On the magnetic properties of cobalt ferrite nano particles

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Magnetism and Magnetic Materials Lab at Quaid-i-Azam University

- What we Have
- Resistivity down to 10k
- Magnetometer 77K, 20 KOe
- XRD
- AC susceptibility 77K, H_{dc} up to 6KOe
- Furnace 1600 C

- What we'll Have
- MPMS (Quantum Design)
  - Magnetic and transport properties measurement system
- Thin film Laser ablation
- Single crystal growth facility

Syntheses of the nanocrystals

We synthesis magnetic nanoparticles

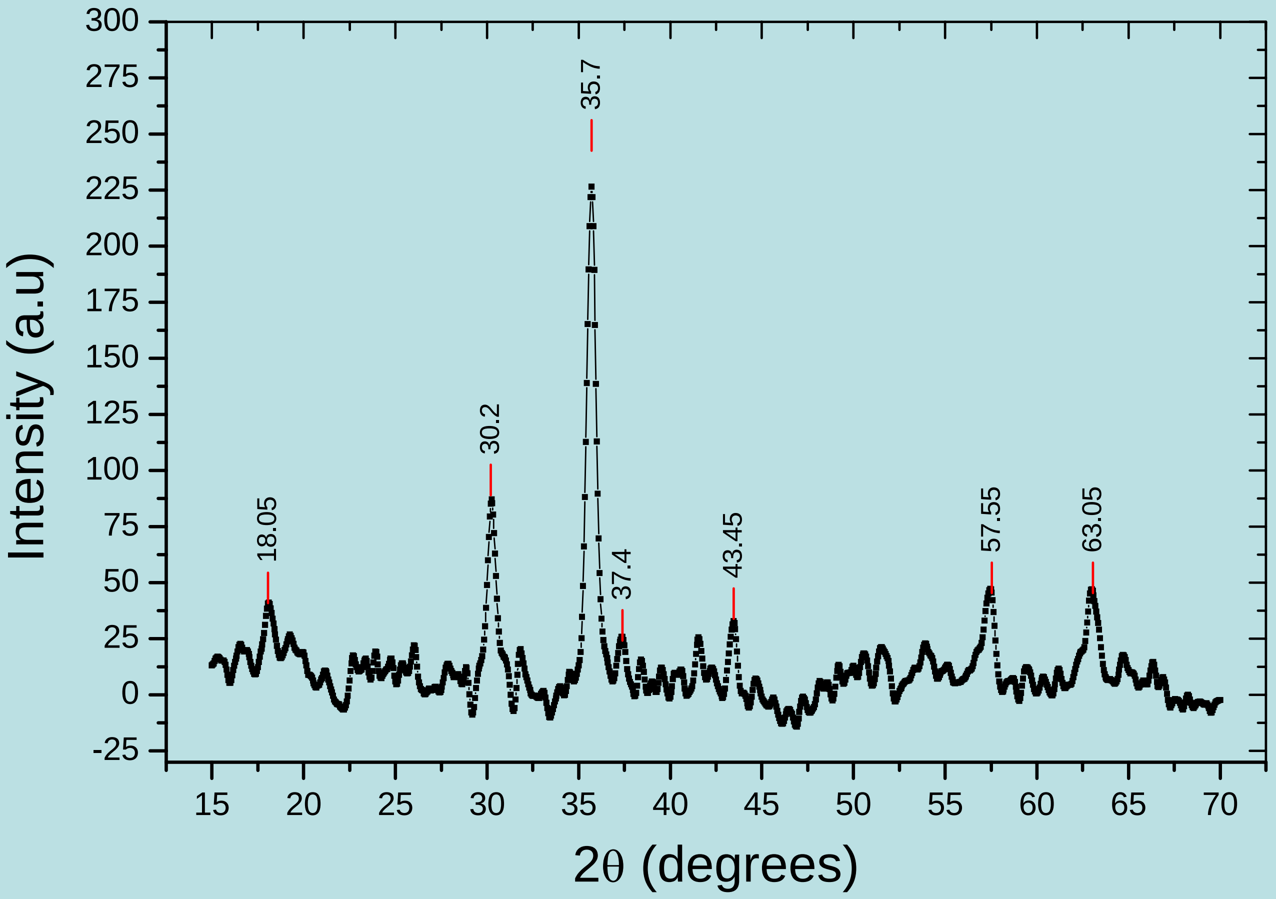
- Ferrites e.g, CoFe2O4
- Fe_2O_3
- Manganite Rare earth perovoskite $La_{1-x}Ca_xMnO_3$, Commonly called CMR

Sol Gel
Normal micelle
Reverse micelle

Nanoparticles exhibit size dependent properties that are profoundly different from the corresponding bulk material.

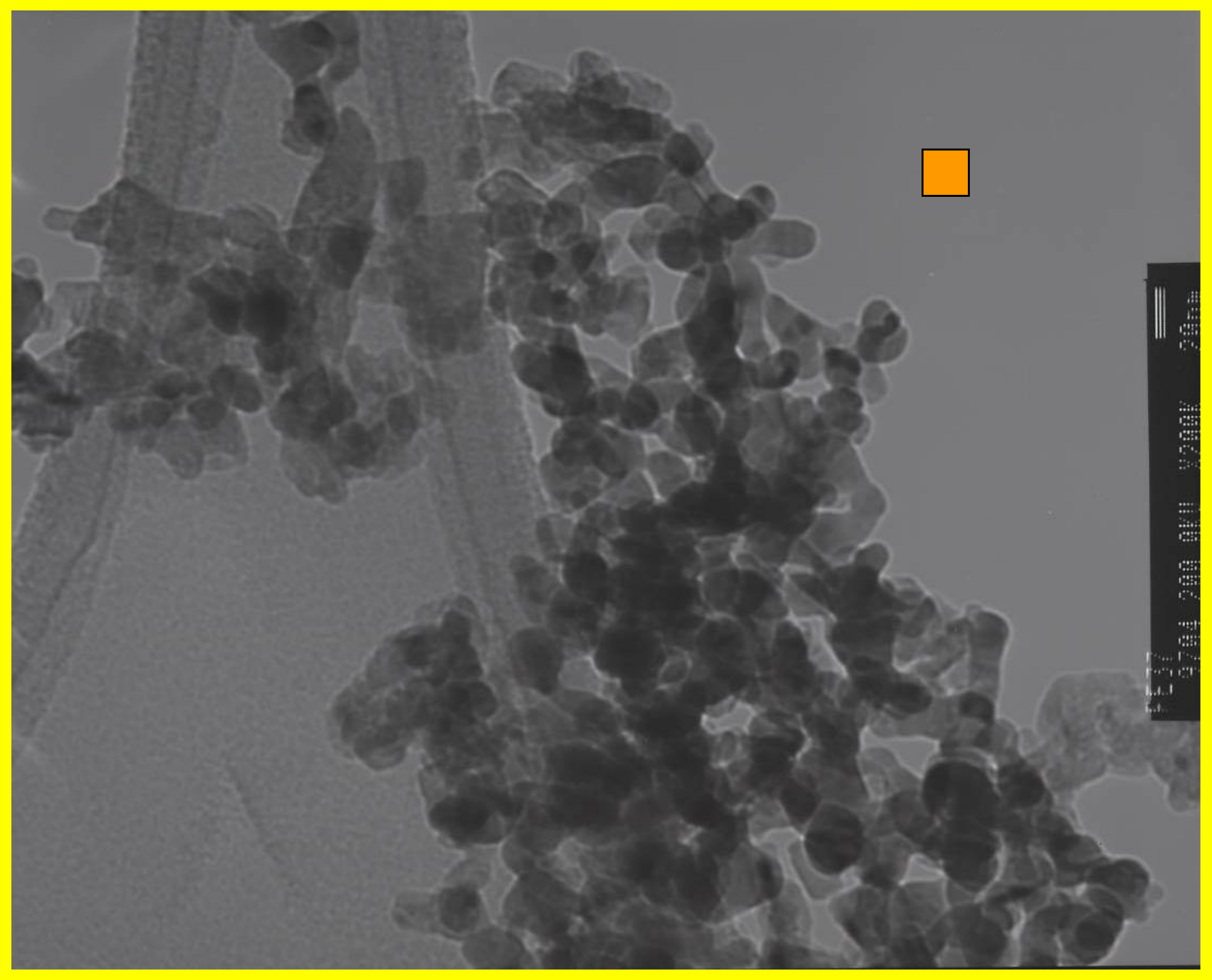
Electrical	higher electrical conductivity in ceramics and magnetic nanocomposites; higher resistivity in metals
Magnetic	increase in magnetic coercivity down to a critical size in the nanoscale regime; below critical crystalline size, decrease in the coersivity leading to the superparamagnetic behavior
Mechanical	increase in hardness and strength of metals and alloys; enhanced ductility, toughness and formability of ceramics; super strength and superplasticity
Optical	blue shift of optical spectra of quantum-confined crystallites; increase in luminescent efficiency of semiconductors
Chemical	fundamental understanding of heterogeneous catalytic properties

XRD $CoFe_2O_4$

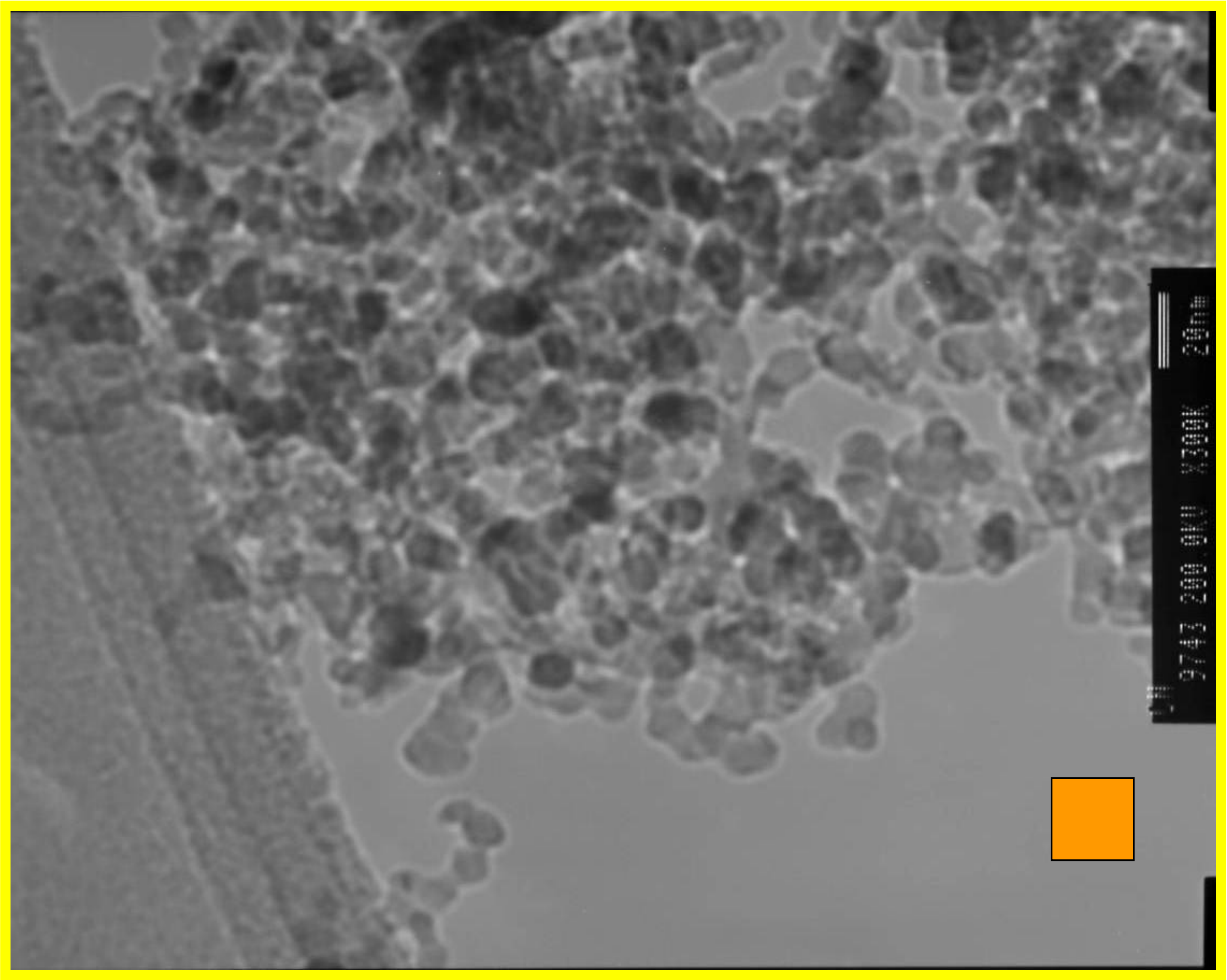


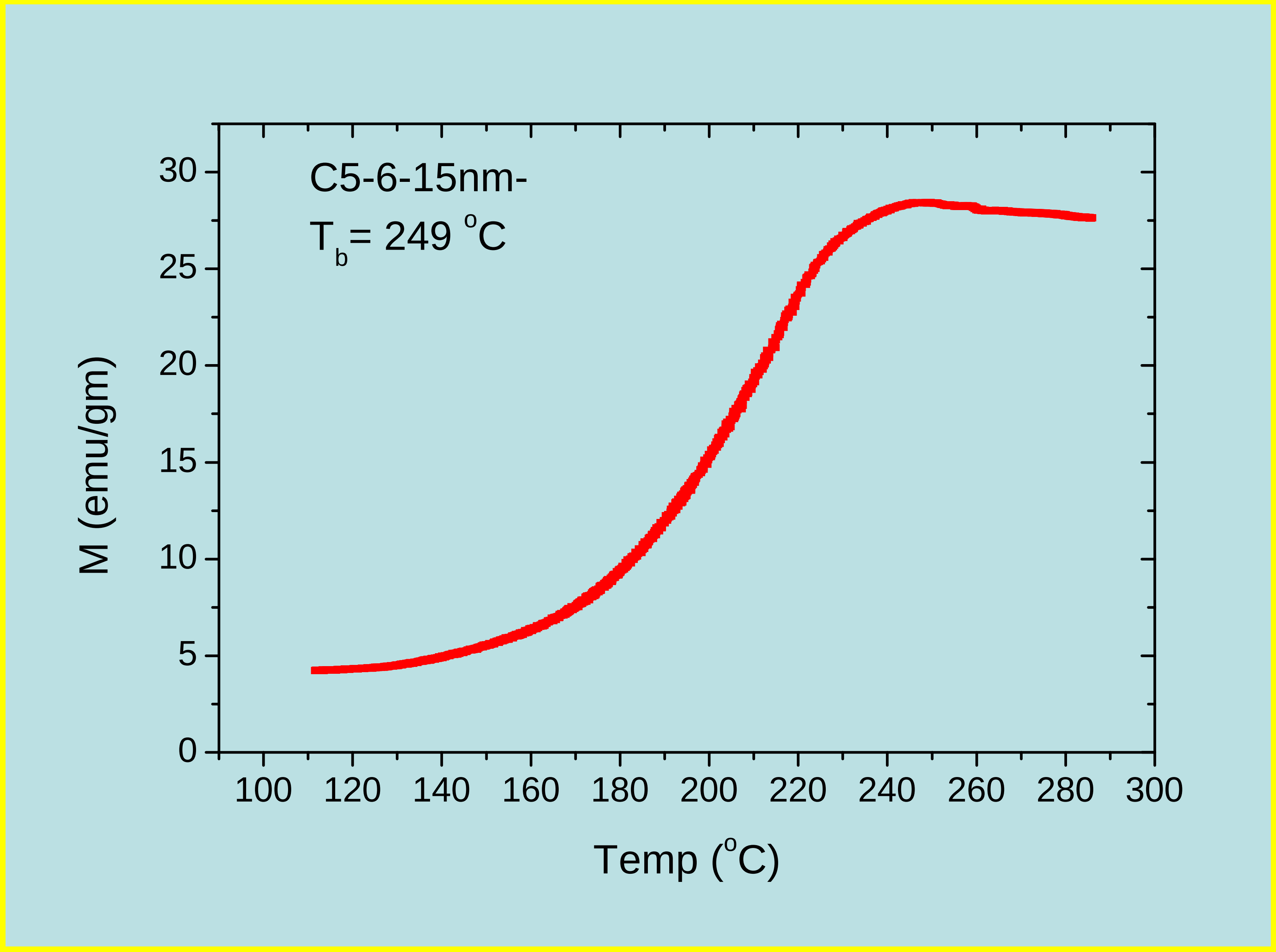
Intensity (a.u)
2θ (degrees)
300
275
250
225
200
175
150
125
100
75
50
25
0
-25
15
20
25
30
35
40
45
50
55
60
65
70
18.05
30.2
35.7
37.4
43.45
57.55
63.05

TEM Image

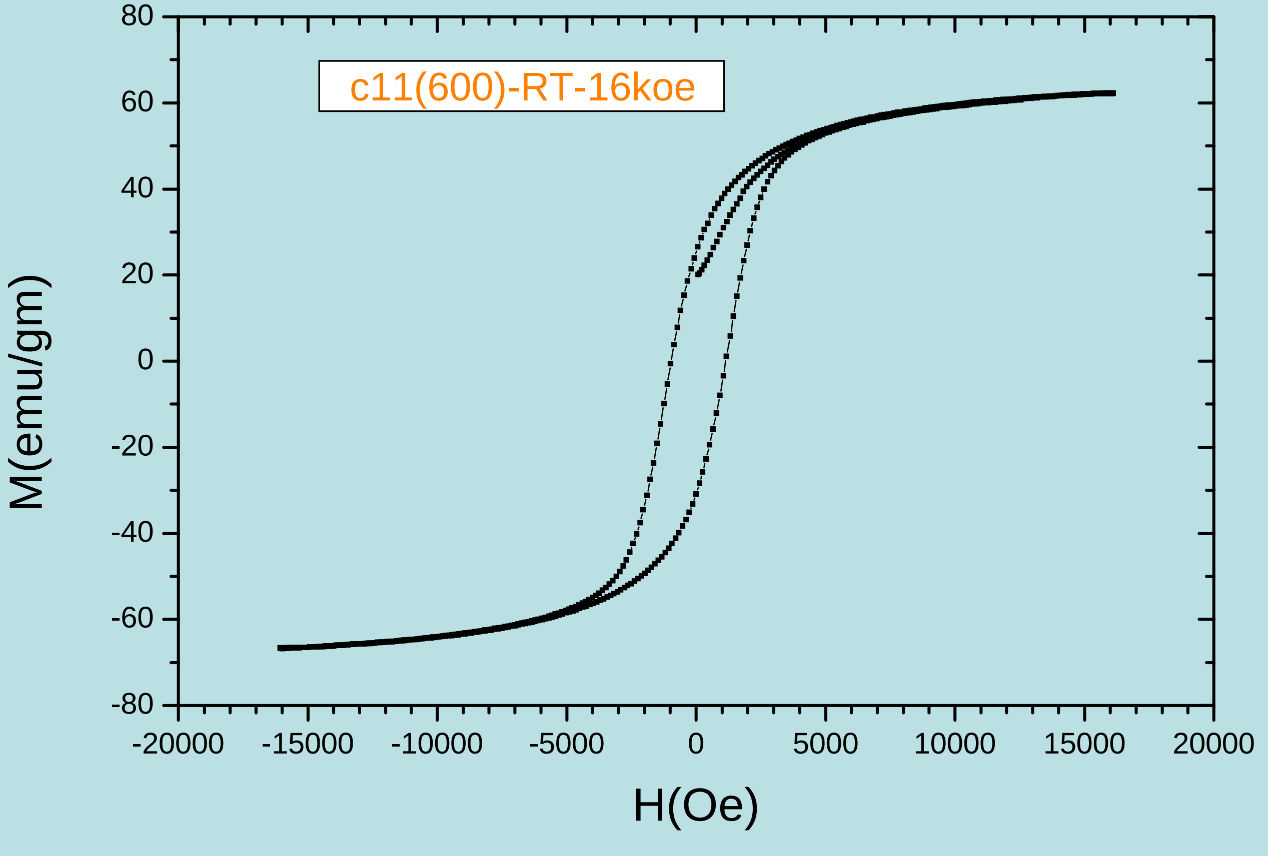


Size control is achieved either by annealing or by changing PH


9743 200.0KV X300K 20nm

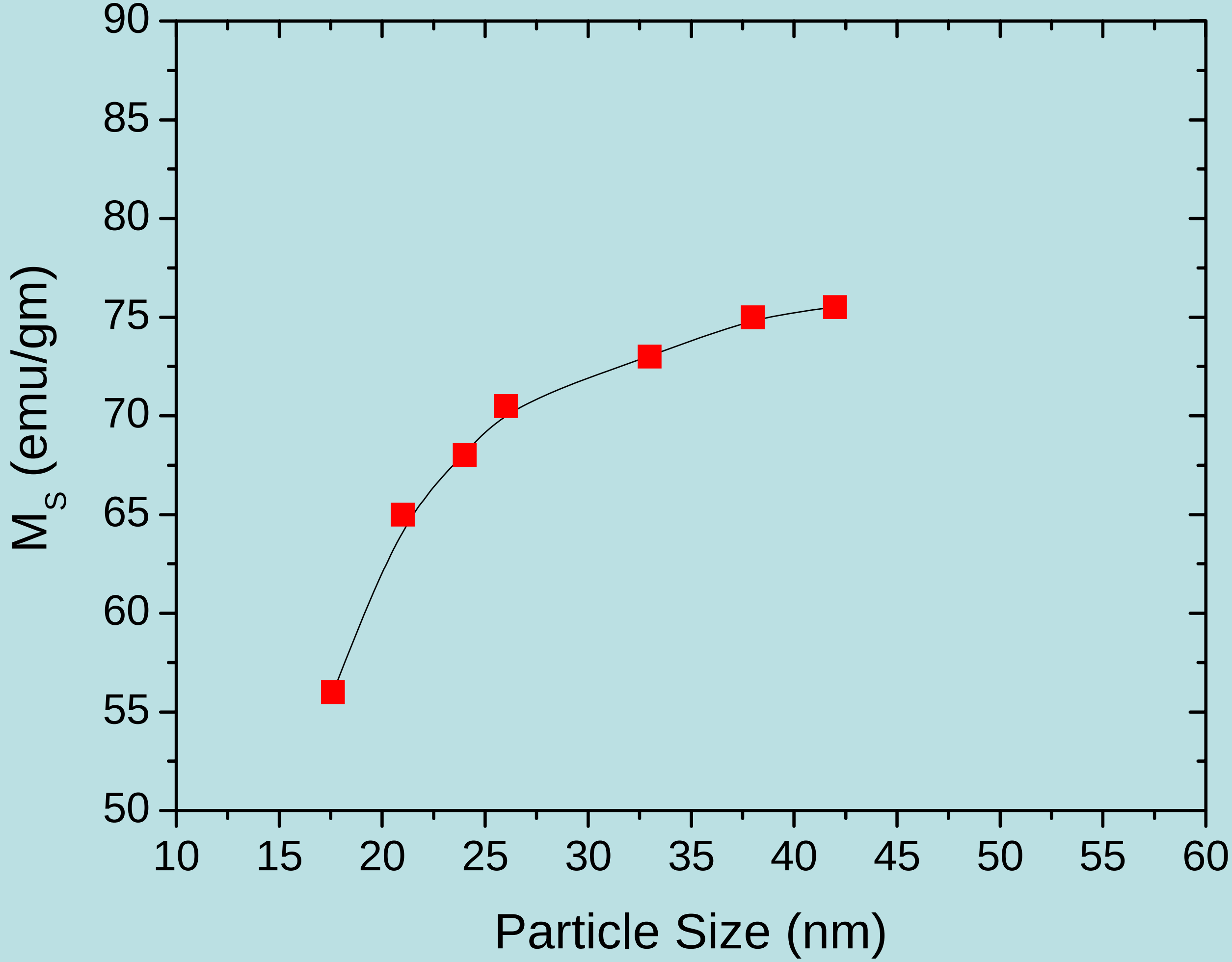

C5-6-15nm-
T_b= 249 °C
M (emu/gm)
Temp (°C)
0
5
10
15
20
25
30
100
120
140
160
180
200
220
240
260
280
300

Hysteresis Loop

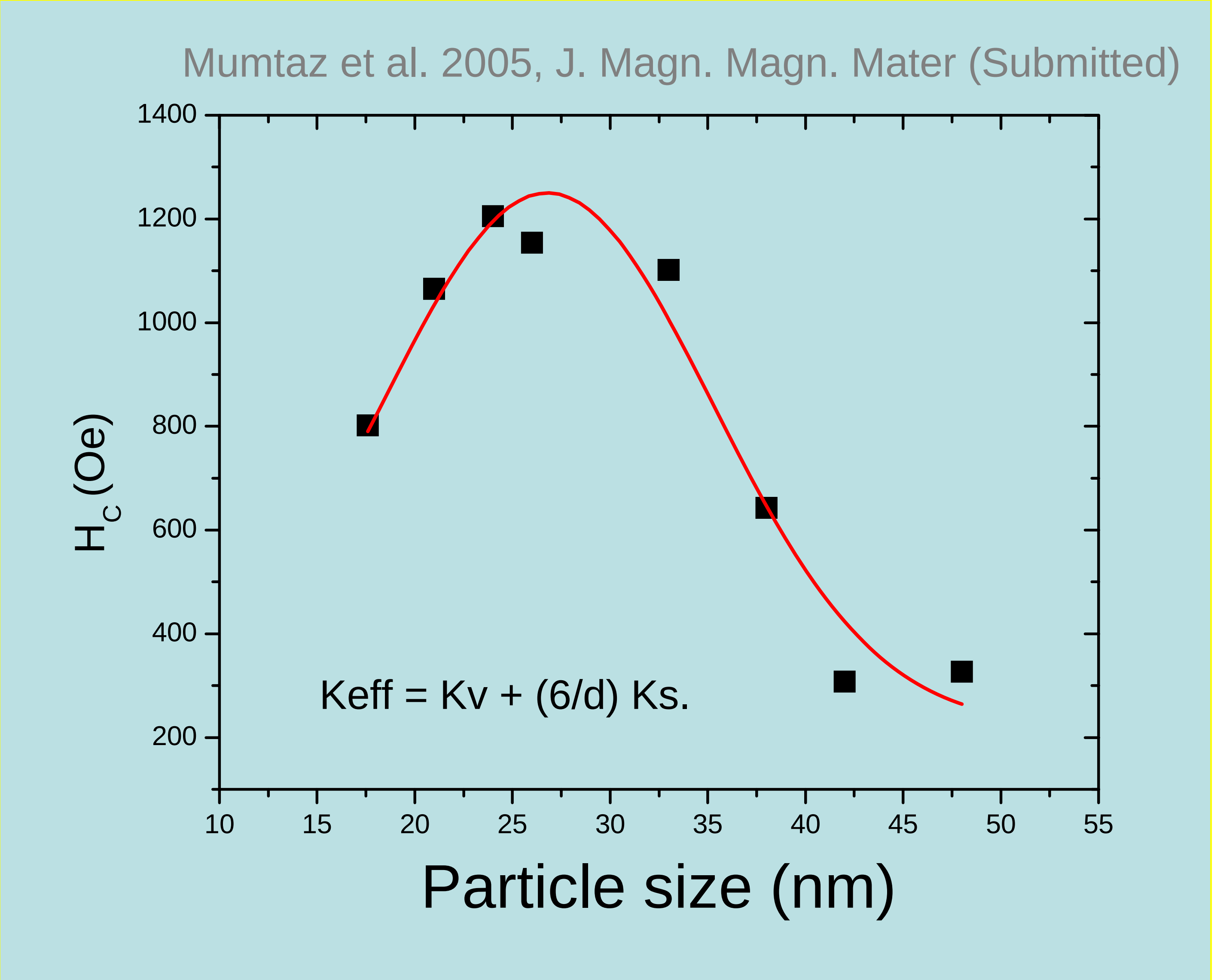


Variation of saturation magnetization with size

Mumtaz et al. 2005, J. Magn. Magn. Mater (Submitted)

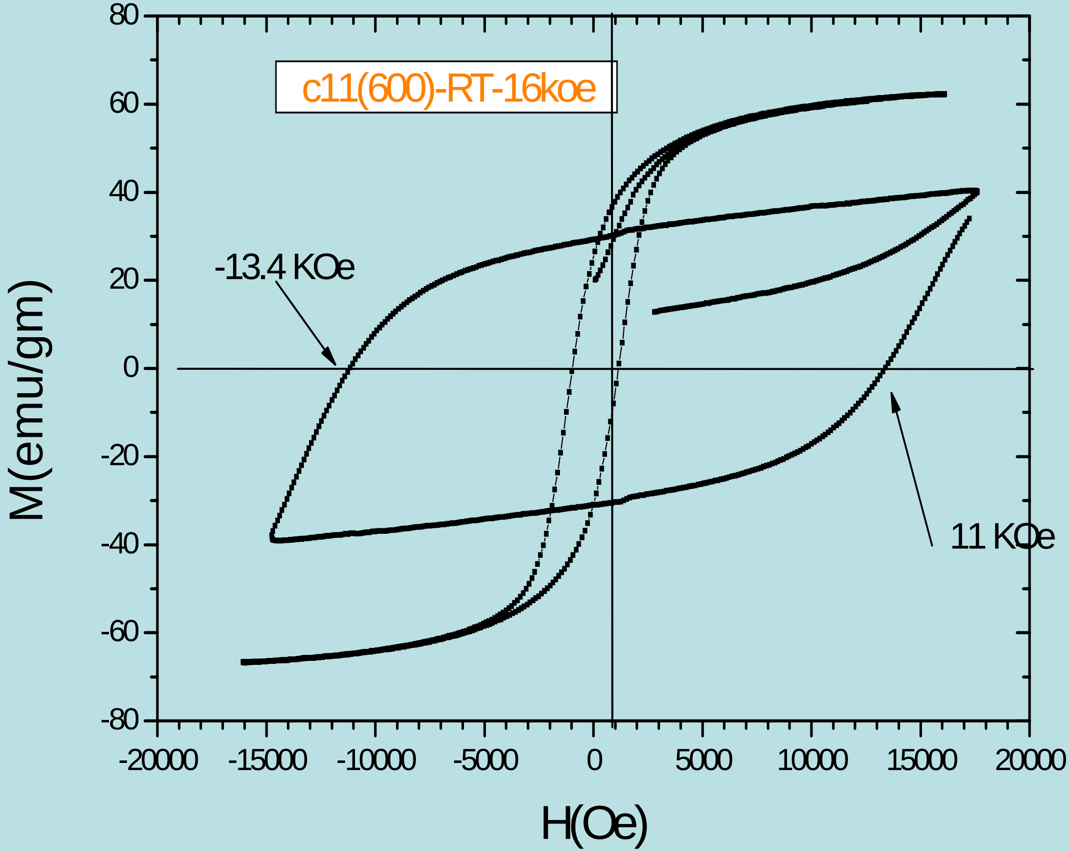


Variation of H_c with Particle size



Magnetization Loops

Mumtaz et al. 2005, J. Magn. Magn. Mater (Submitted)



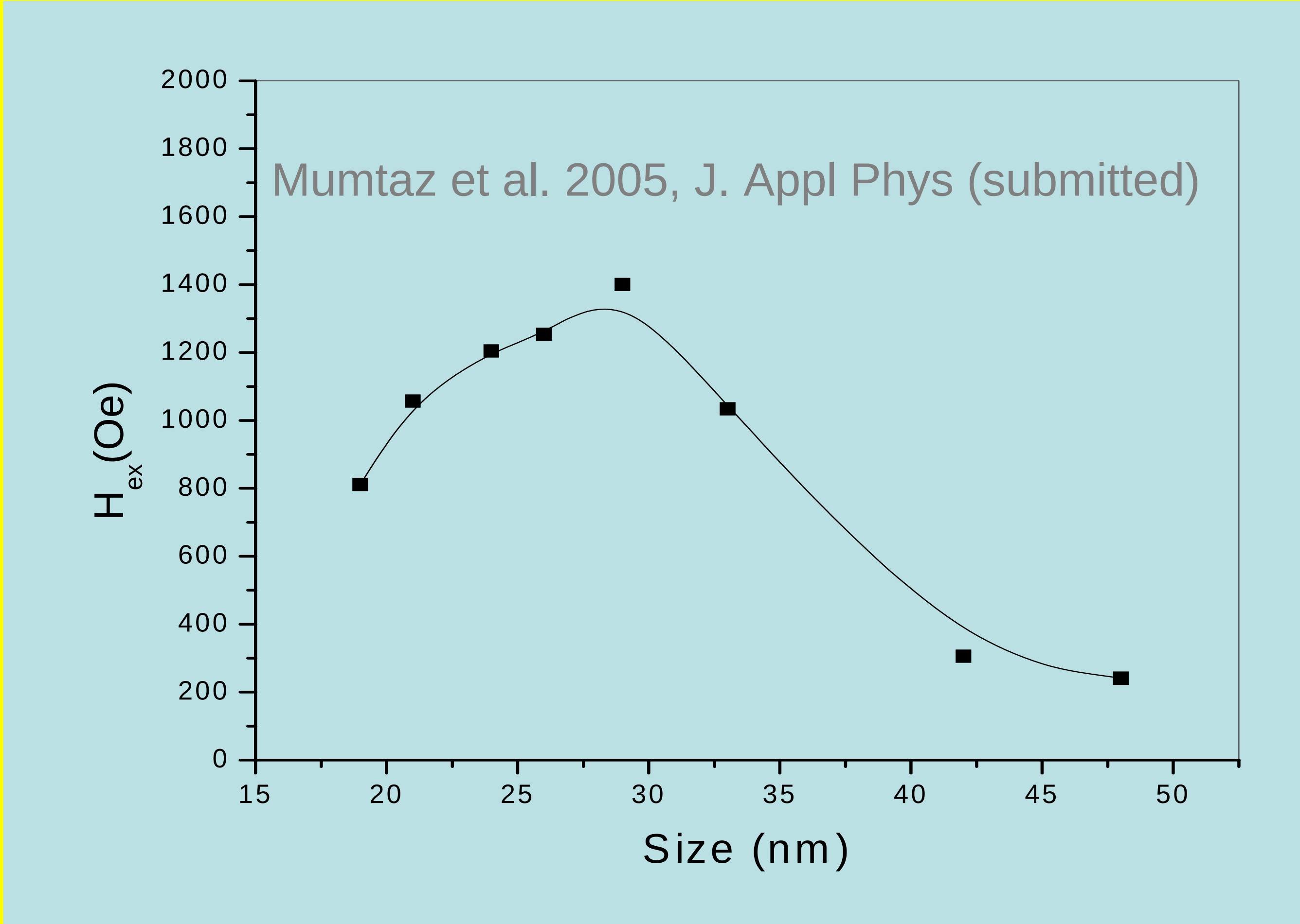
Points to Note

Asymmetry in the field axis

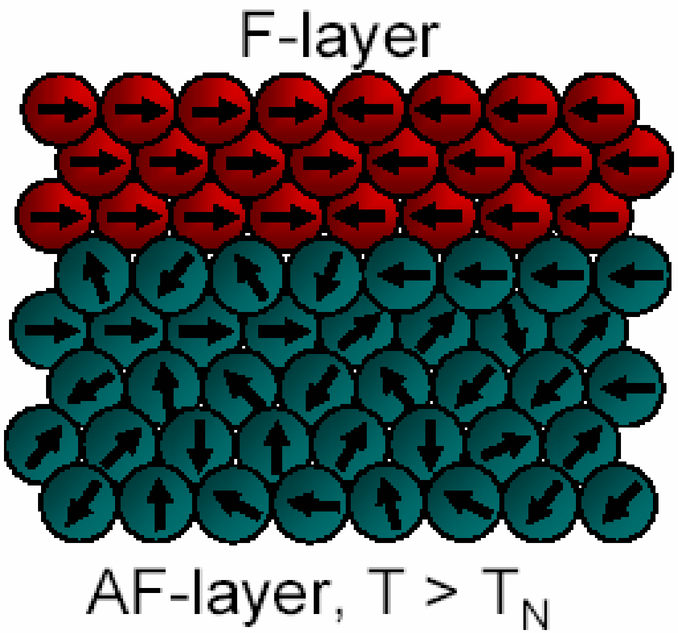
Vertical shift

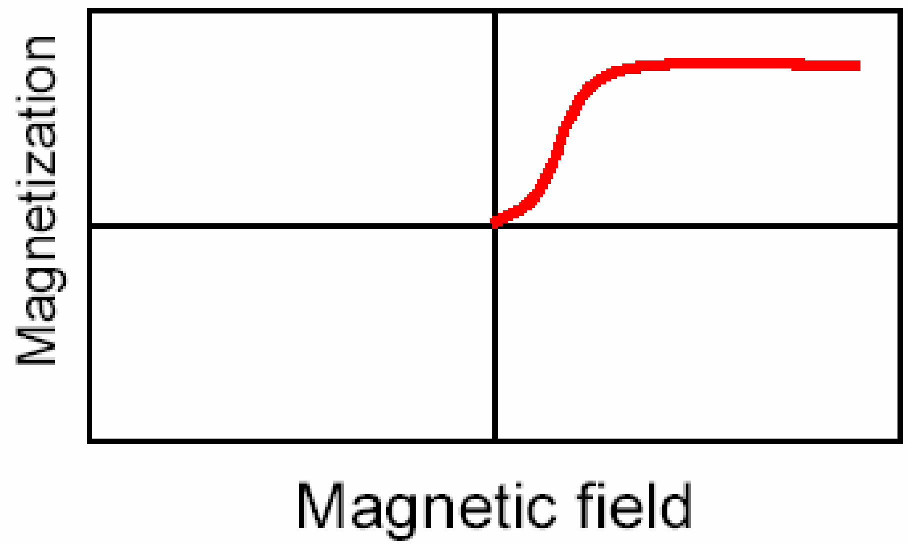
Hex = (Hc2 + Hc1)/2

Size dependence

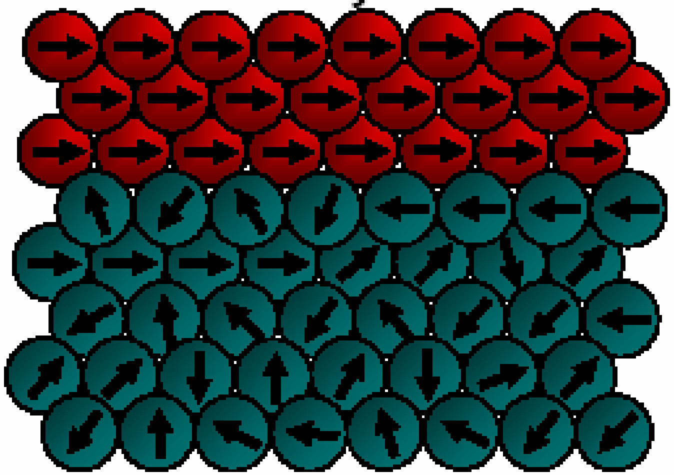


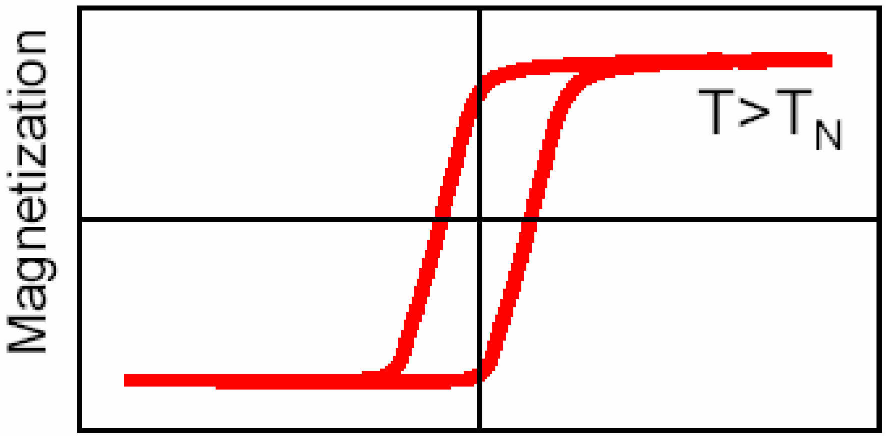
Exchange Anisotropy



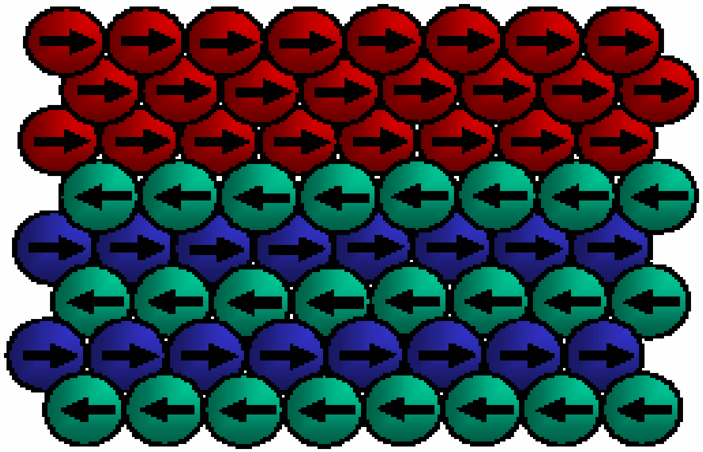


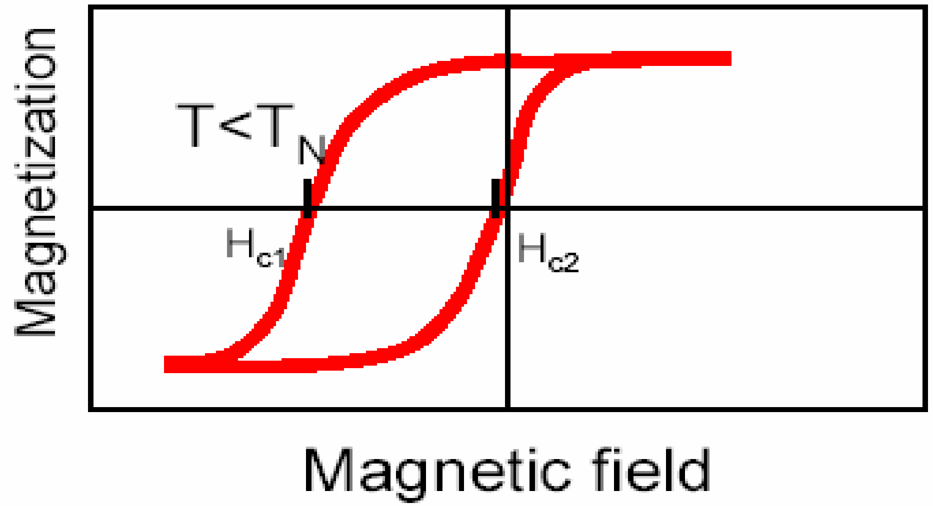
1. F-layer saturation in positive field





1. F-layer saturation in positive field
2. F-layer saturation hysteresis w/o field cooling





1. F-layer saturation in positive field
2. F-layer hysteresis w/o field cooling
3. F-layer hysteresis after field cooling

Exchange bias field:

$$H_{EB} = \frac{H_{c2} + H_{c1}}{2}$$

Core-Shell Structure

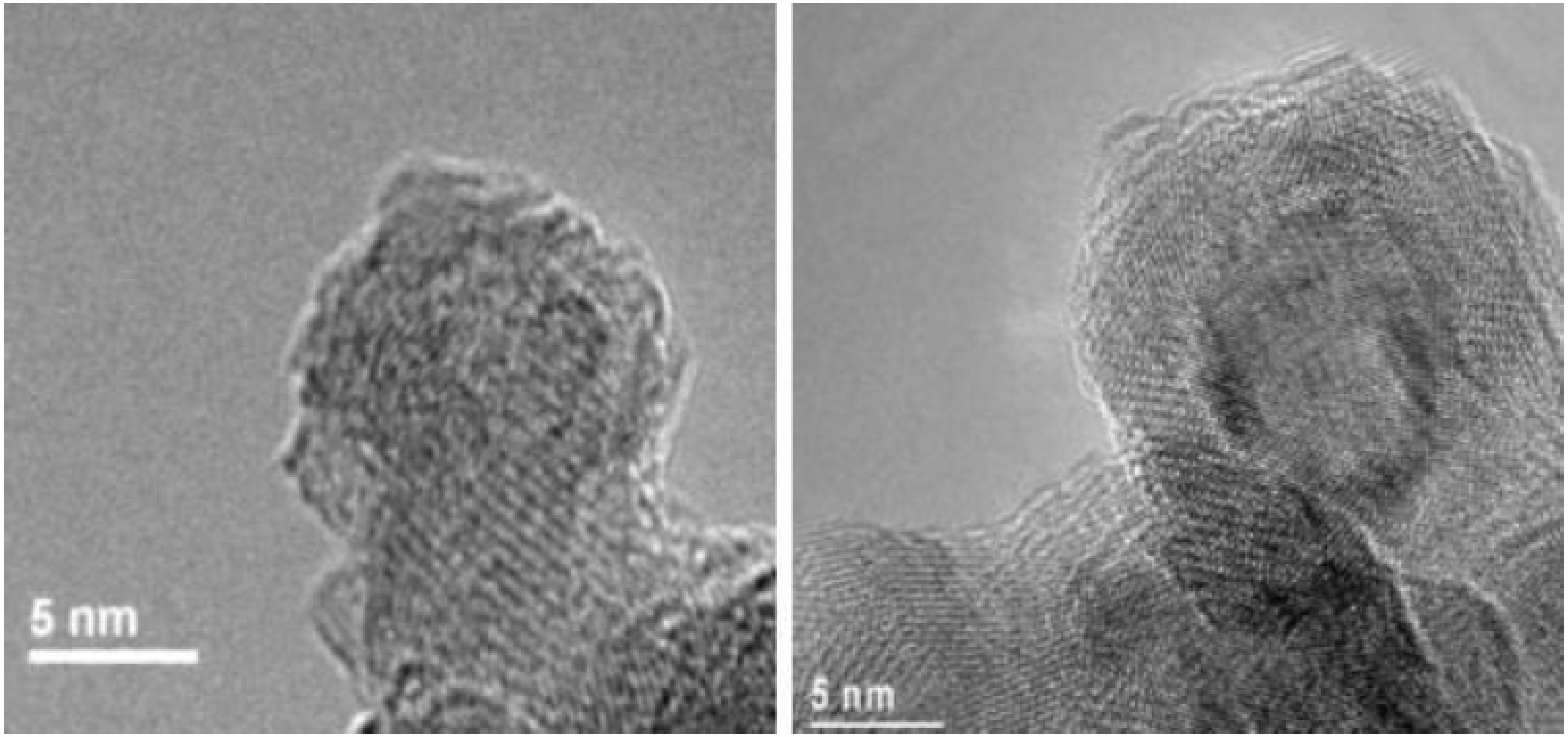
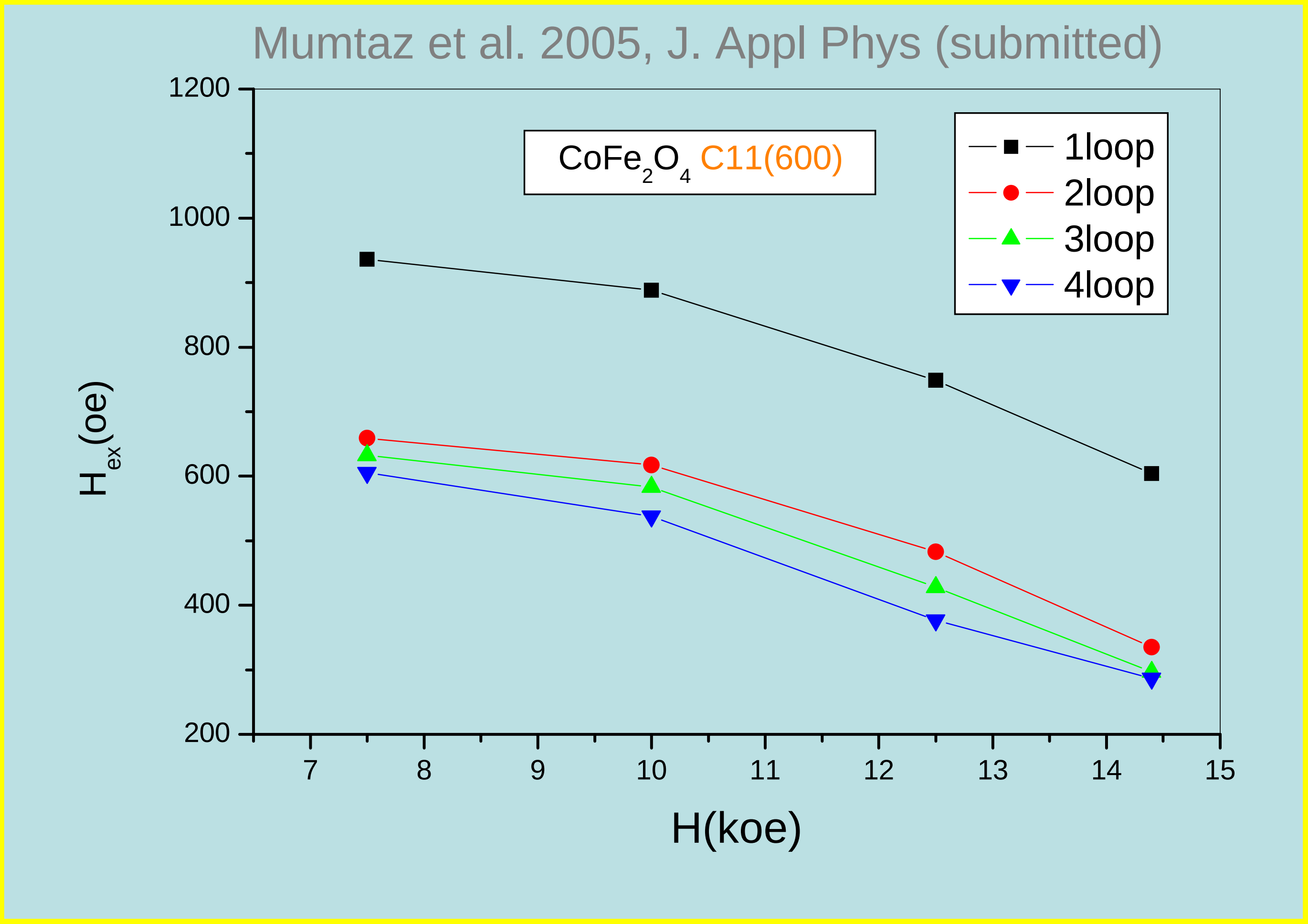


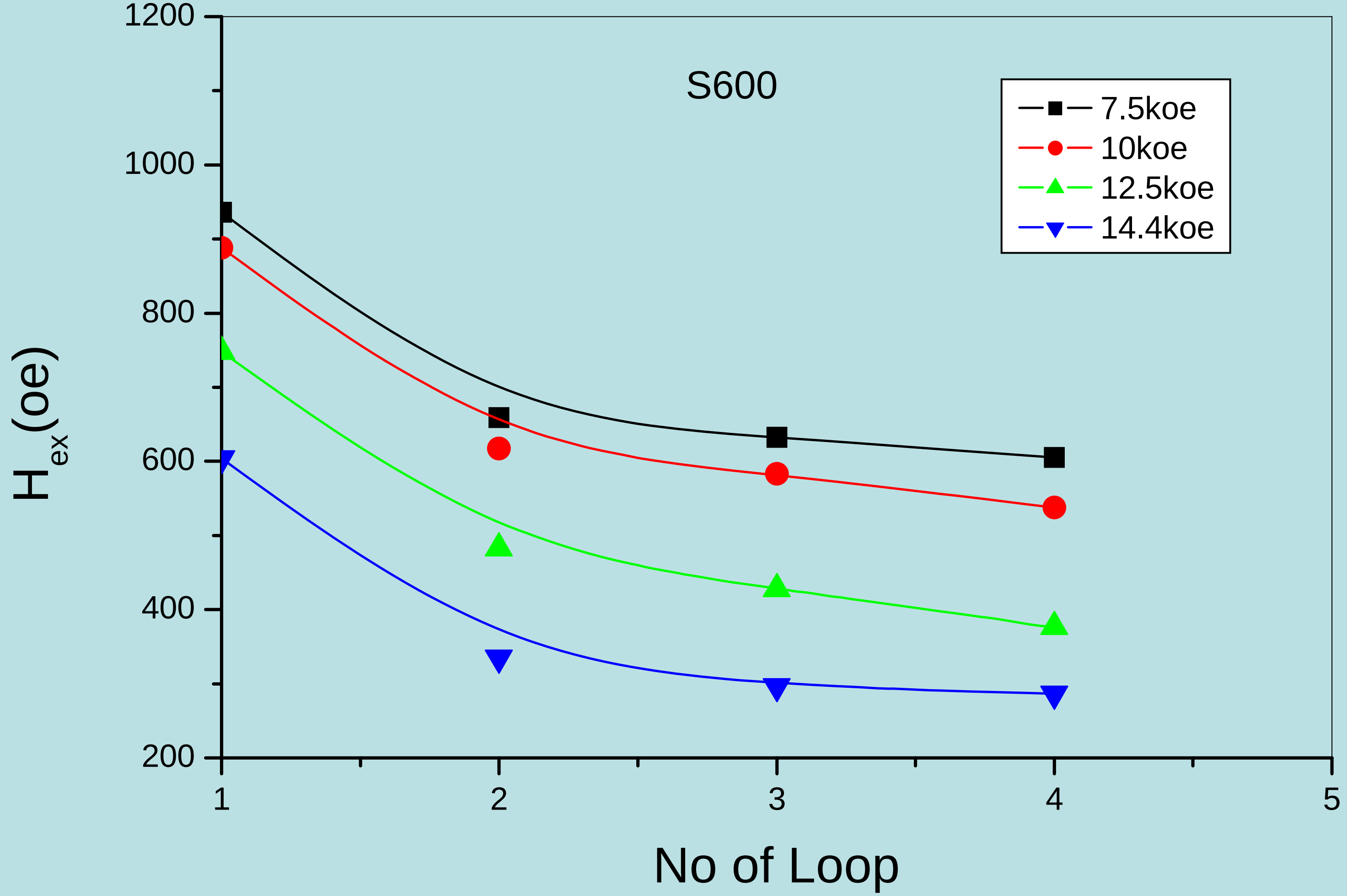
Figure 2: Abdullah Ceylan, C.C. Baker, S. K. Hasanain and S. Ismat Shah

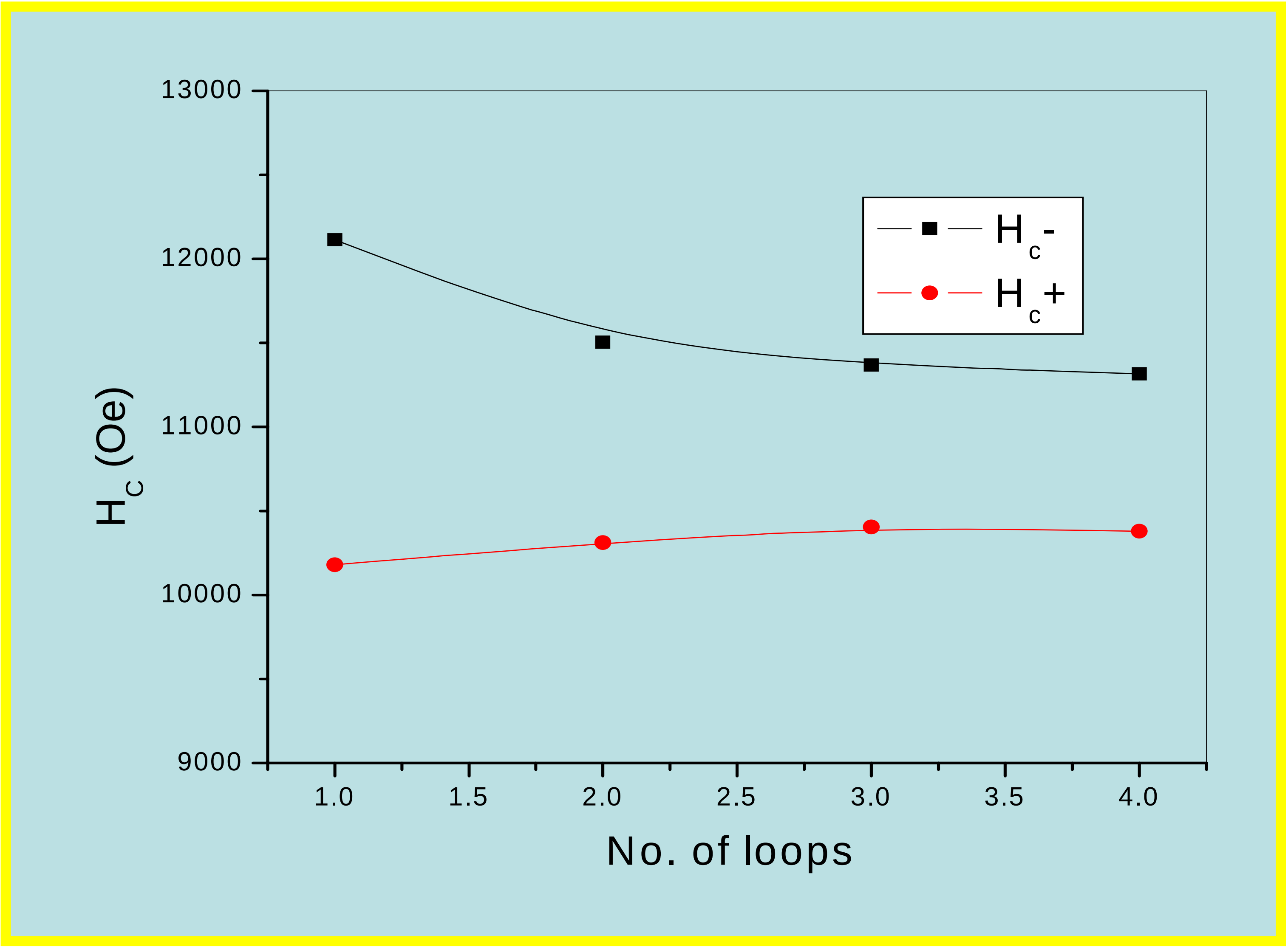
Effects of the cooling Field



Training Effect

Mumtaz et al. 2005, J. Appl Phys (submitted)




13000
12000
11000
10000
9000
1.0
1.5
2.0
2.5
3.0
3.5
4.0
No. of loops
H
c
(Oe)
H
c
-
H
c
+

Why Study Exchange Bias

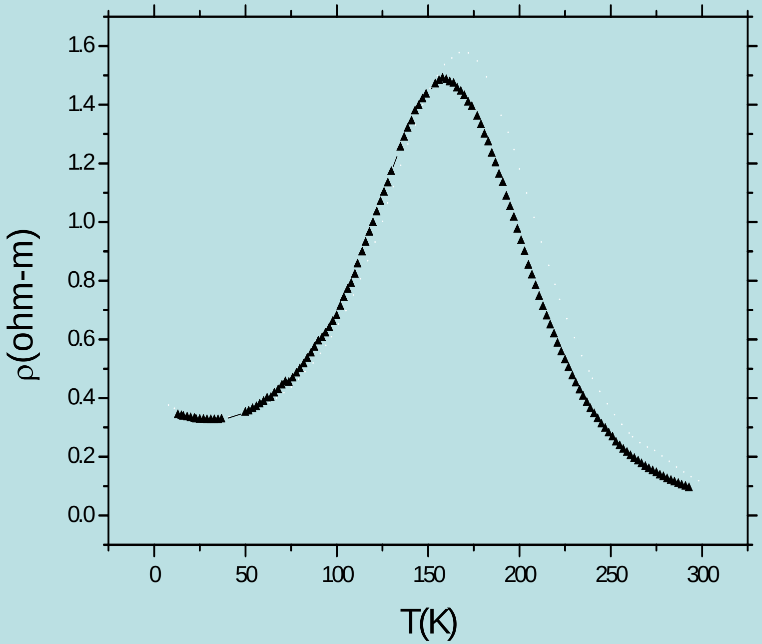
- Pinning of FM layer by an AFM layer is important for spintronic device application
  - Current read heads in hard-drives use exchange bias
  - Future MRAMs would use a similar architecture

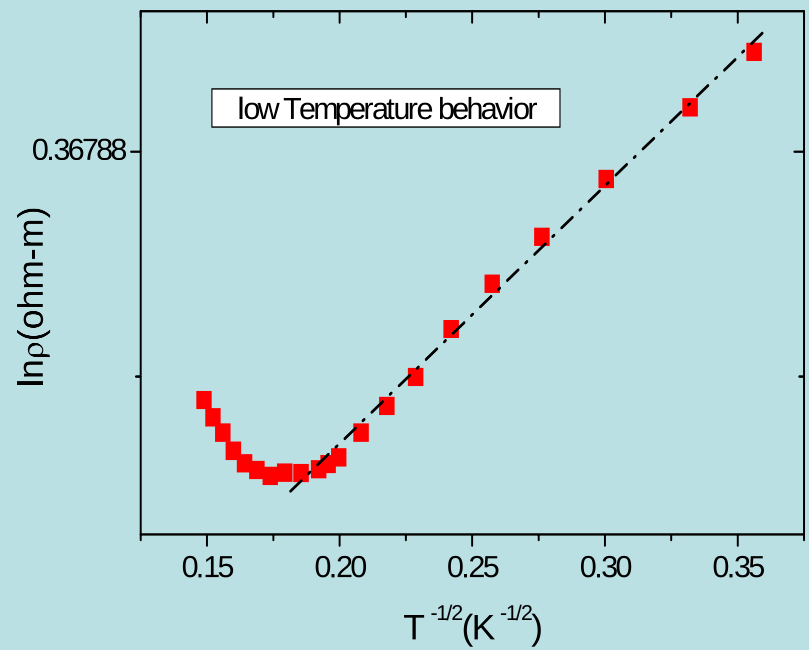
  Key Issues

  What is the role of interface

  How the spin structure transform after cycling

Mumtaz et al. 2005, J. Appl Physics (to be submitted)





- $R_t \alpha (1+P^2m^2) \exp(\Delta/T)^{1/2}$
- Where P is the spin polarization, m=M/Ms is the relative magnetization and Δ is proportional to the coulomb charging energy and barrier thickness

Magnetism and Magnetic Materials Group