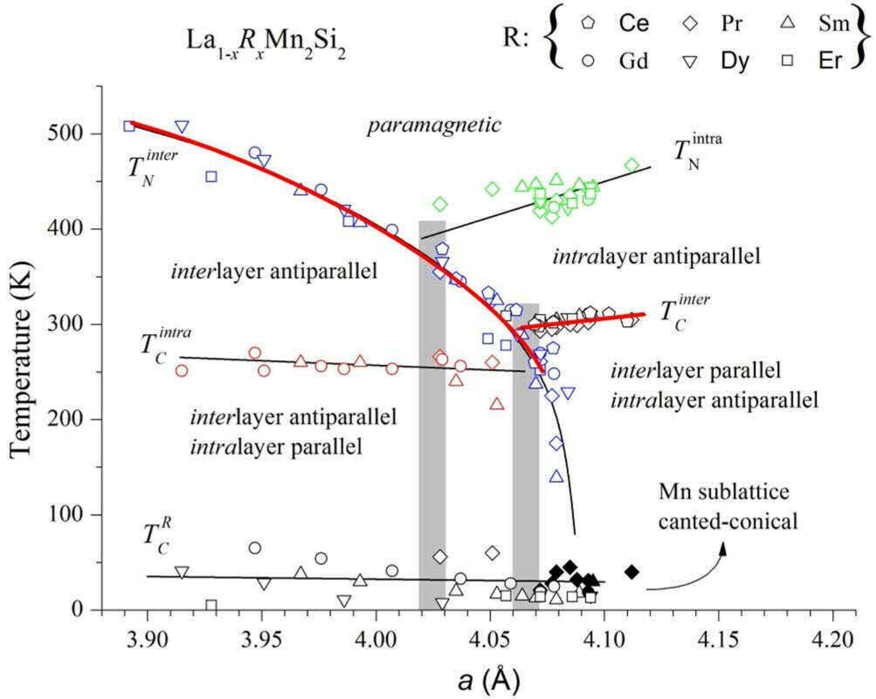


Magnetization of Ni-Mn based Heuslers

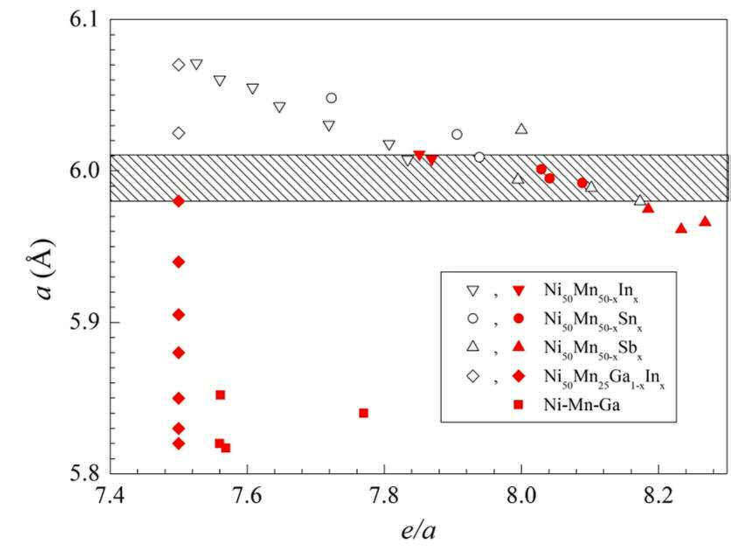


A. Planes et al. J. Phys.: Condens. Matter 21, 233201 (2009)

Mn-Mn: 4.25 Å



$La_{1-x}R_xMn_2Si_2$
R: Ce Pr Sm Gd Dy Er
paramagnetic
T_N^{inter}
T_N^{intra}
interlayer antiparallel
intralayer antiparallel
T_C^{inter}
T_C^{intra}
interlayer parallel
intralayer antiparallel
interlayer antiparallel
intralayer parallel
T_C^R
Mn sublattice
canted-conical
Temperature (K)
a (Å)



a (Å)
e/a
$Ni_{50}Mn_{50-x}In_x$
$Ni_{50}Mn_{50-x}Sn_x$
$Ni_{50}Mn_{50-x}Sb_x$
$Ni_{50}Mn_{25}Ga_{1-x}In_x$
Ni-Mn-Ga