



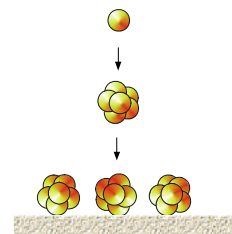
2010

-

--

--

2010 3 18









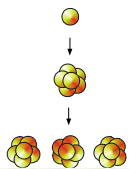




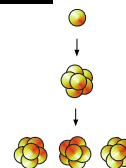


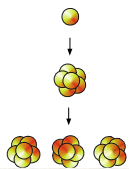
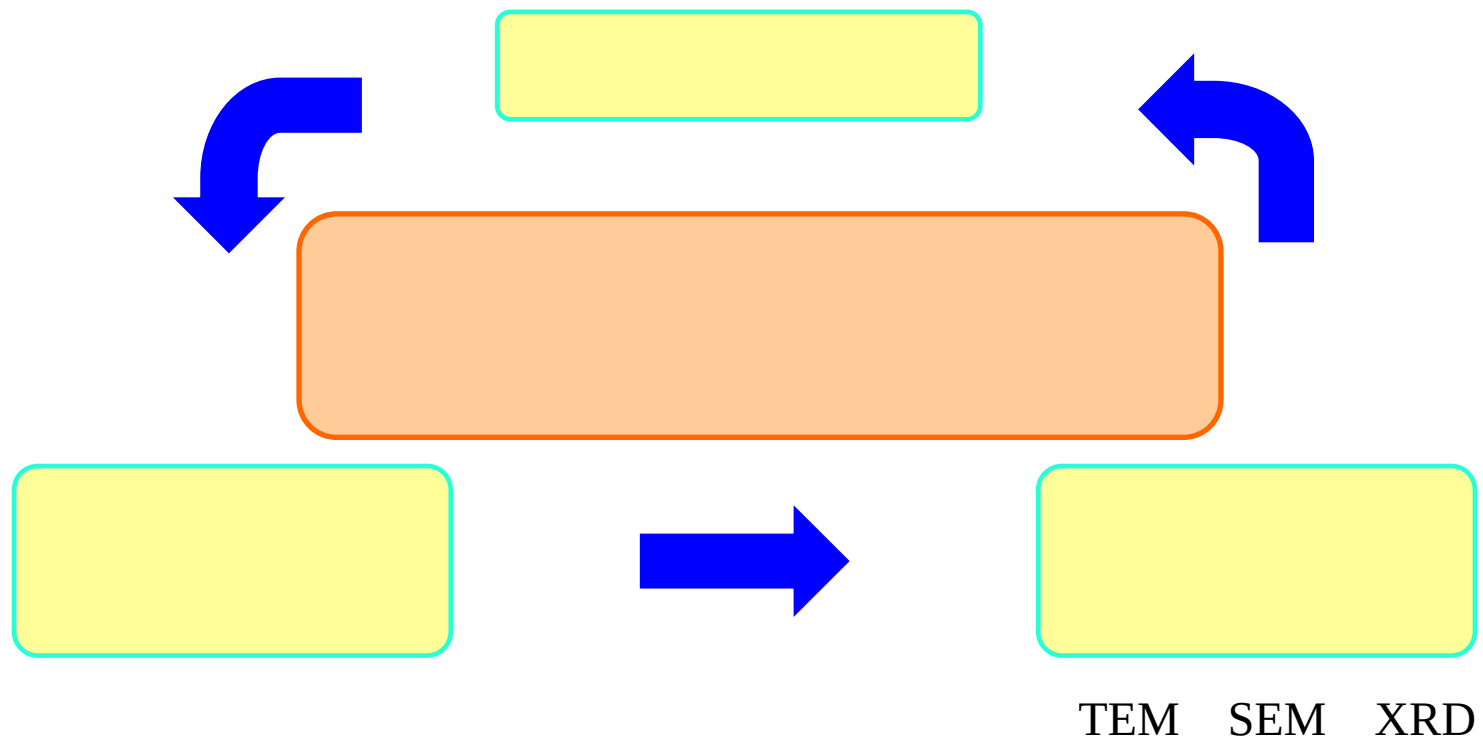


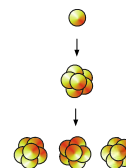
Short Outline

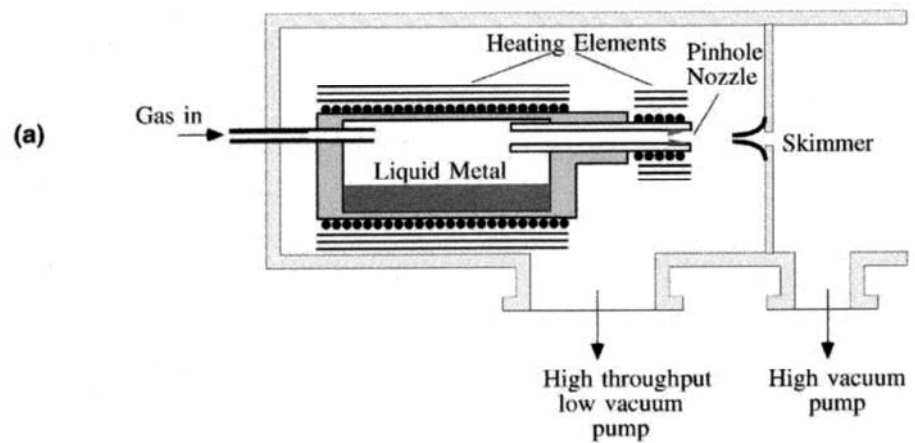




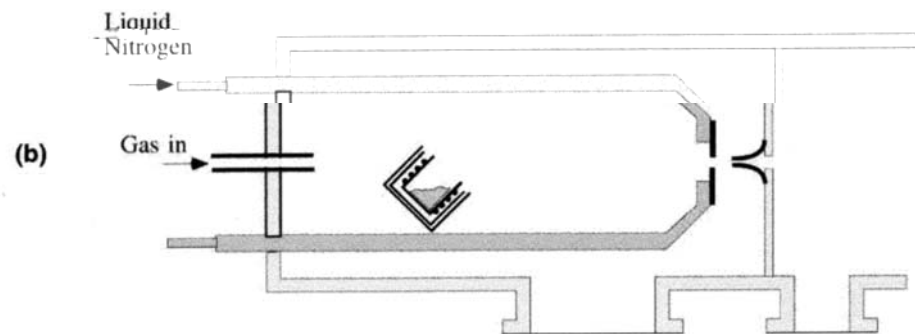






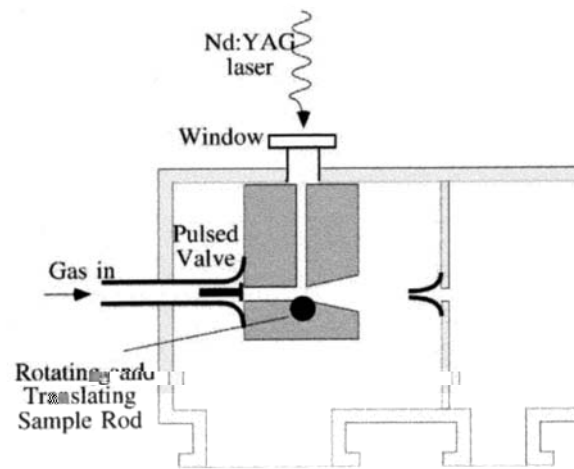


(a) (b)

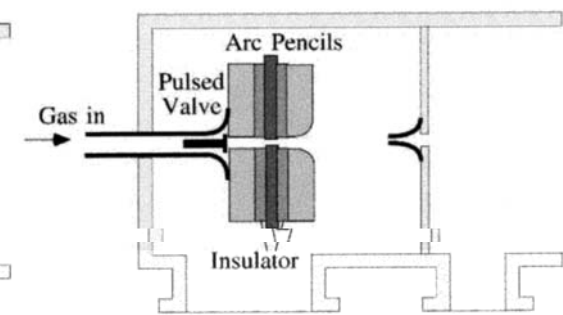


(c)

(d)



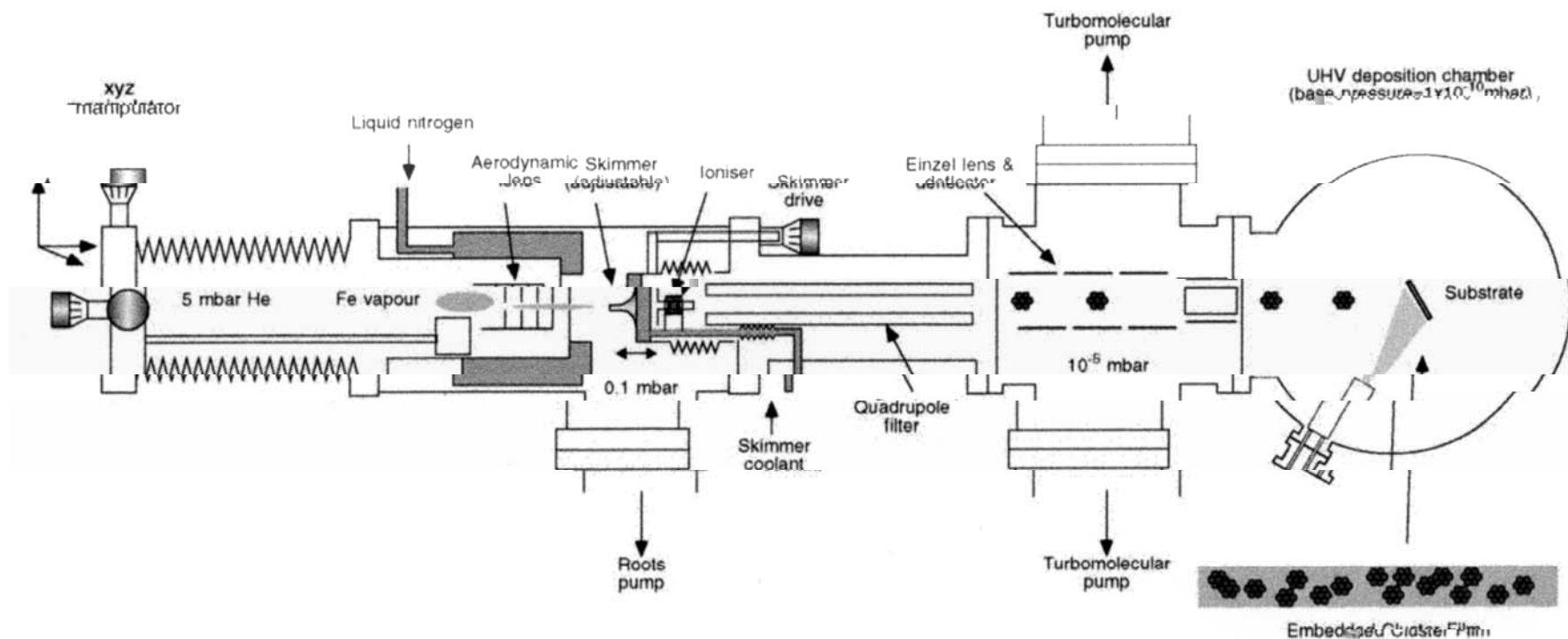
(c)



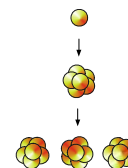
(d)



Set-up of the Binns' group, UK

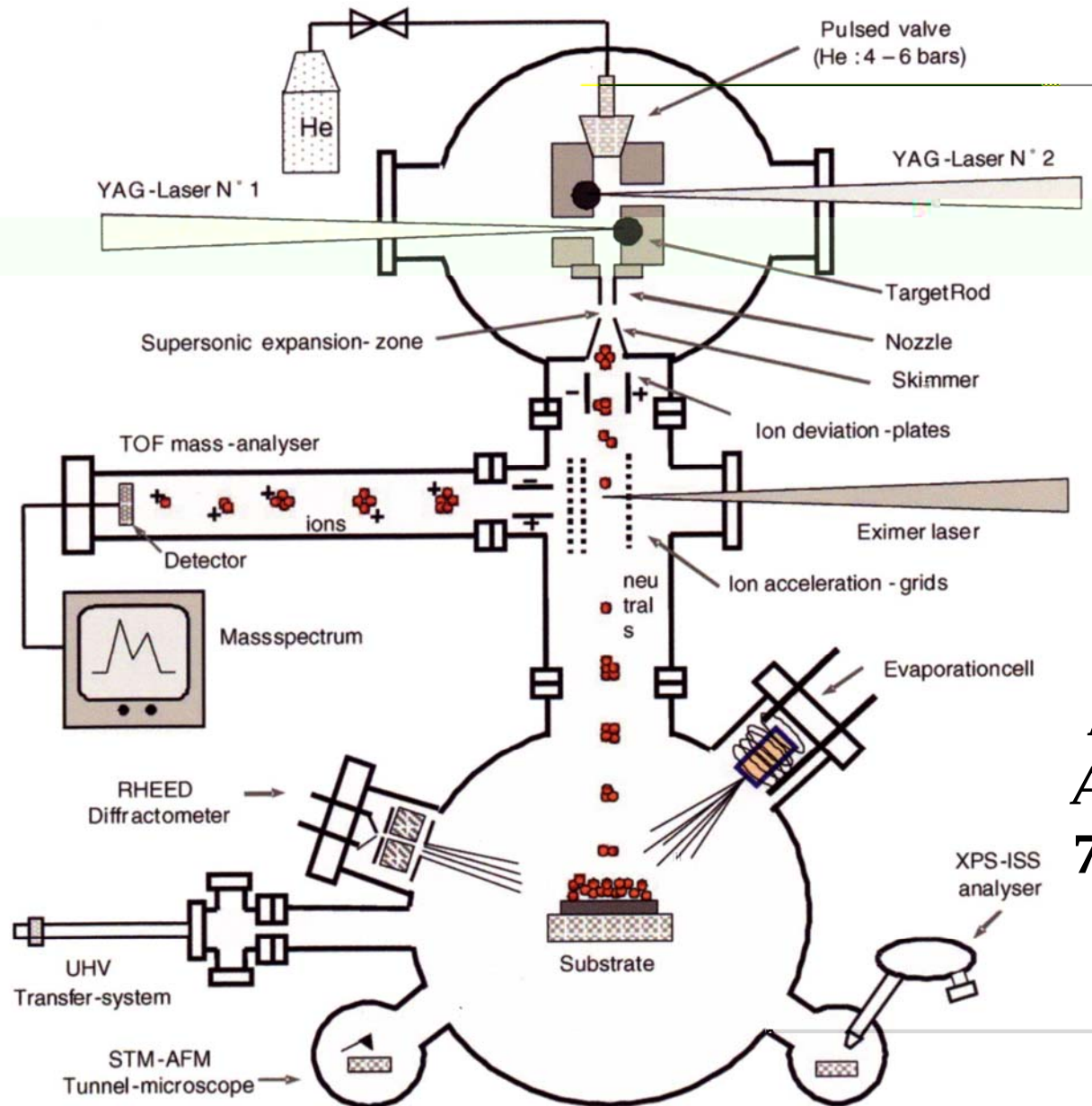


S.H. Baker *et al.*, *Rev. Sci. Instrum.* 71 (2000) 3178.

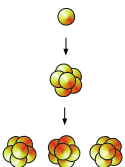




Set-up of the Perez's group, France

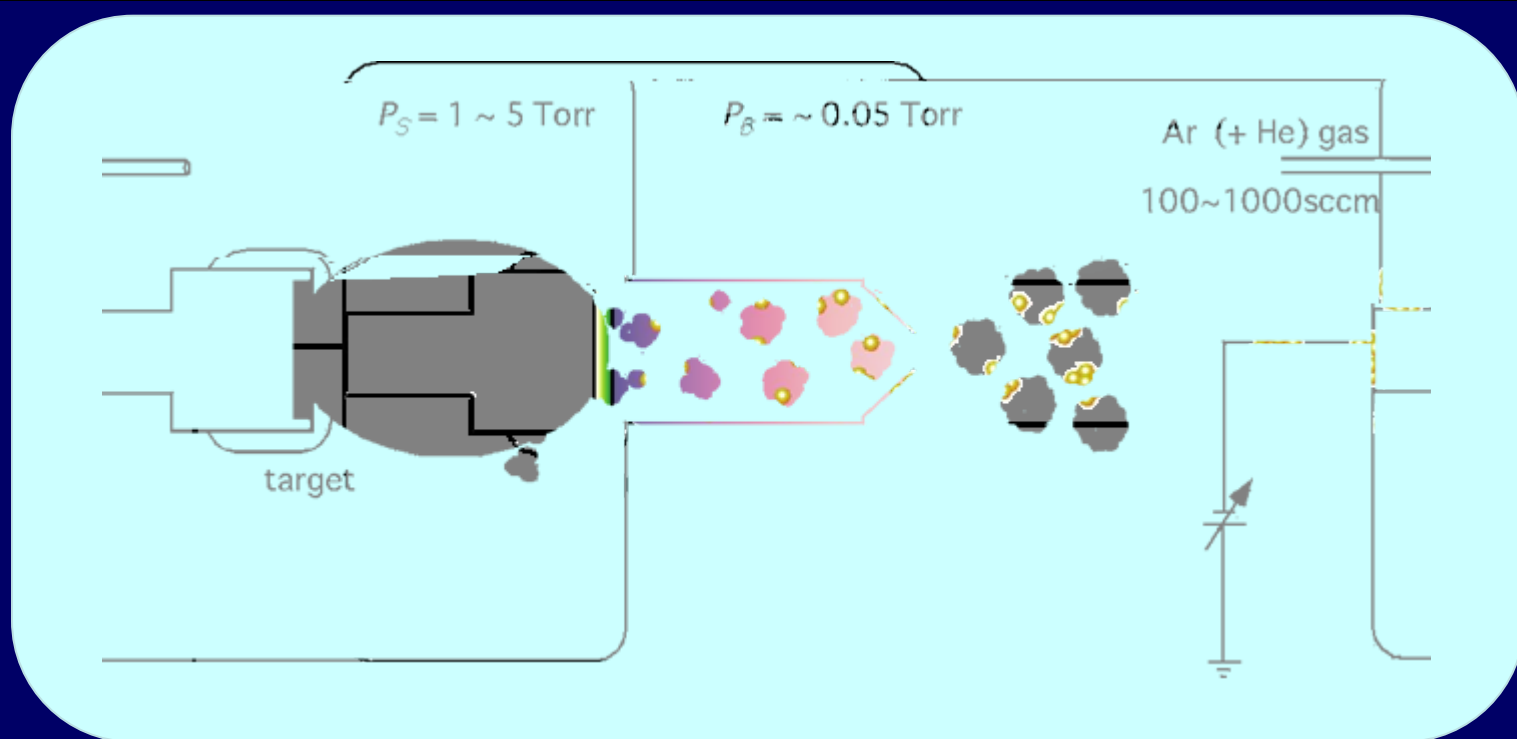


**A. Perez et al.,
Adv. Eng. Mater.,
7 (3.7j2 475**

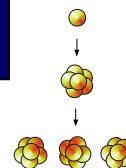


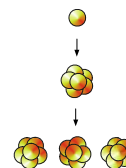
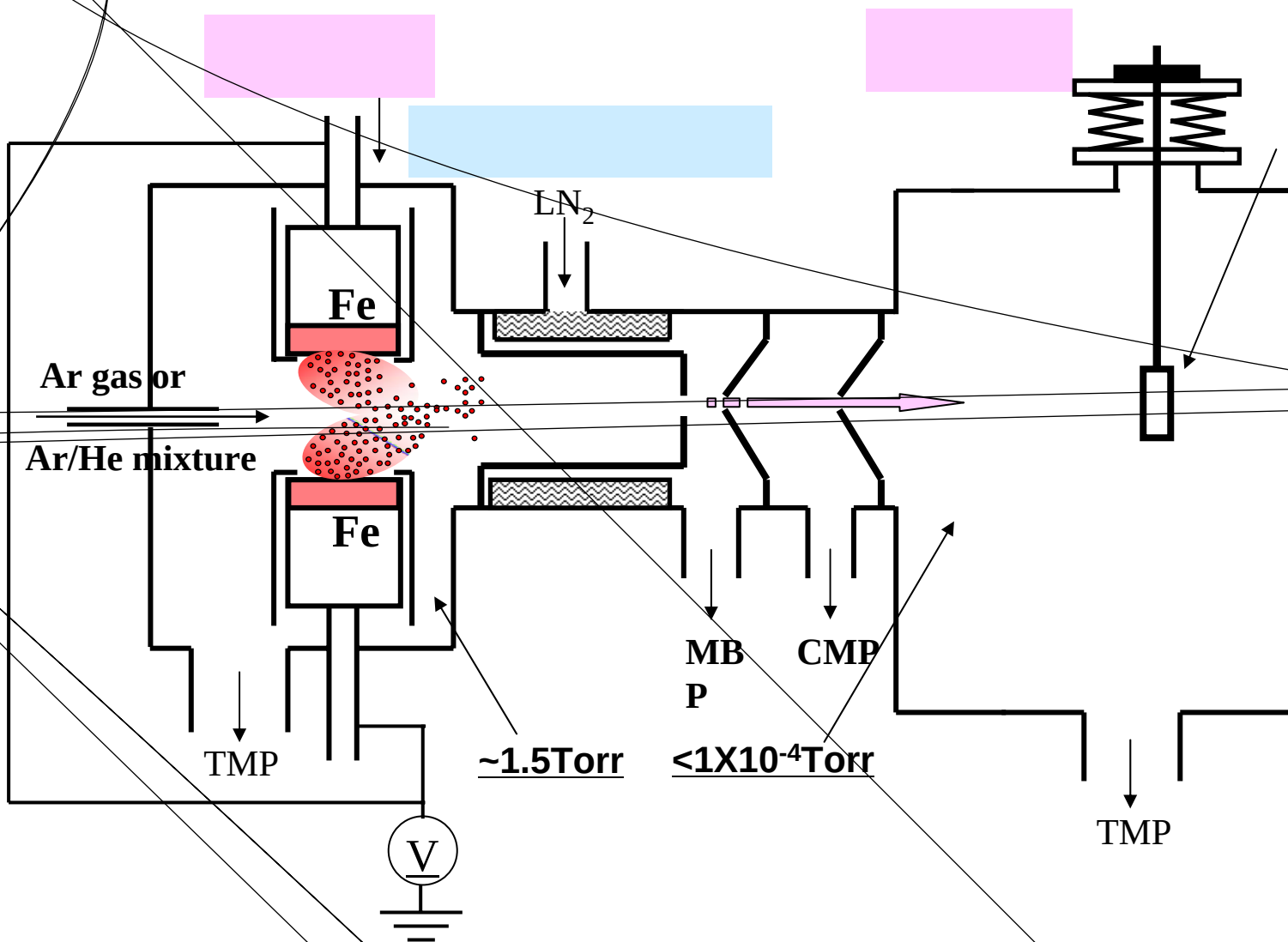


Plasma-Gas-Condensation (PGC) Cluster Source (The original Haberland source, Germany)



+

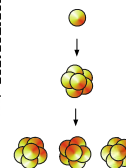
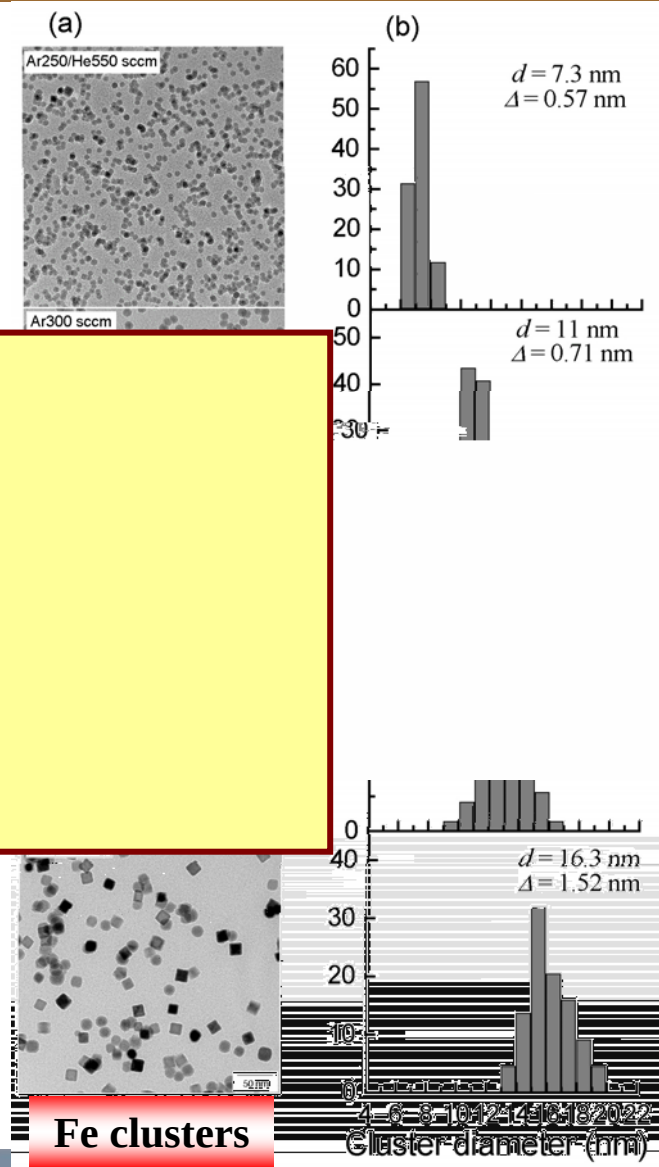
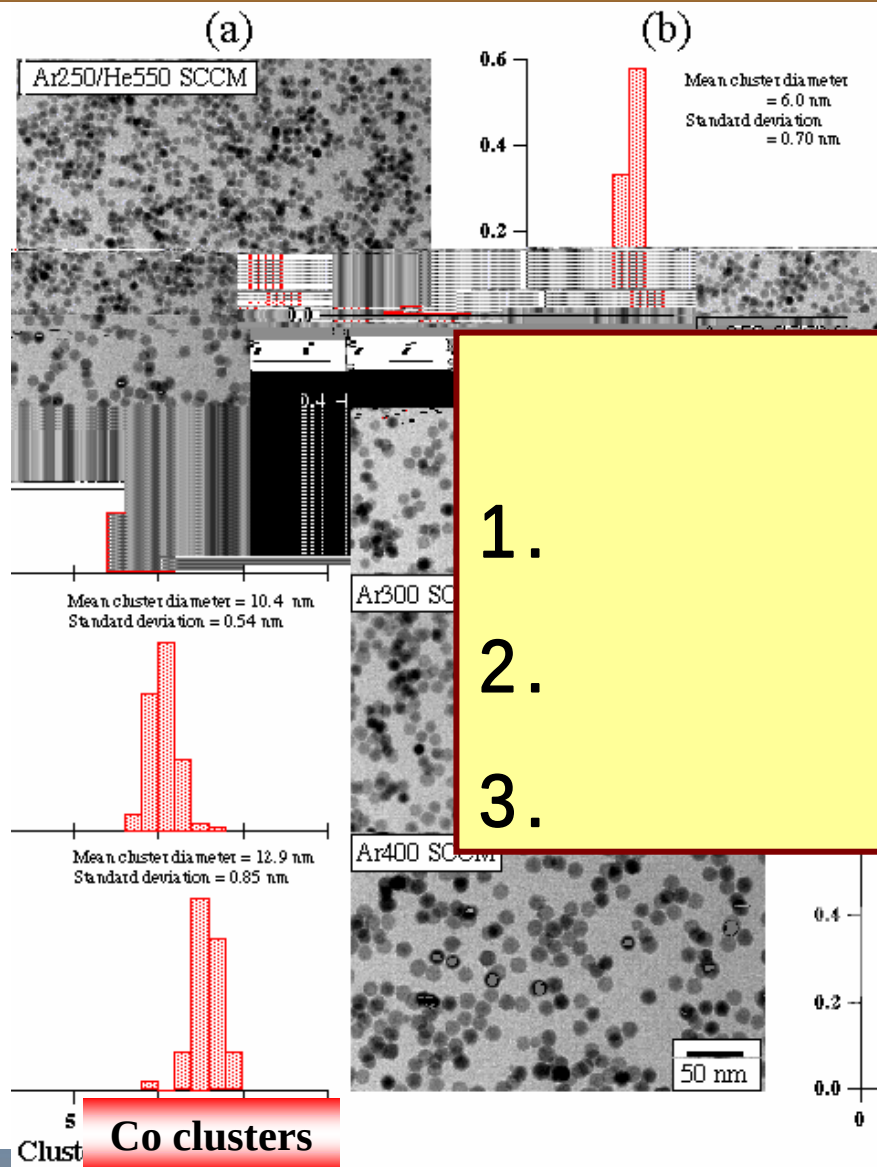


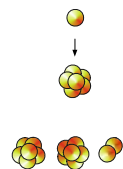




Fe

(TEM)

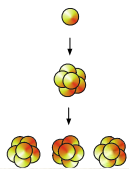
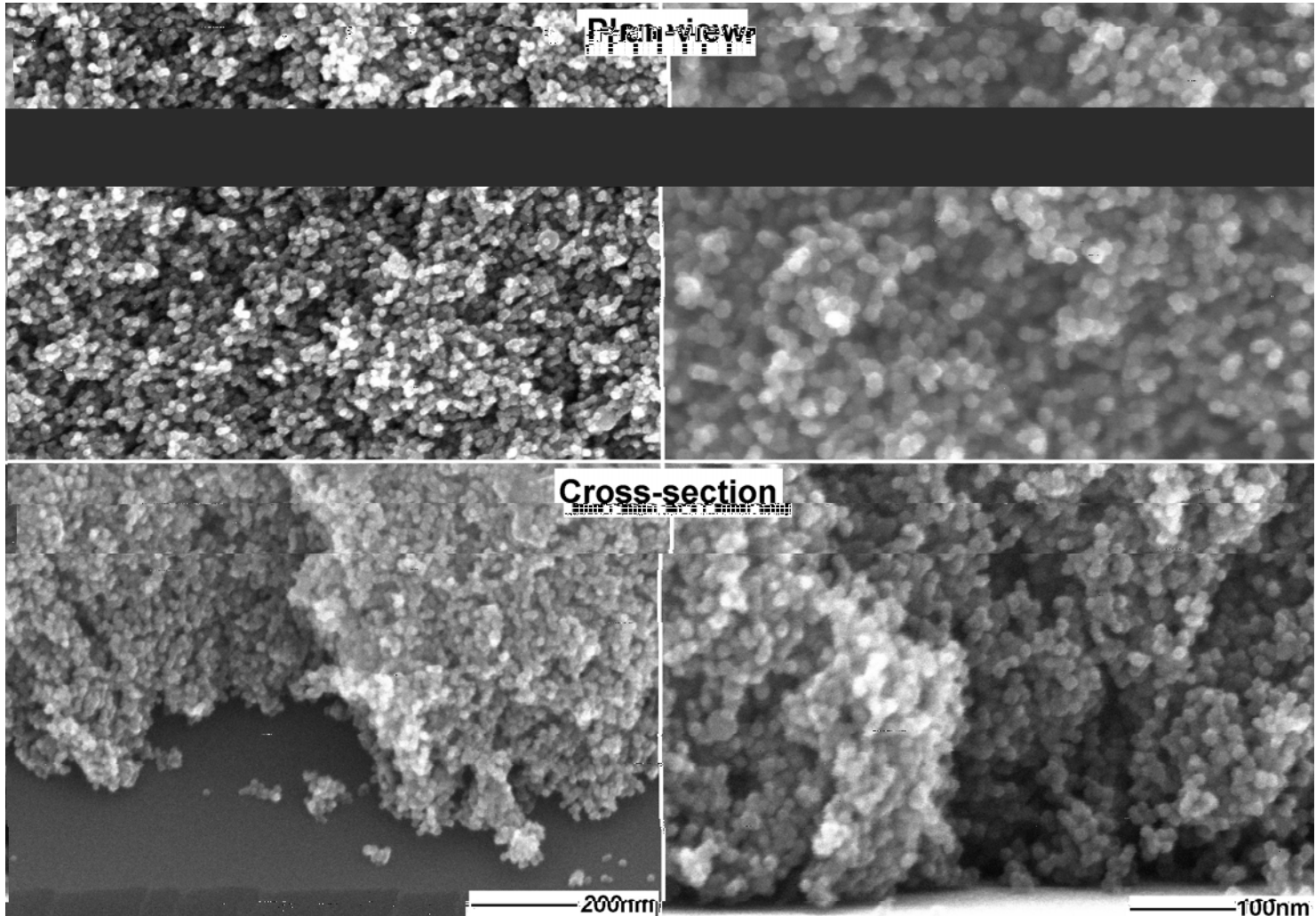






Fe

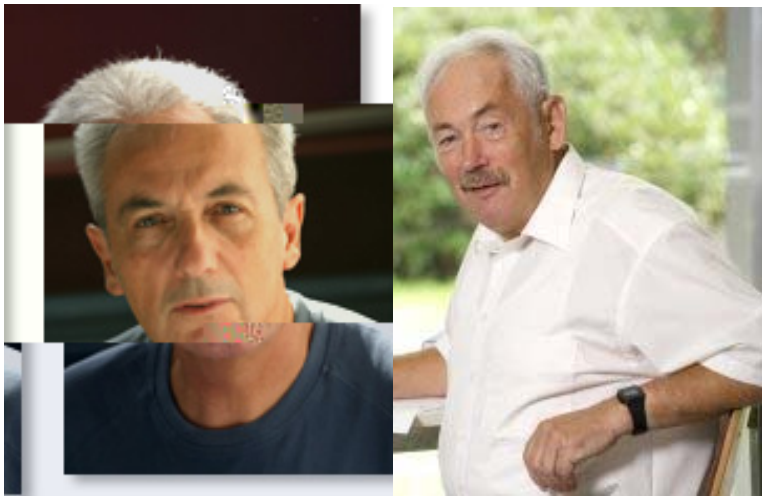
SEM





GMR

A. Fert P. Grünberg



1988

2007

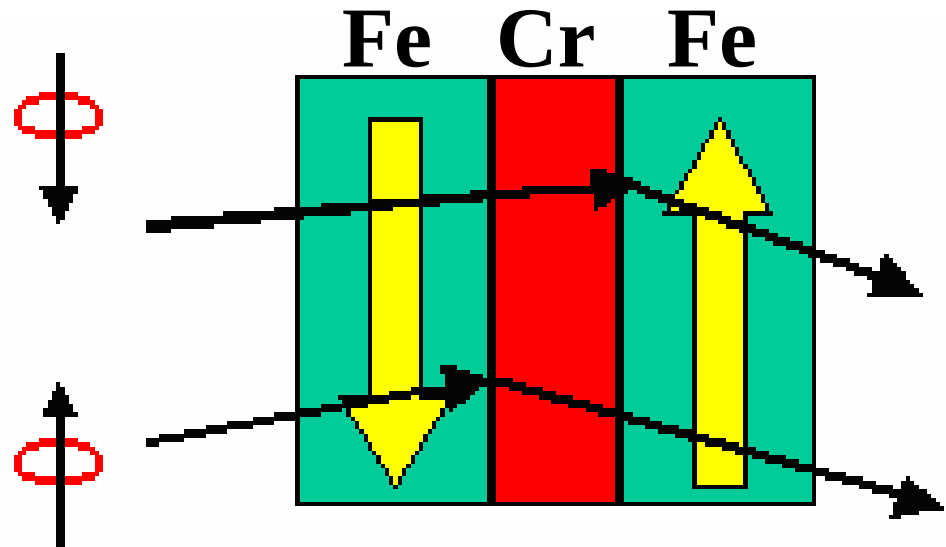
1986

Peter Gruenberg

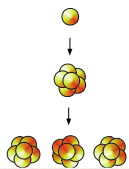
1988

Fe/Cr

Albert Fert

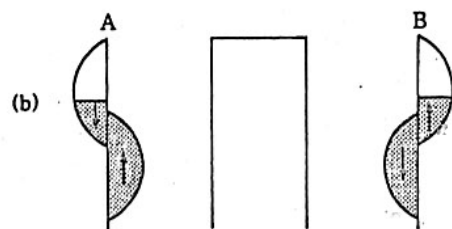
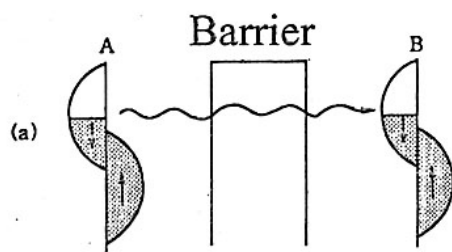
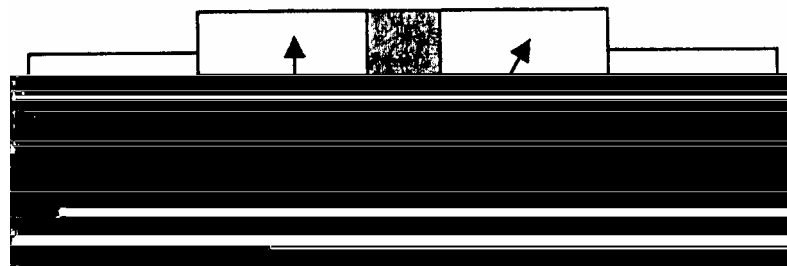


Fe/Cr/Fe





- TMR of ferromagnetic tunnel junction



(a) $M_A \uparrow \uparrow M_B$

(b) $M_A \uparrow \downarrow M_B$

$$G = \sum_{\sigma=\pm} |T|^2 D_{A\sigma}(E_F) D_{B\sigma}(E_F + eV)$$

$$|T|^2 \propto \exp(-2s\kappa), \kappa = (2m\phi)^{1/2}/\hbar$$

$$G_{\uparrow\uparrow} \propto D_{A\uparrow} D_{B\uparrow} + D_{A\downarrow} D_{B\downarrow}$$

$$G_{\uparrow\downarrow} \propto 2 D_{A\uparrow} D_{B\downarrow}$$

$$TMR = (G_{\uparrow\downarrow}^{-1} - G_{\uparrow\uparrow}^{-1}) / G_{\uparrow\downarrow}^{-1}$$

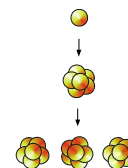
$$= 2P_A P_B / (1 + P_A P_B)$$

P_A, P_B : Spin polarization

$$P_{\zeta} = (D_{\zeta+} - D_{\zeta-}) / (D_{\zeta+} + D_{\zeta-})$$

$$(\zeta = A, B)$$

$$P_{Fe} = 44\%, P_{Co} = 34\%, P_{Ni} = 11\%$$





- TMR of magnetic metal-insulator granular system

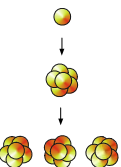
$$MR = \frac{P^2 m^2}{1 + P^2 m^2}$$

E_c : charge energy

P : spin polarization

m : relative magnetization

$$P_{\text{Fe}} = 0.44$$





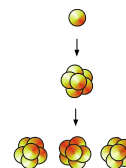
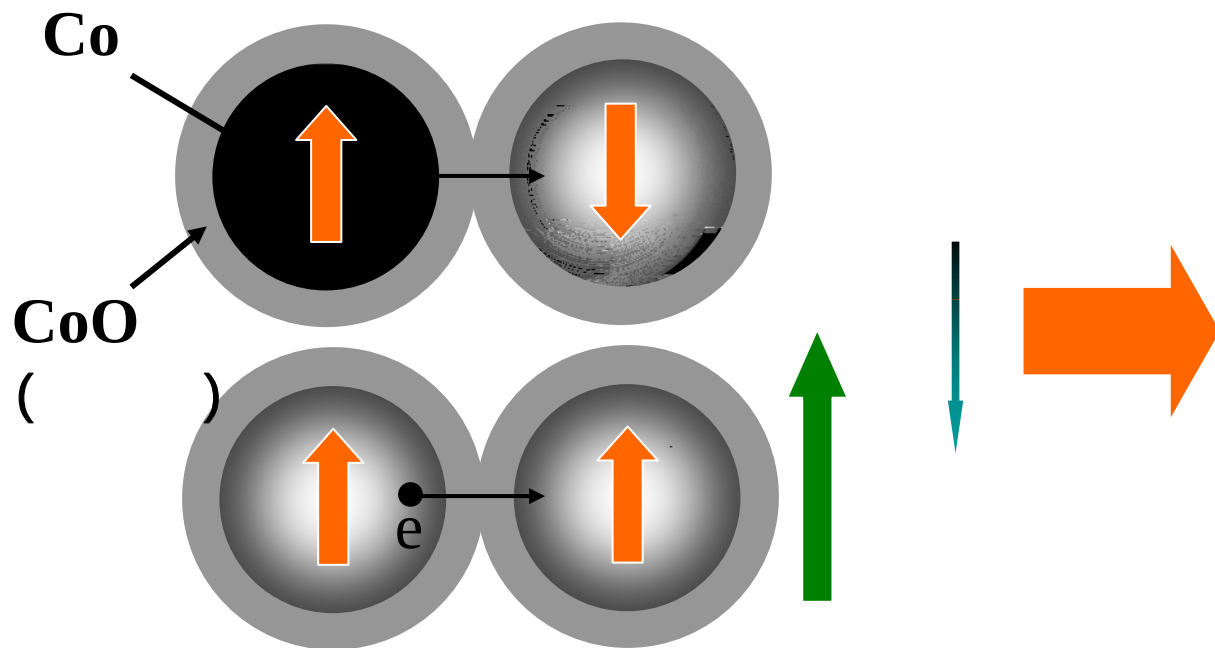
-

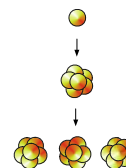
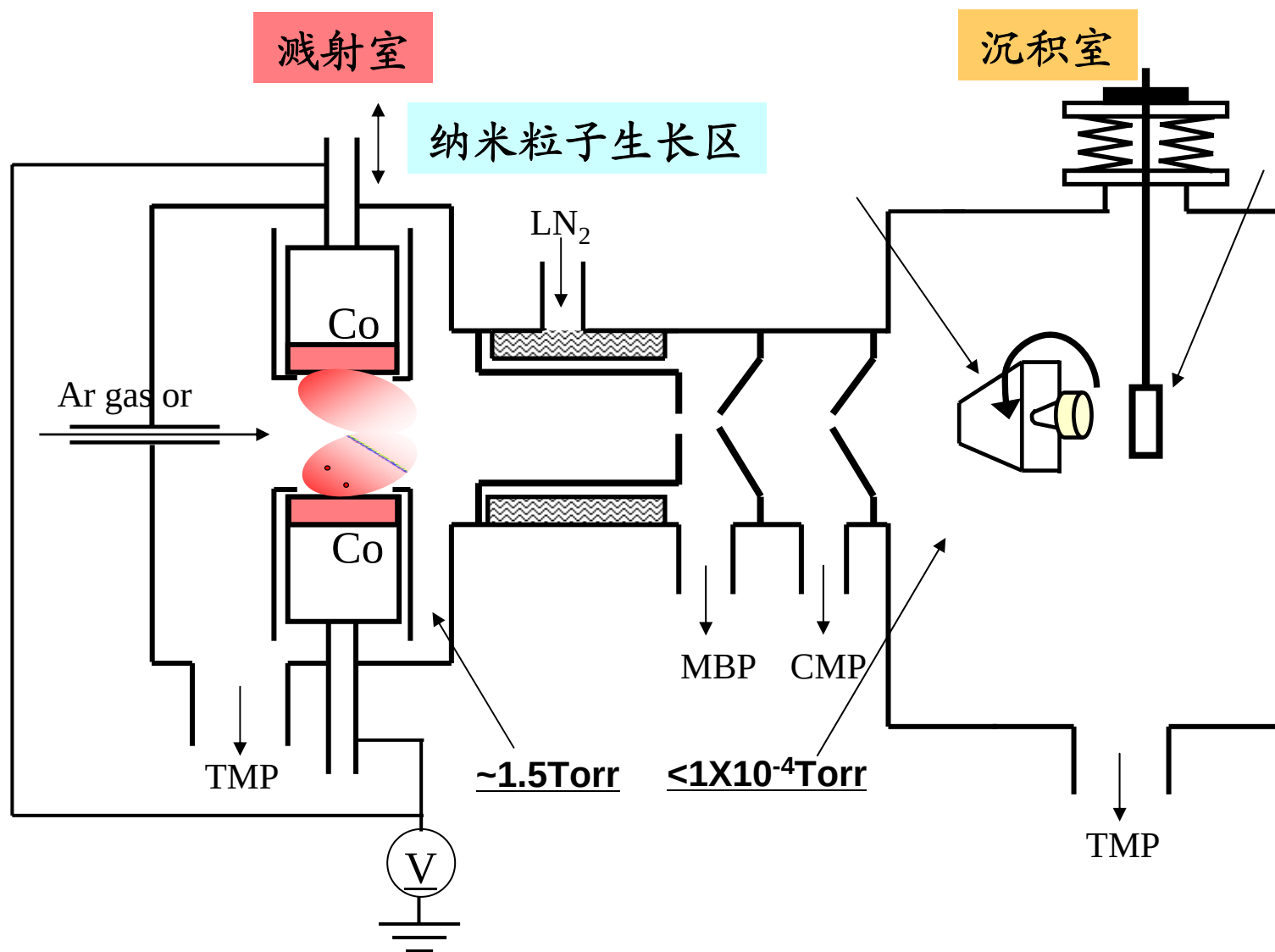


(TMR) ??



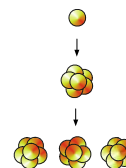
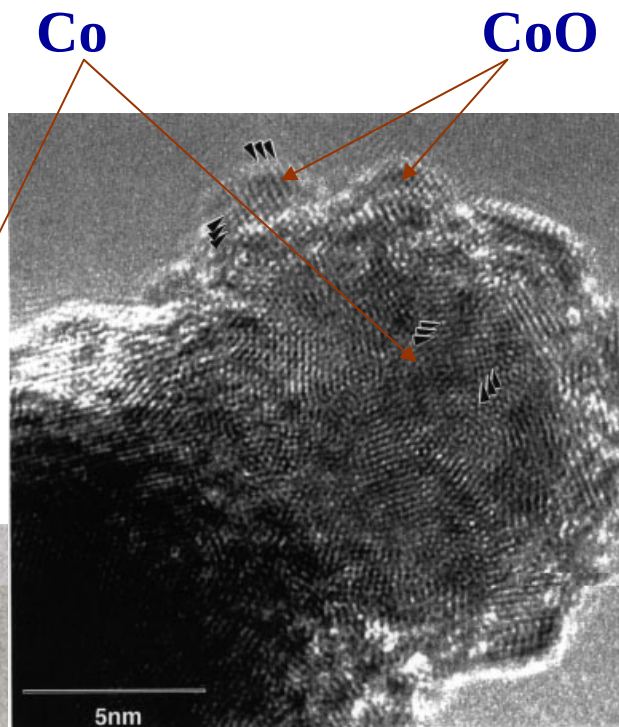
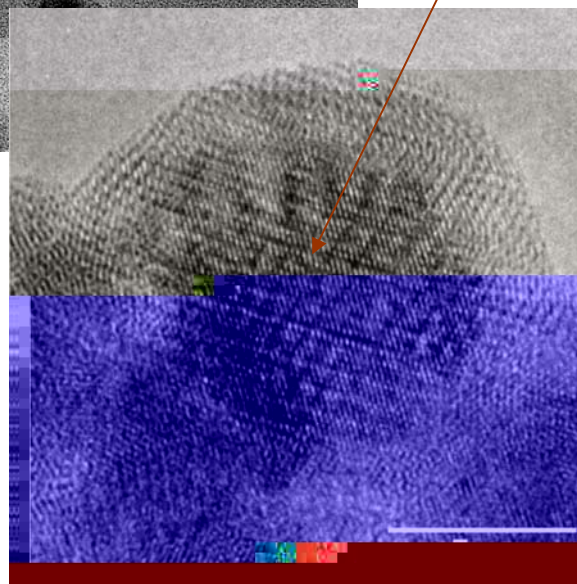
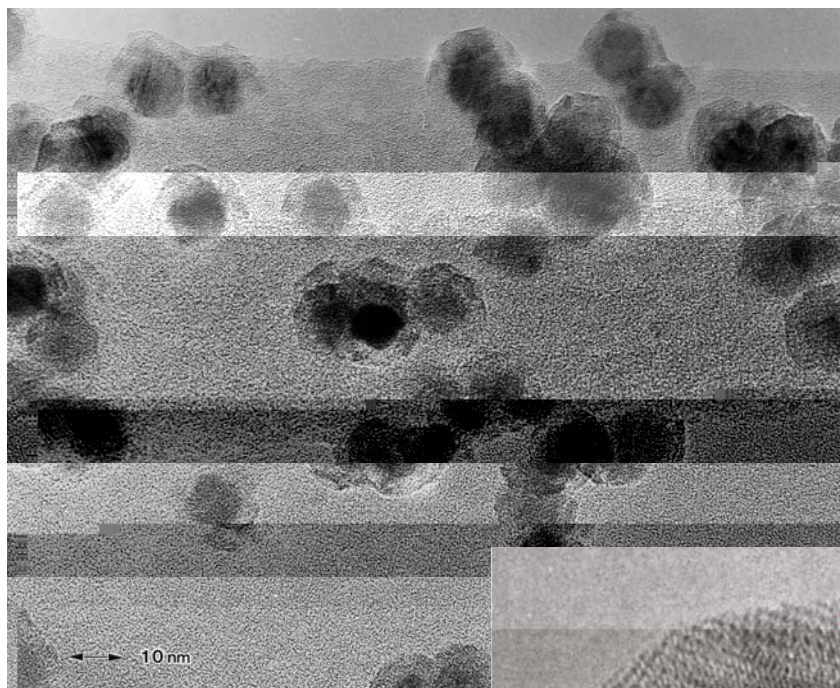
??





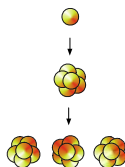
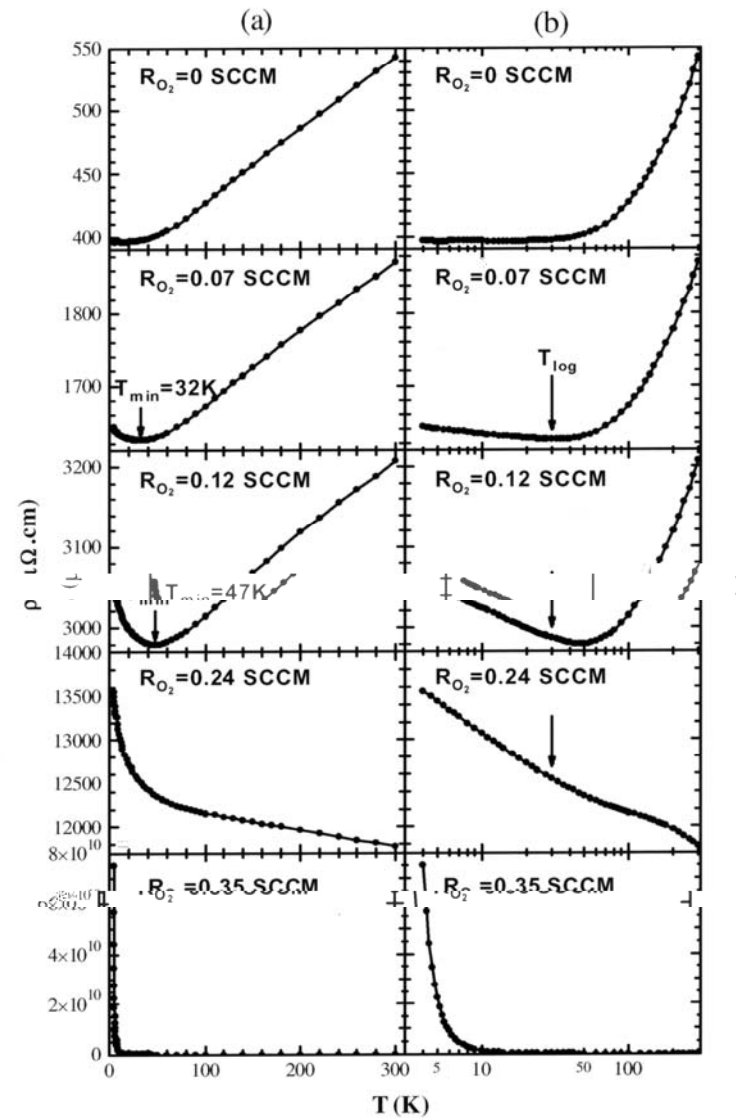
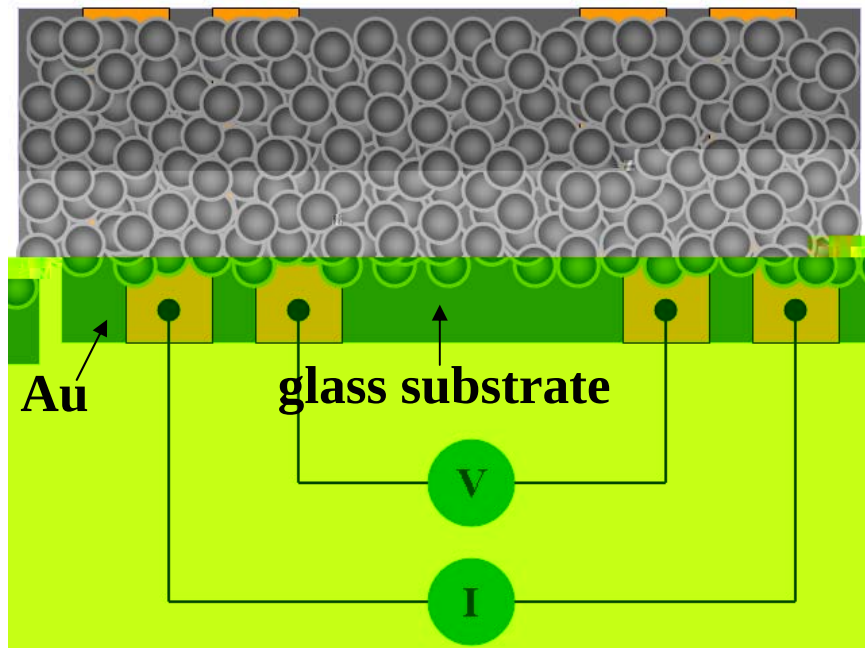


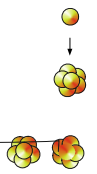
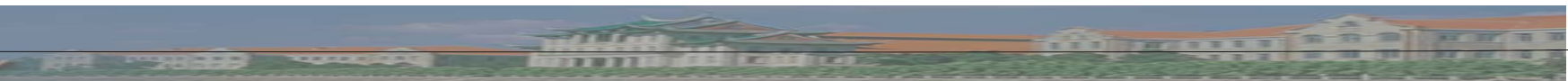
Co/CoO -

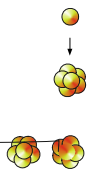
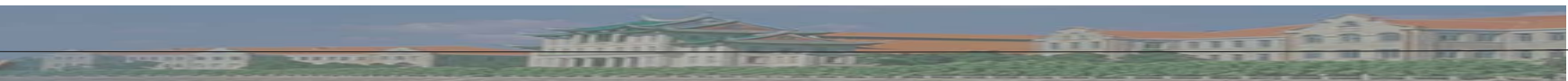




Co/CoO





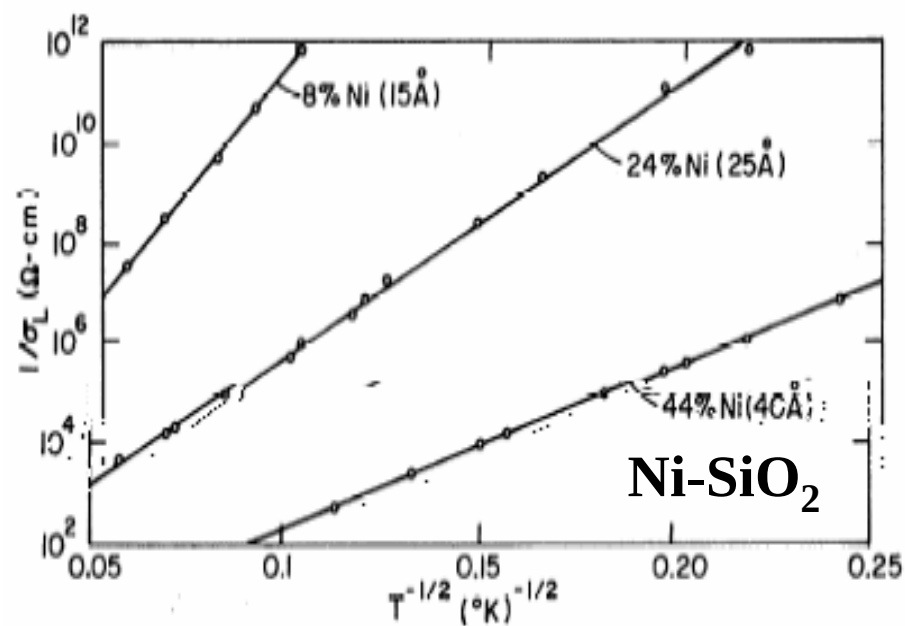




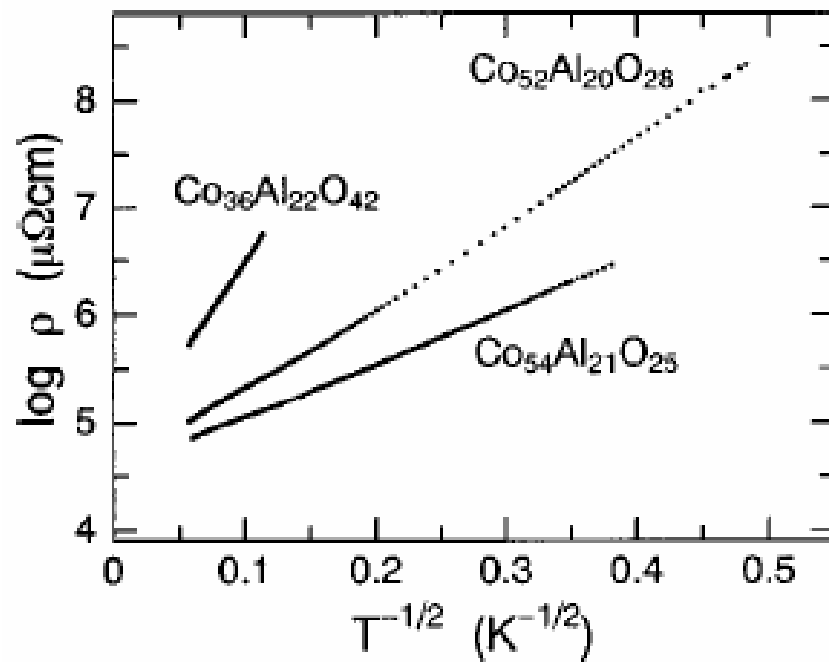
“

”

(Granular films)



Ping Sheng et al., *PRL*, 31(1973)44



S. Mitani et al., *JAP*, 83(1998)6524

25

$$\sigma \propto \exp(-b/T^{1/2})$$





$$\sigma \propto \exp(-bT^{-1/2})$$

Sheng & Abeles' Tunneling Conduction Theory in Granular Metals PRL 37(1976)1429

$$\sigma \propto \int_0^\infty \int_0^\infty ds dr D(s,r) \exp(-2\kappa s - E_c/2k_B T), \quad (1)$$

Charging energy: $E_c \propto 1/r$

On the basis of the assumption:

$$sE_c = C \text{ (constant) or } s \propto r,$$

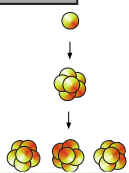
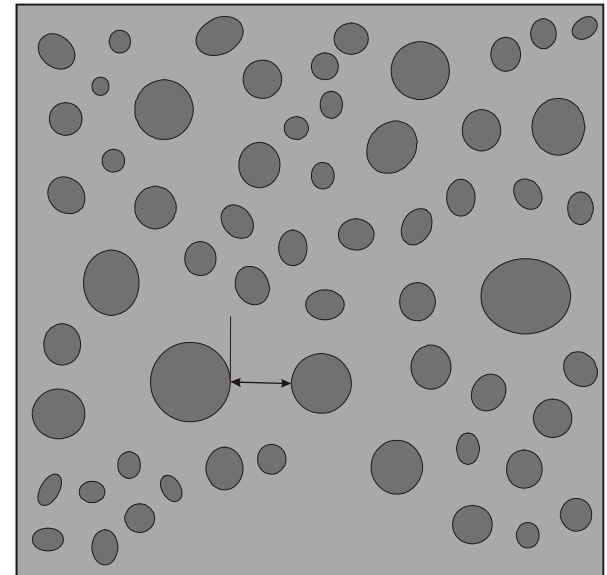
$$\sigma \propto \int_0^\infty ds D(s) \exp(-2\kappa s - E_c/2k_B T),$$

$\exp(-2\kappa s - E_c/2k_B T) \longrightarrow \text{maximum}$

$$s_m = (C/4\kappa k_B T)^{1/2}.$$

The dominant temperature dependence:

$$\sigma \propto \exp(-b/T^{1/2}) \quad (2)$$





$$\sigma \propto \exp(-bT^{-1})$$

Neugebauer and Webb, JAP 33(1962)74

Conductivity:

$$\sigma \propto \int_0^\infty \int_0^\infty ds dr D(s,r) \exp(-2\kappa s - E_c/2k_B T), \quad (1)$$

κ is the tunneling exponent of electron wave functions in the insulator, $\kappa = [2m^*(\phi + E_F - E)/h^2]^{1/2}$.

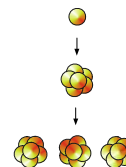
Charging energy: $E_c \propto 1/r$

r : the size of metal grains

s : the separation of neighboring metal grains

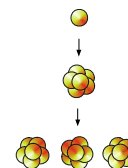
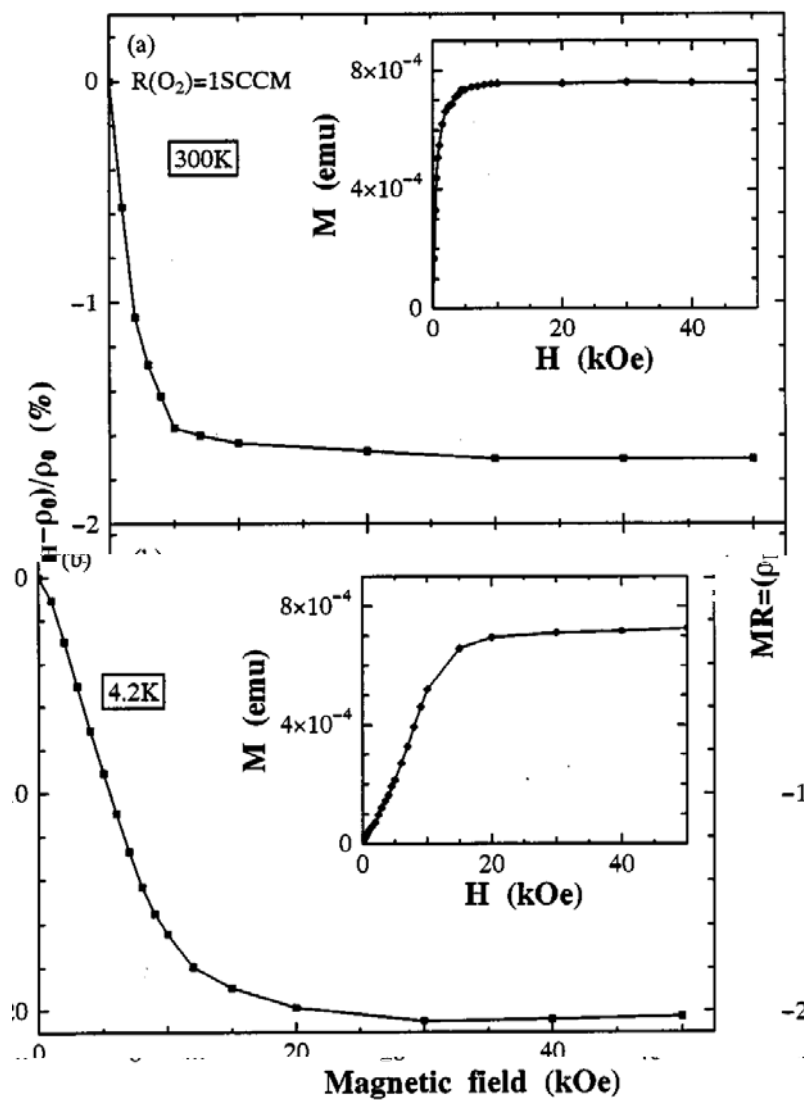
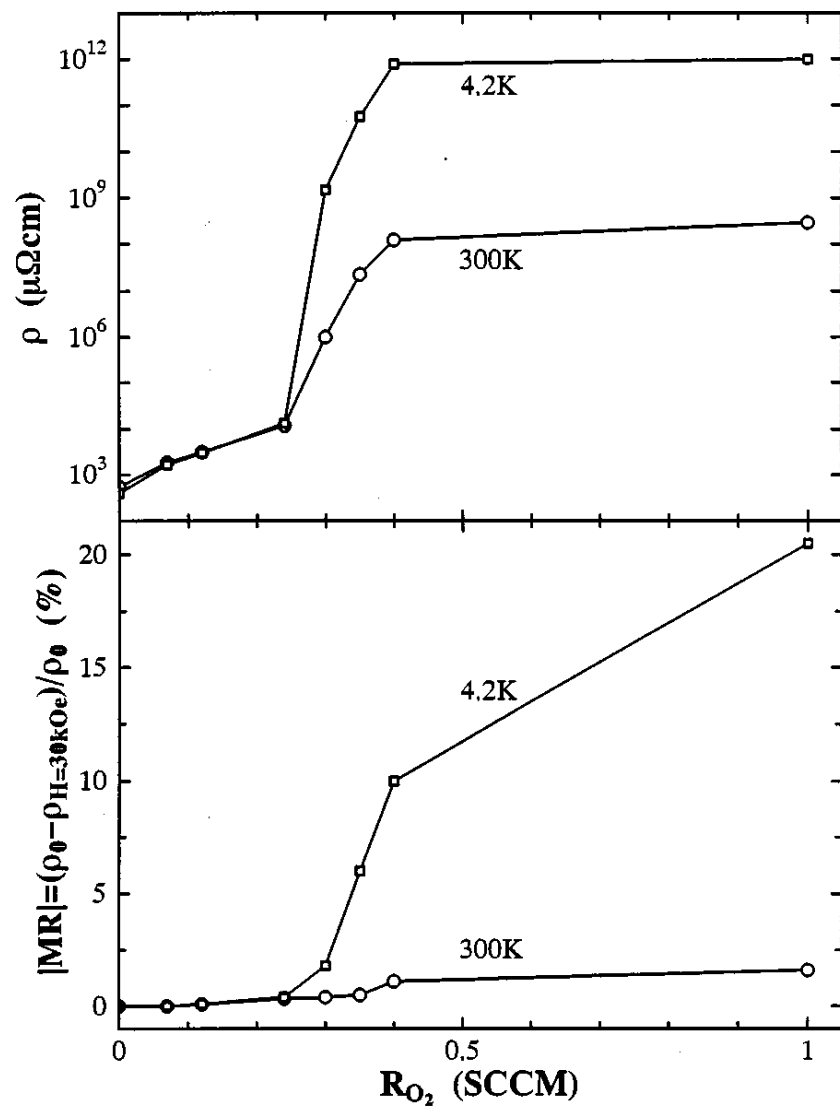
When the cluster size is monodispersed and the intercluster distance is uniform,

$$\sigma(T) \propto \exp(-E_c/2k_B T) \propto \exp(-1/T). \quad (2)$$





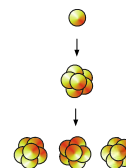
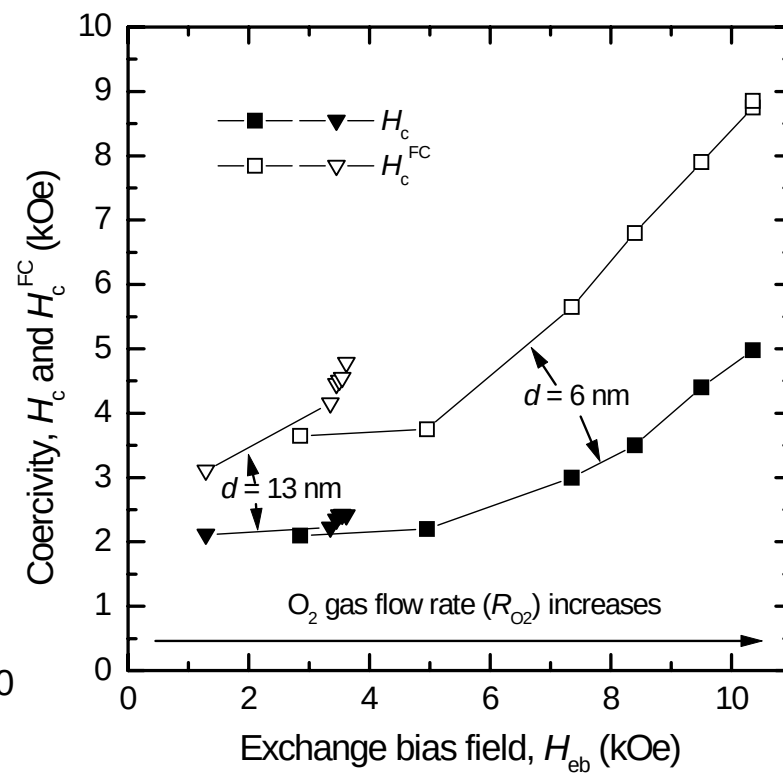
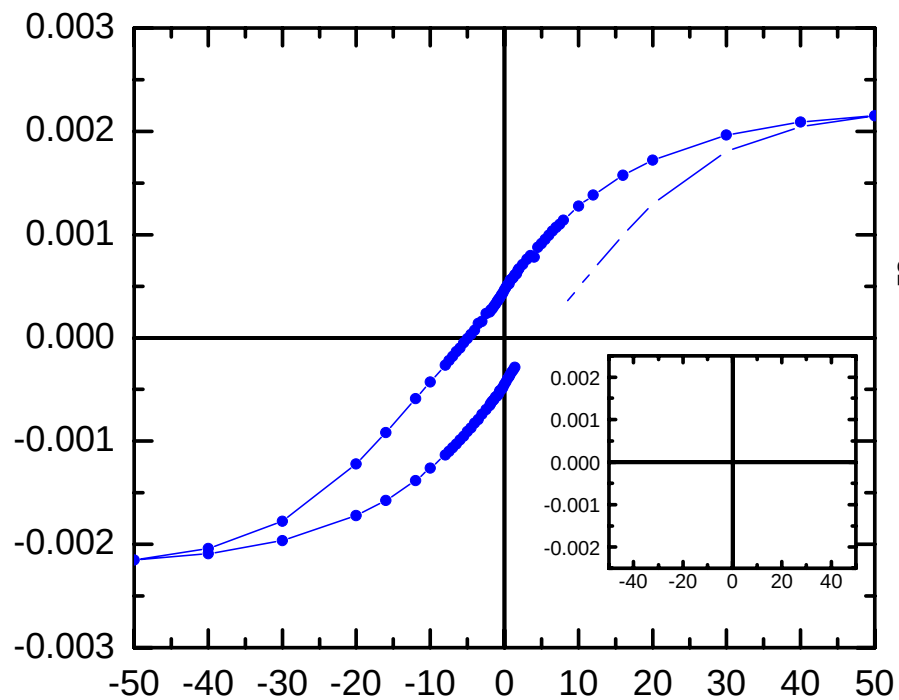
Co/CoO

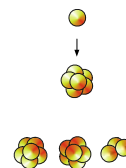


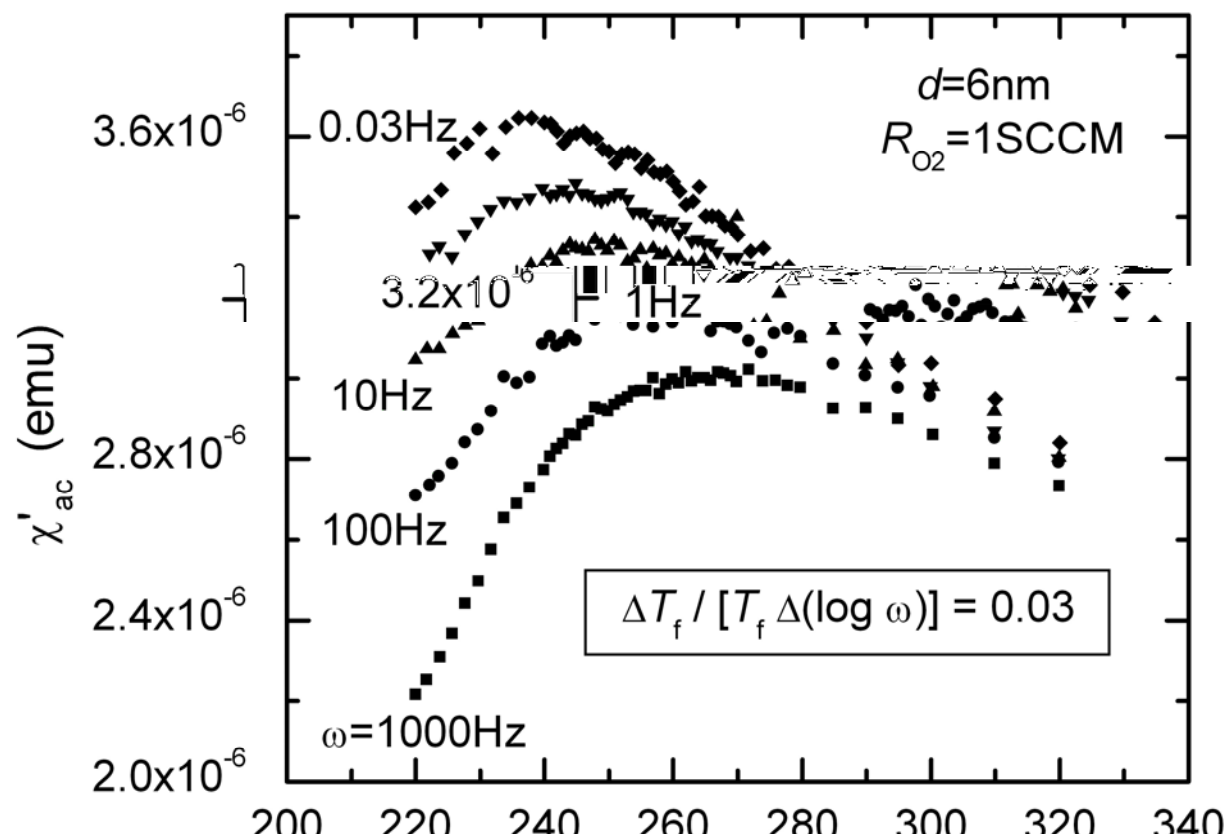


Co/CoO

Co

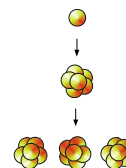






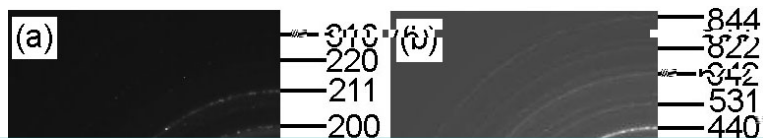
**Spin-glass-like
state in the
interfacial layer.**

$\Delta T_f / [T_f \Delta(\log \omega)]$ is the same order as those of the spin glasses and smaller than the values (0.2-0.3) of the superparamagnets.

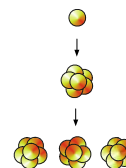
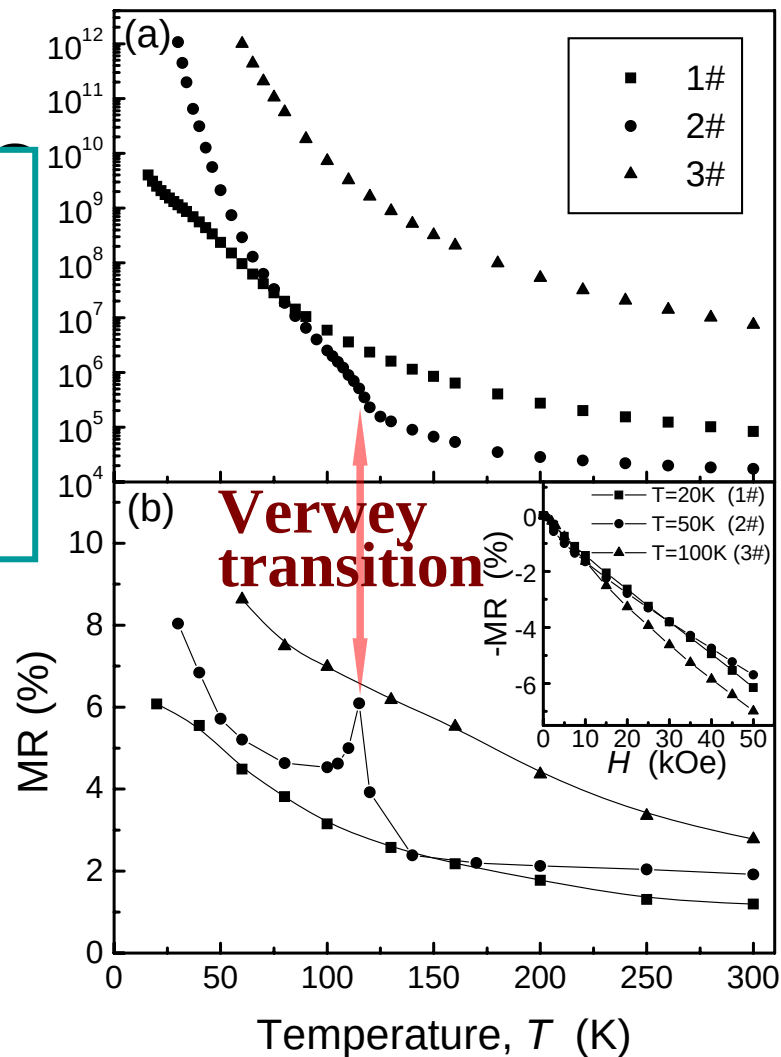
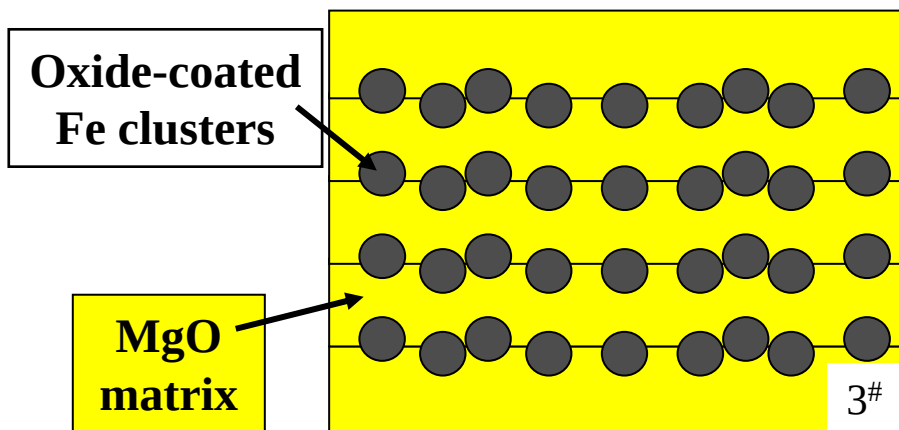




Fe

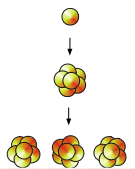
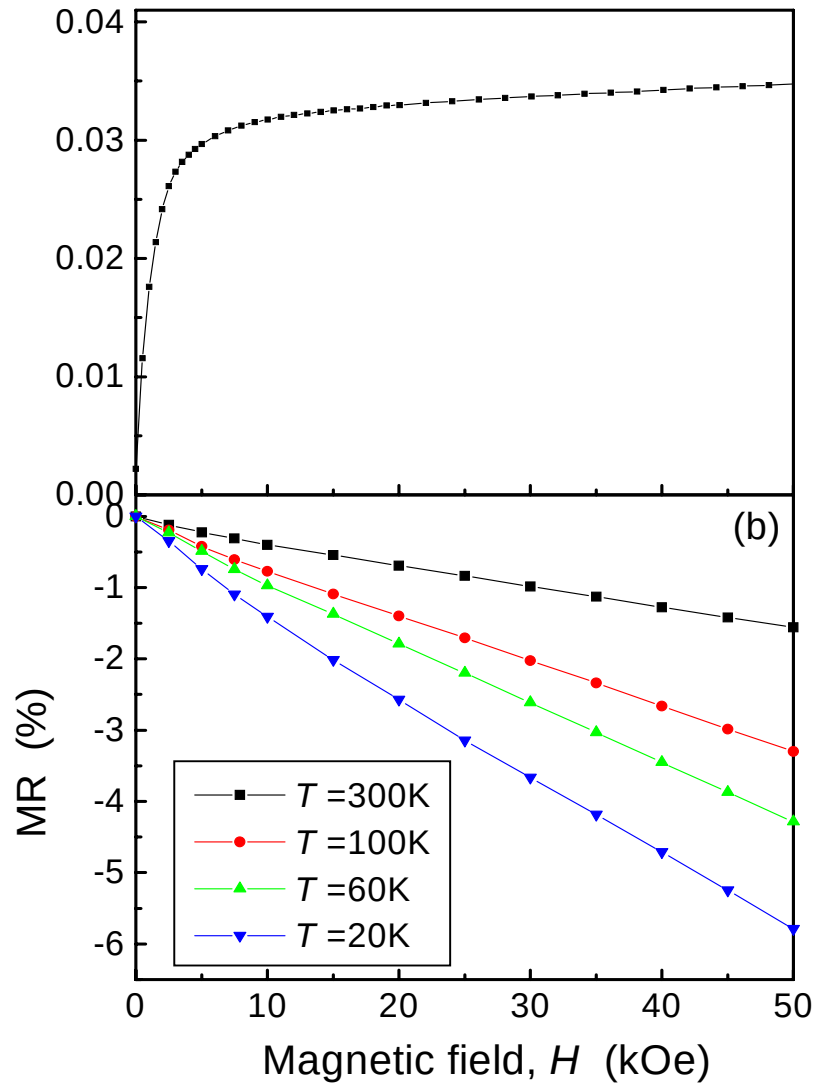


在表面氧化Fe核-壳结构的纳米粒子组装体系统中隧穿巨磁阻效应显示特殊规律性；非常小的表面氧化物颗粒导致了高磁场非饱和磁阻特性；为了增强高温巨磁阻效用，非磁性障碍层的引入是非常重要的。



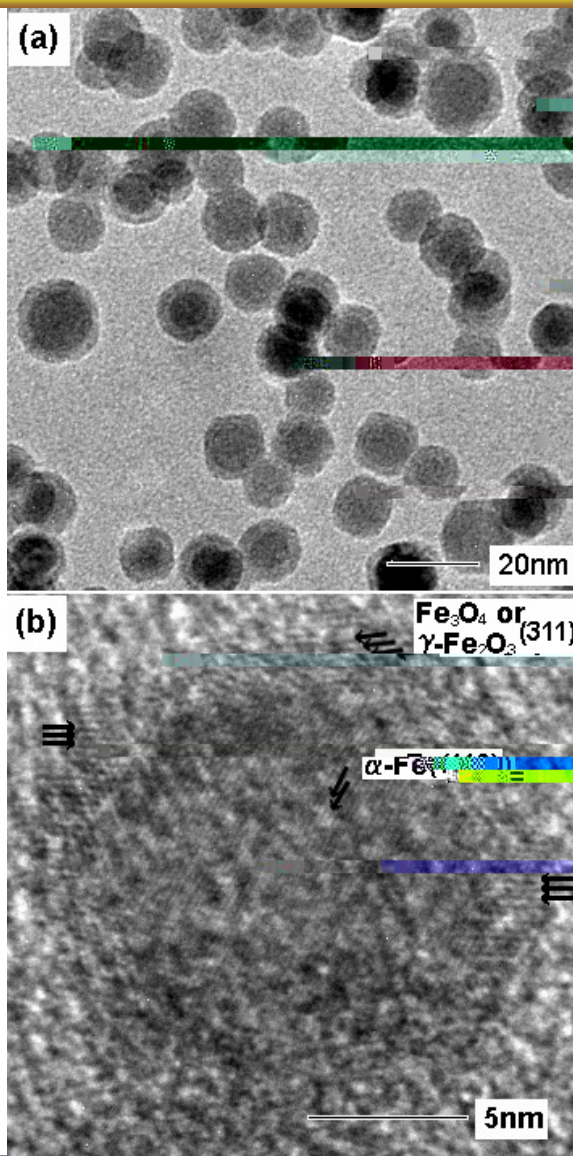


Comparison of magnetic field dependence of magnetization and MR

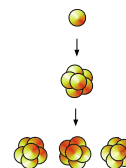




TEM images of the oxide-coated Fe clusters with $d = 13$ nm

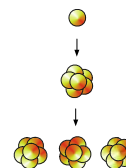
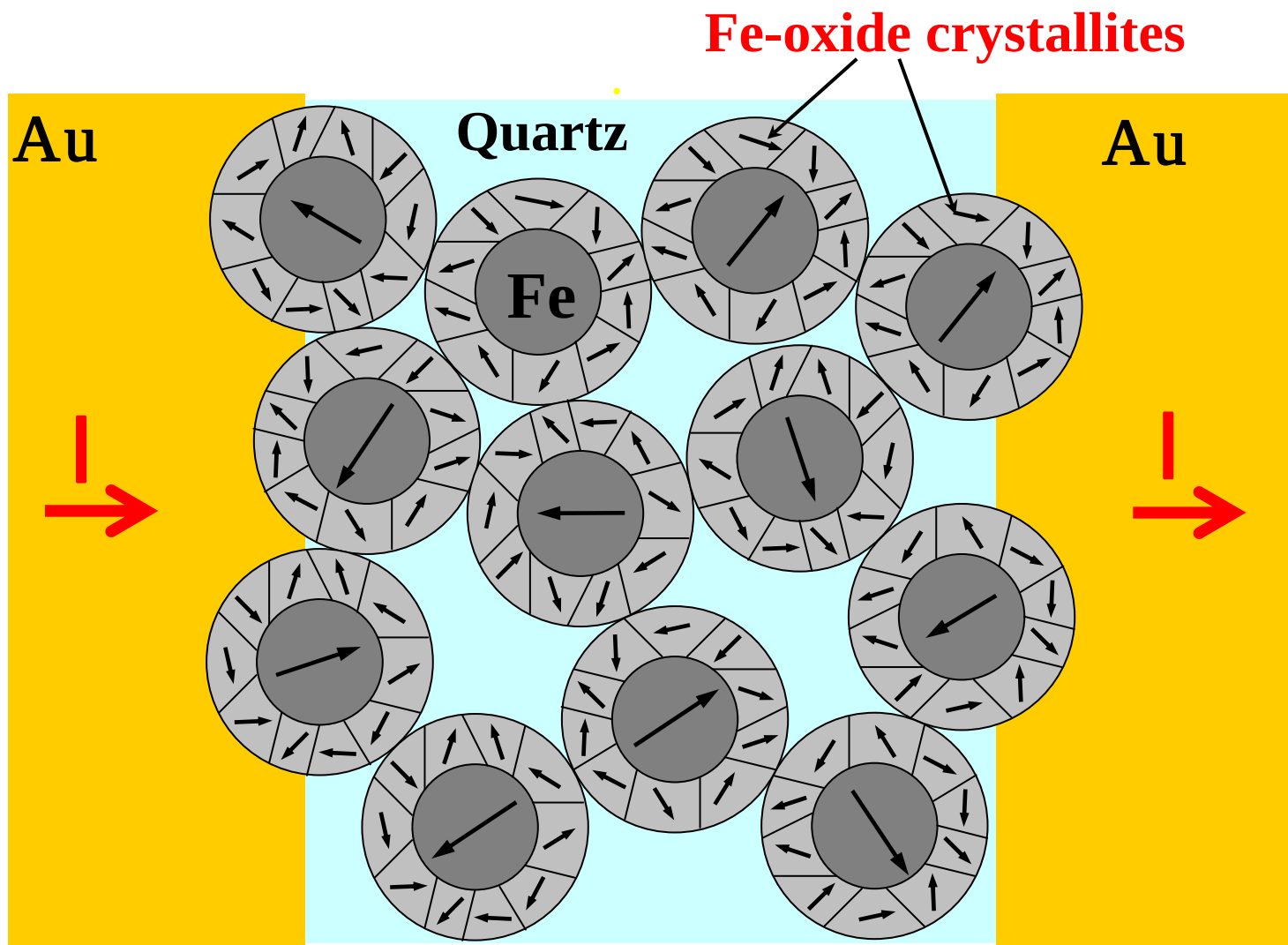


**Core-shell structure
and small oxide shell
crystallites**





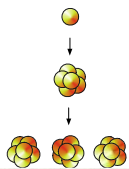
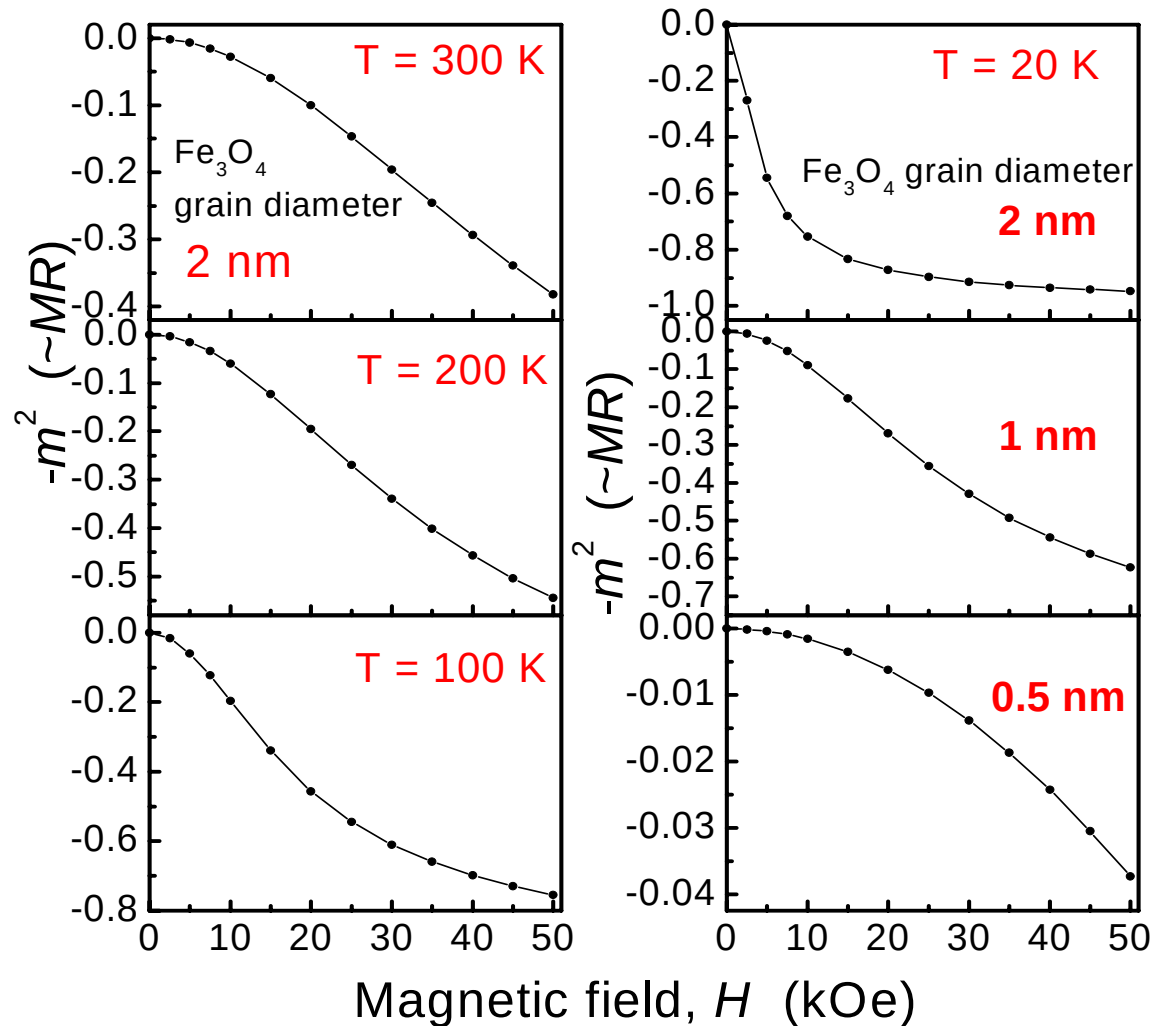
Schematic illustration for tunneling conduction in this core-shell-type oxide-coated Fe cluster assembly





Magnetic field H dependence of m^2 and MR when a superparamagnetic state is assumed

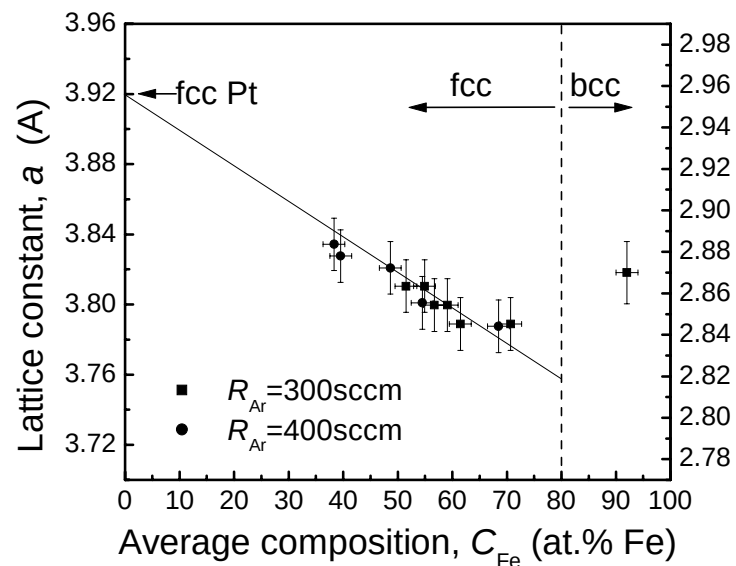
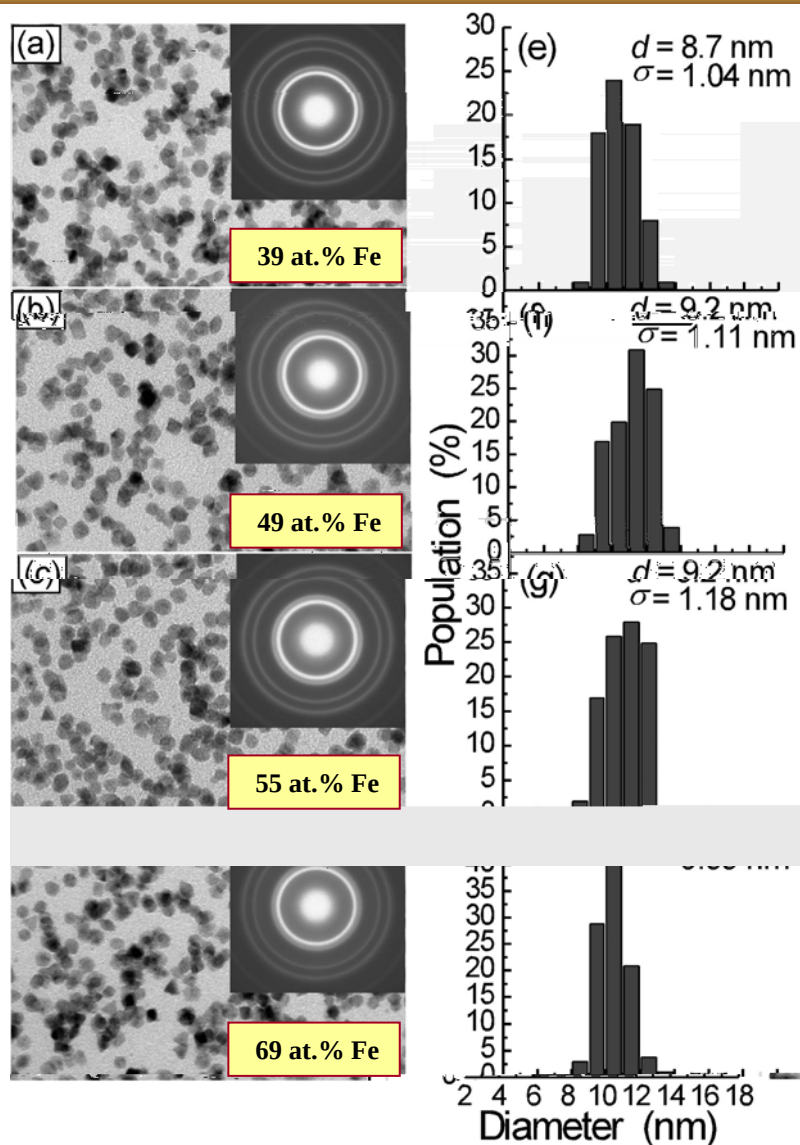
Calculated result using Langevin function $L(\mu H/kT)$



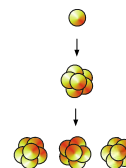




Fe-Pt



对异种单质靶材进行溅射合金化，
可以获得成分可控的合金纳米粒子。





TEM images and ED patterns of $\text{Fe}_{49}\text{Pt}_{51}$ cluster-assembled film with a thickness of $t = 30 \text{ nm}$ ($d = 9 \text{ nm}$)

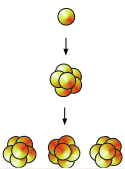
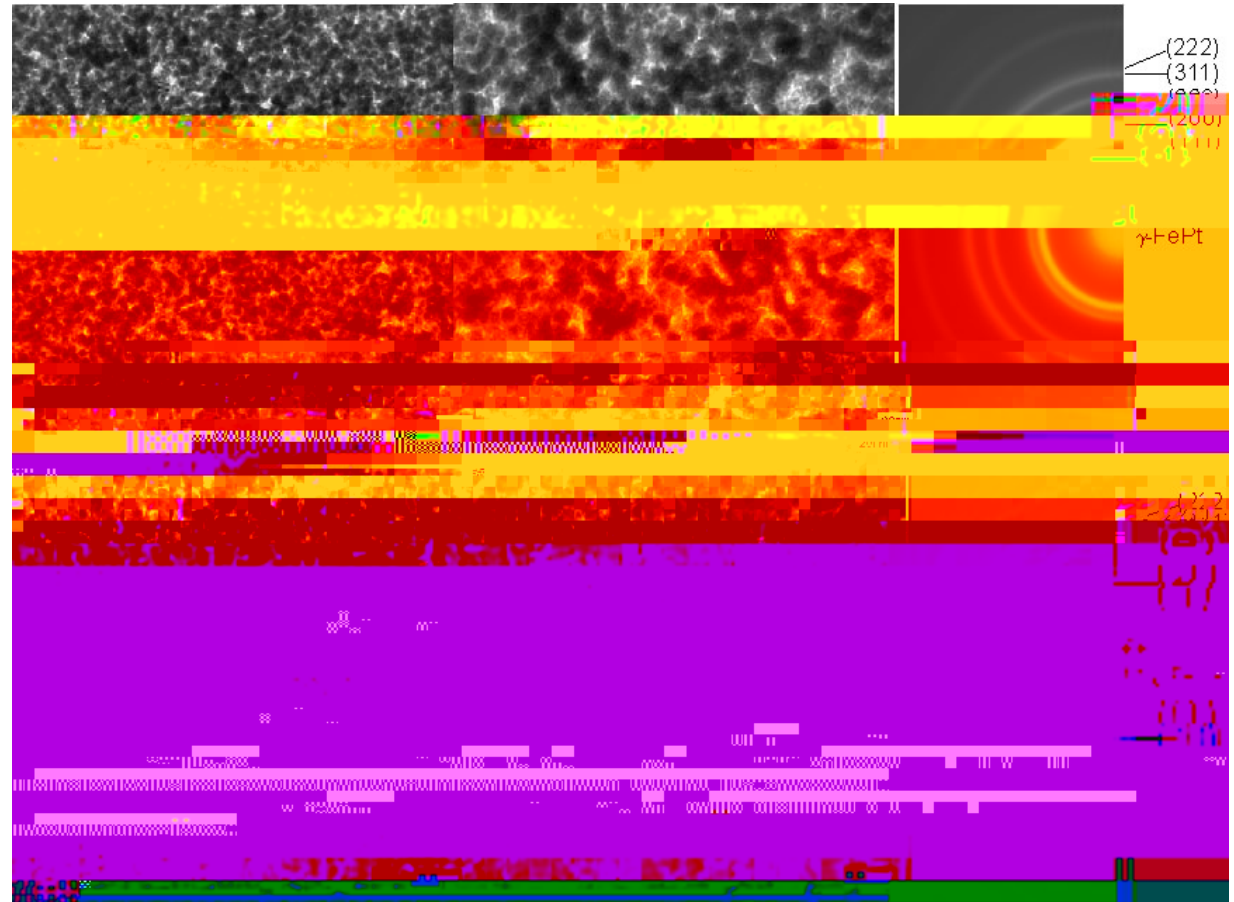
x 50k

x 100k

As-deposited

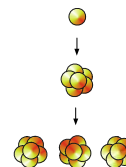
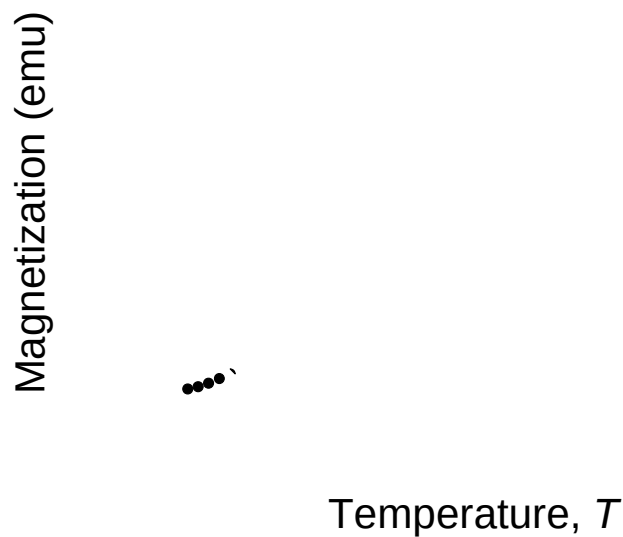
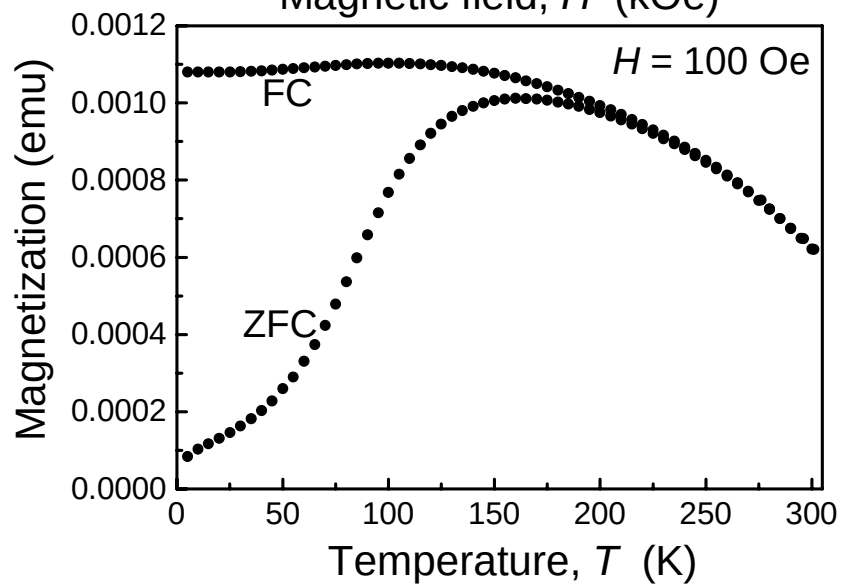
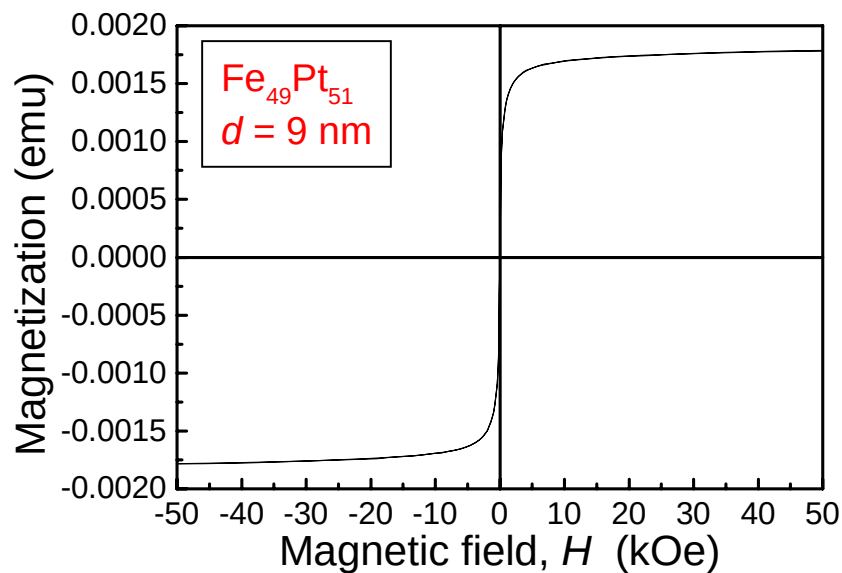
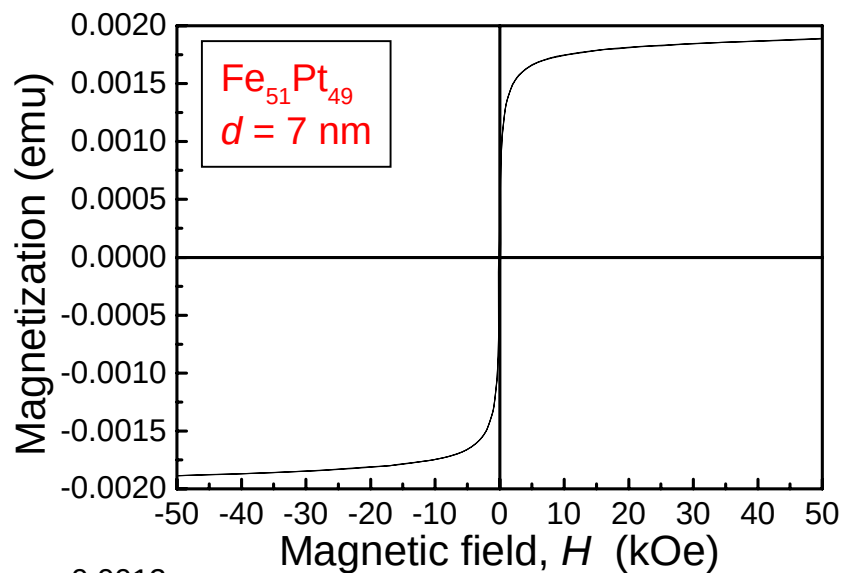
After annealing

$T_{\text{an}} = 600^\circ\text{C}$
 $t_{\text{an}} = 60 \text{ min}$



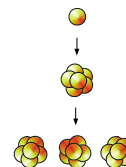
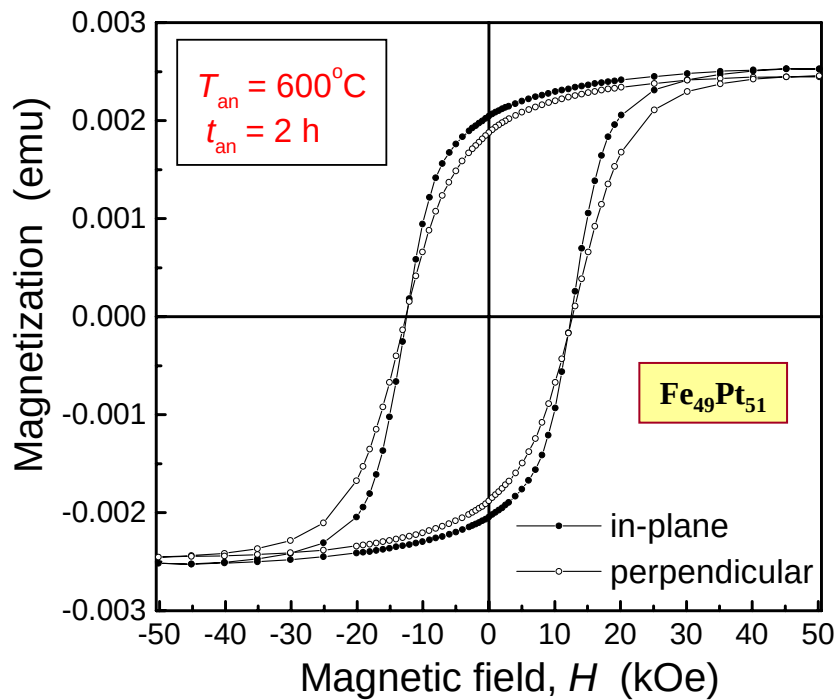
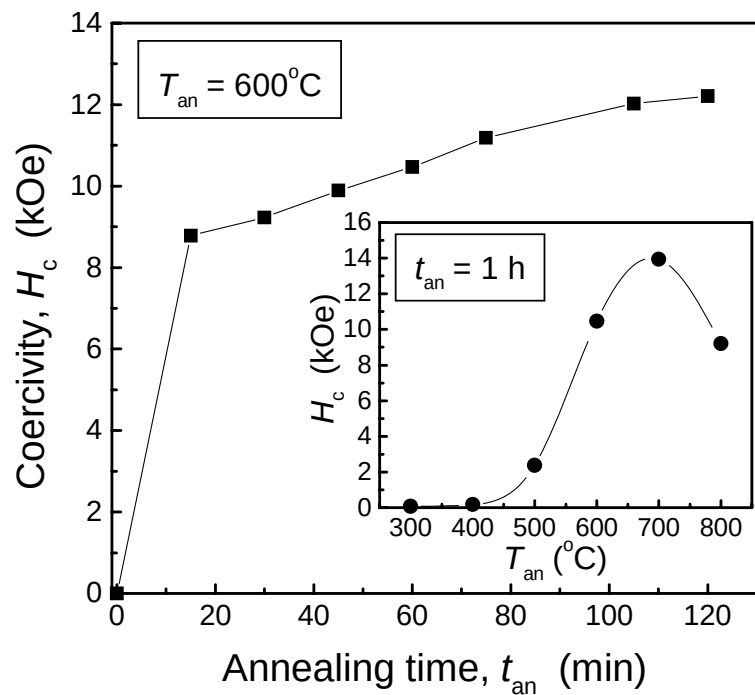


Magnetic measurement results of as-deposited FePt alloy





Fe-Pt





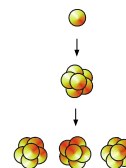
smaller and faster

“ ”

- 高频化 高效率 低维化 低损耗



- 高饱和磁化强度 低矫顽力 高电阻率
高磁导率 高铁磁共振频率 良好的热稳定性...





-

- (CoZrNb, CoZrTa)

- -

- Fe

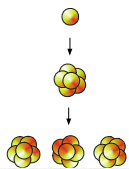


FeCo

✓

✗

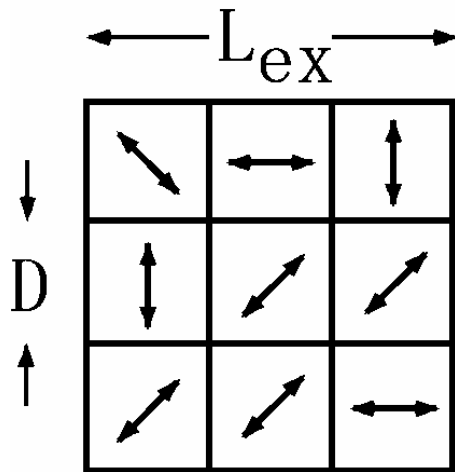
✗





Herzer's random anisotropy model (RAM)

(G. Herzer, *IEEE Trans. Magn.* 26 (1990) 1397)



$$N = (L_{ex} / D)^3$$

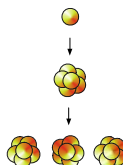
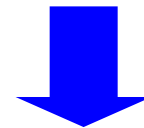
$$L_{ex} = \left(\frac{A}{K_{eff}} \right)^{\frac{1}{2}}$$

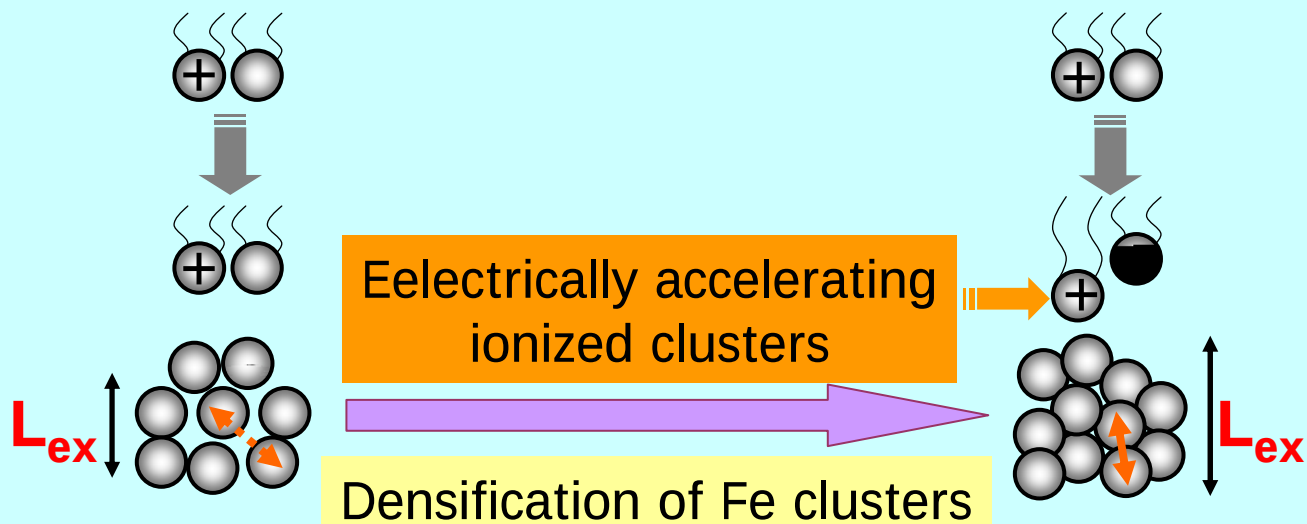
$$K_{eff} = \frac{K_c}{\sqrt{N}} = K_c \left(\frac{D}{L_{ex}} \right)^{\frac{3}{2}}$$

$$\begin{matrix} L_{ex} \\ K_c \\ K_{eff} \end{matrix} \quad L_{ex}$$

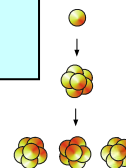
$$K_{eff} \approx \frac{K_c^4 D^6}{A^3}$$

$$H_c = P_c \frac{K_c^4 D^6}{M_s A^3}$$



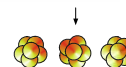
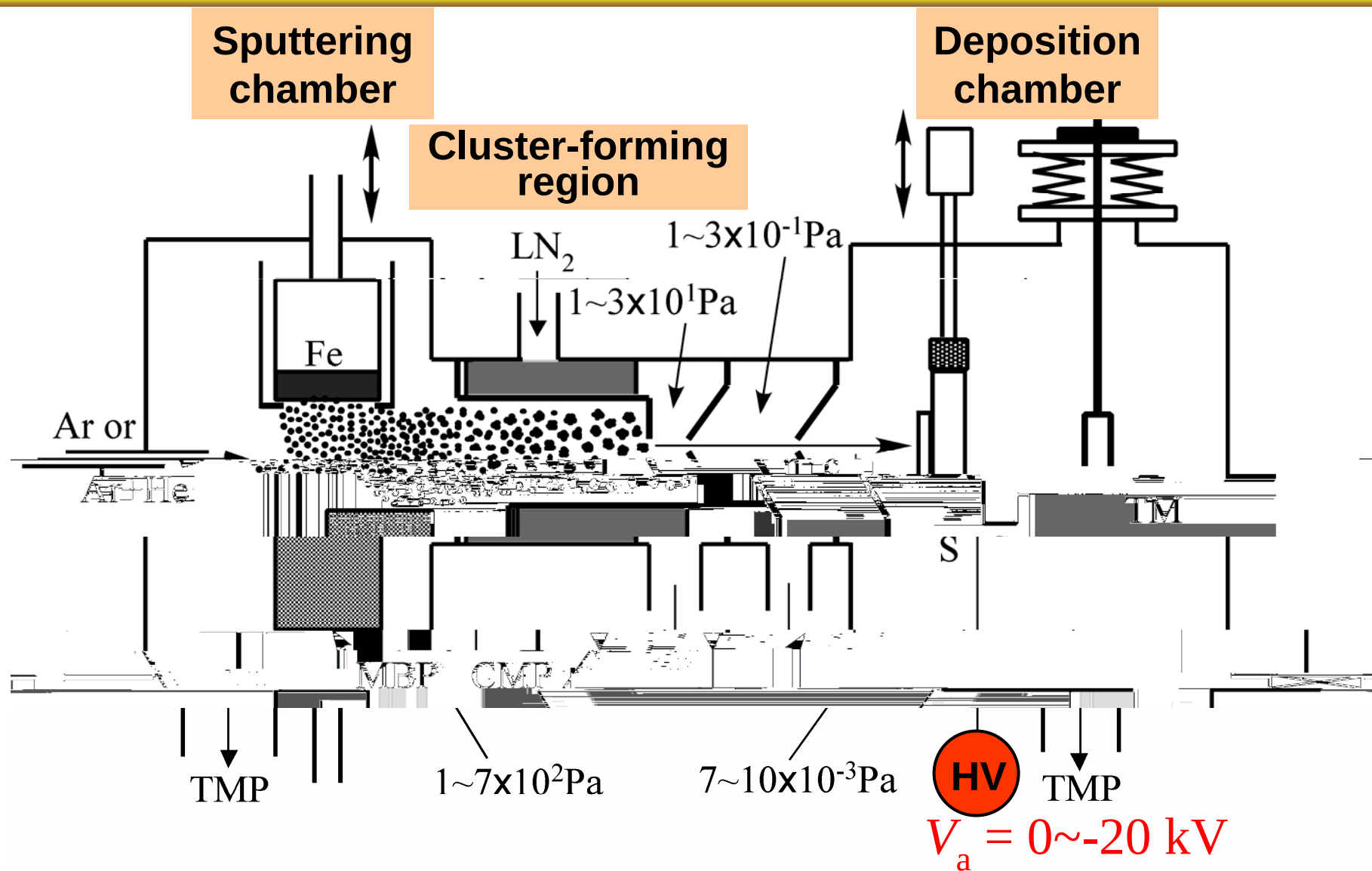


Enhancement of intercluster exchange coupling





Fe





Fe

(a)

(b)

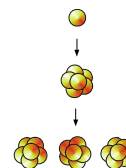
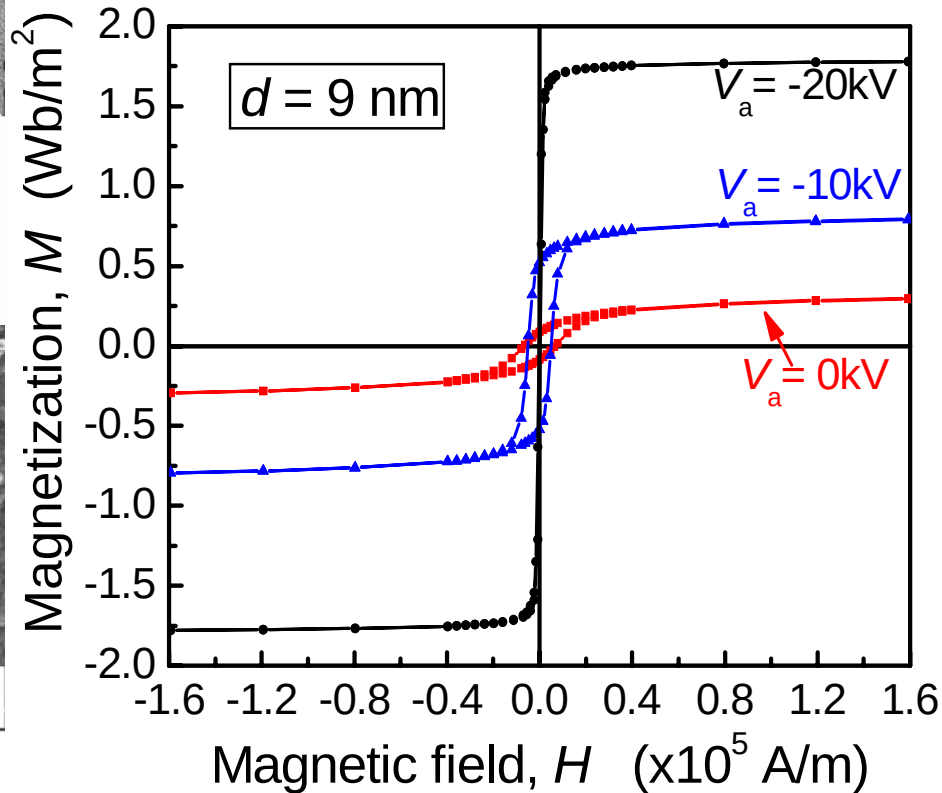
$V_a = 0$ kV

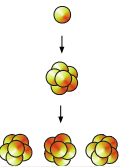
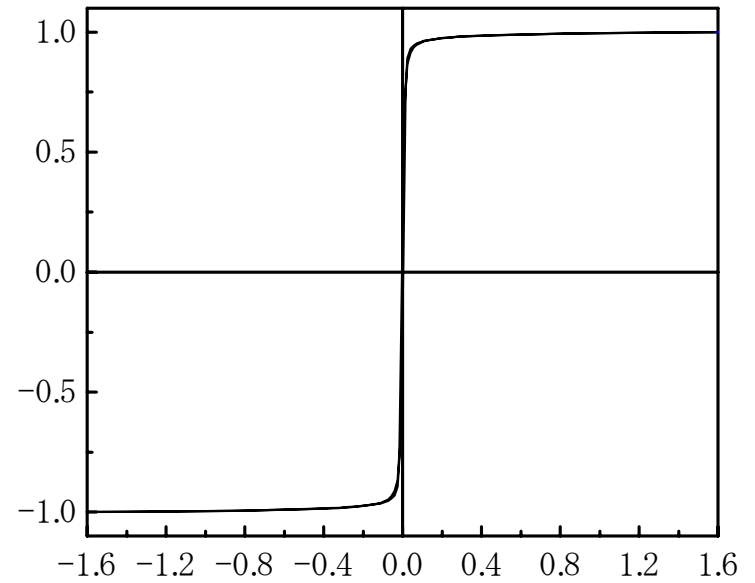
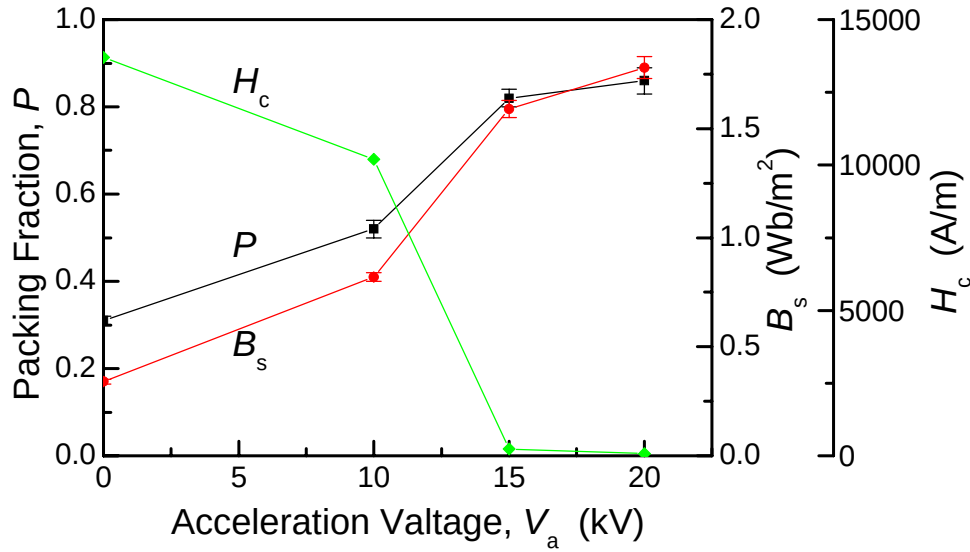
$V_a = -20$ kV

$P = 31\%$

$P = 86\%$

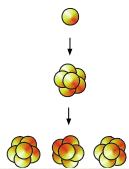
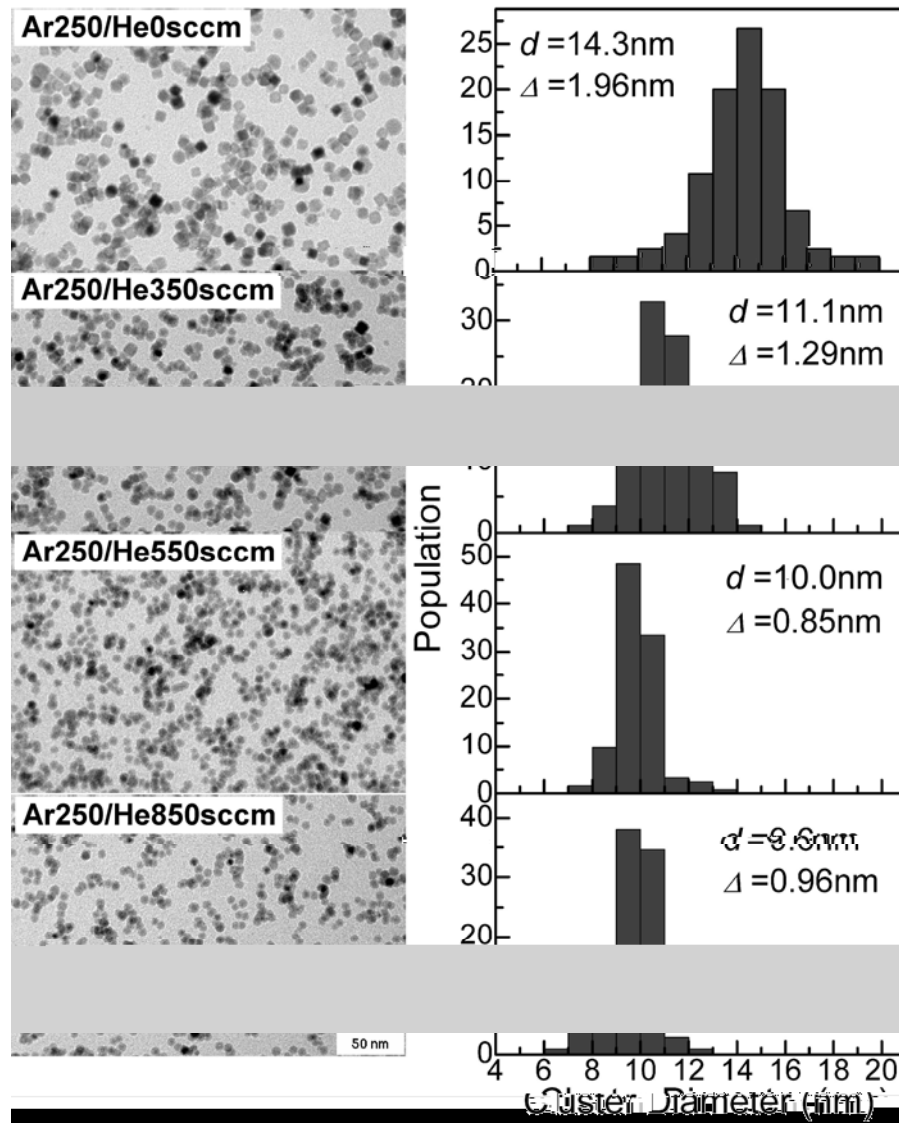
100nm





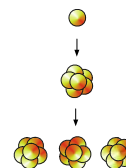
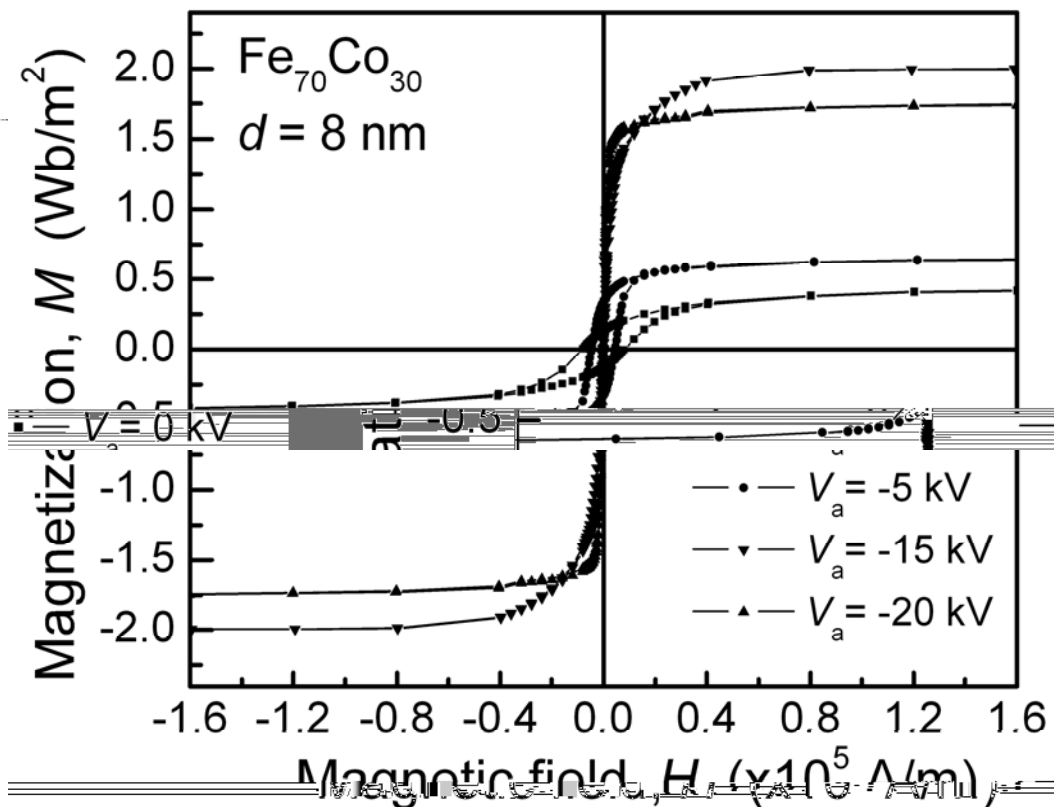
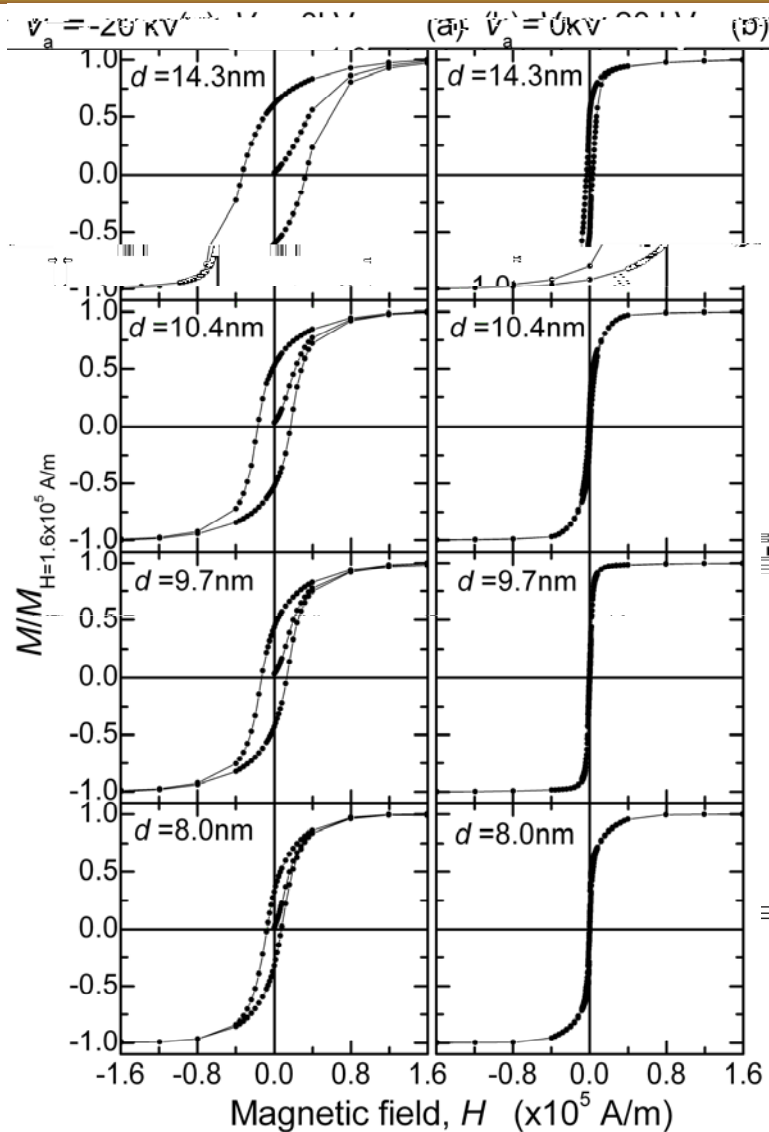


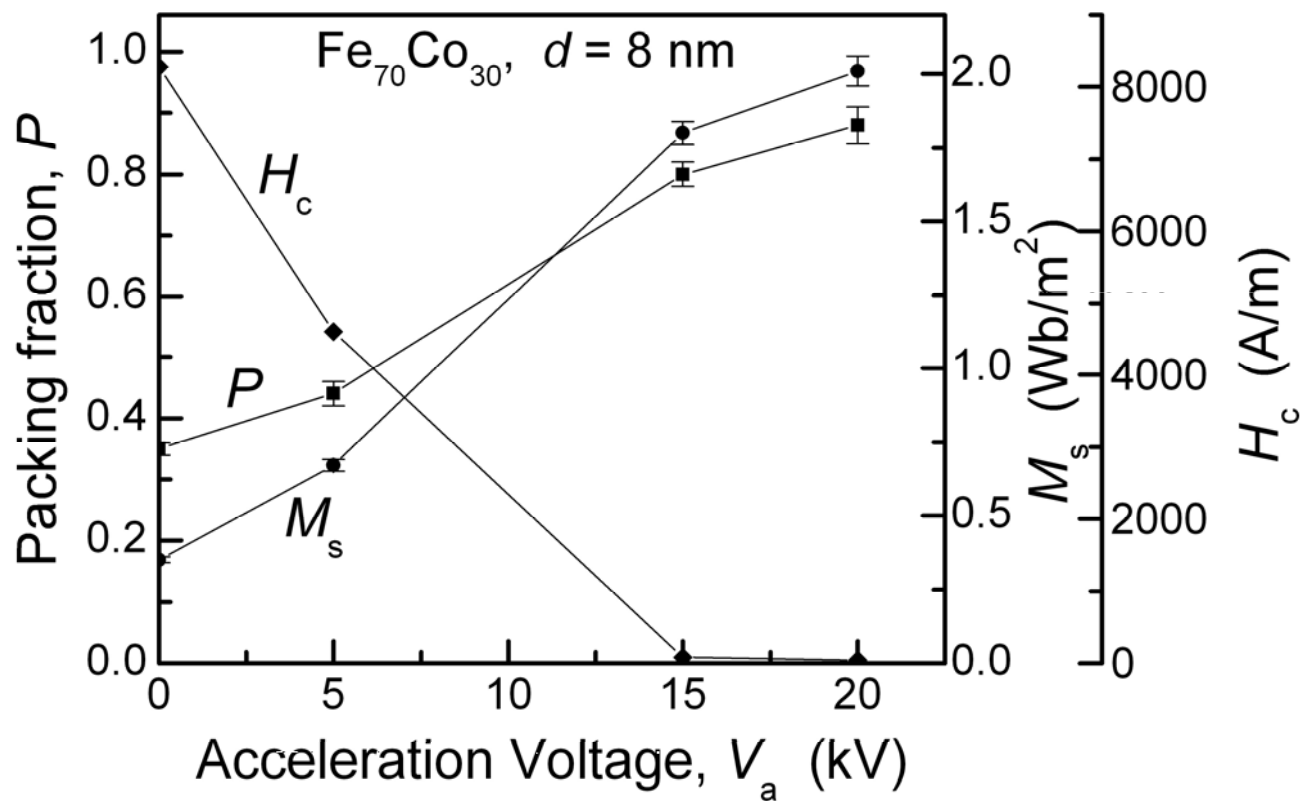
Fe-Co



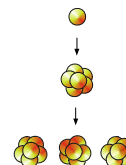


Fe-Co



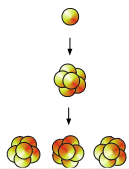
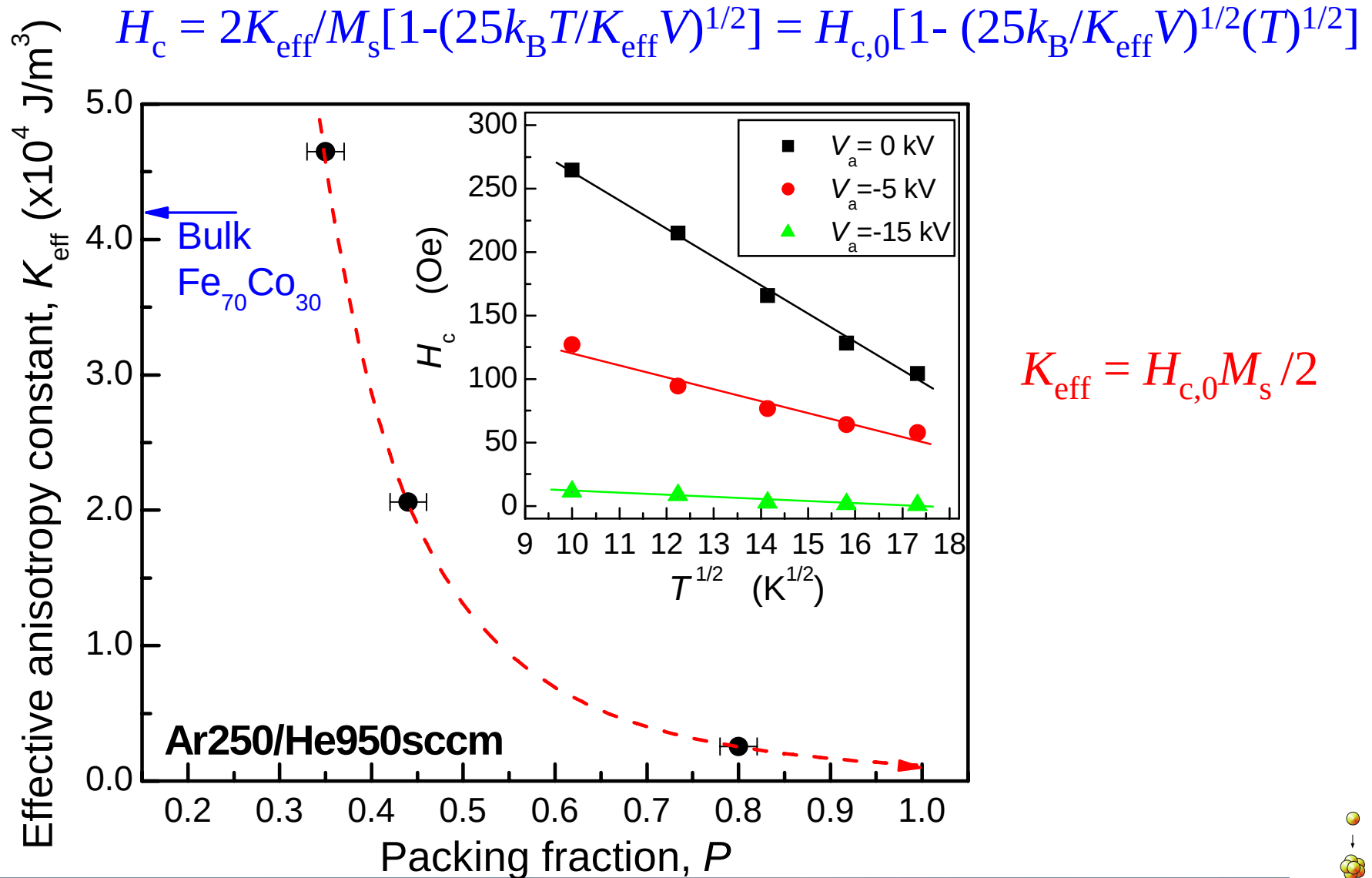


$$M_s = 2.01 \text{ Wb/m}^2; \quad H_c < 1 \text{ Oe}$$





Fe-Co

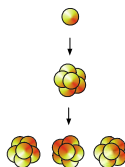
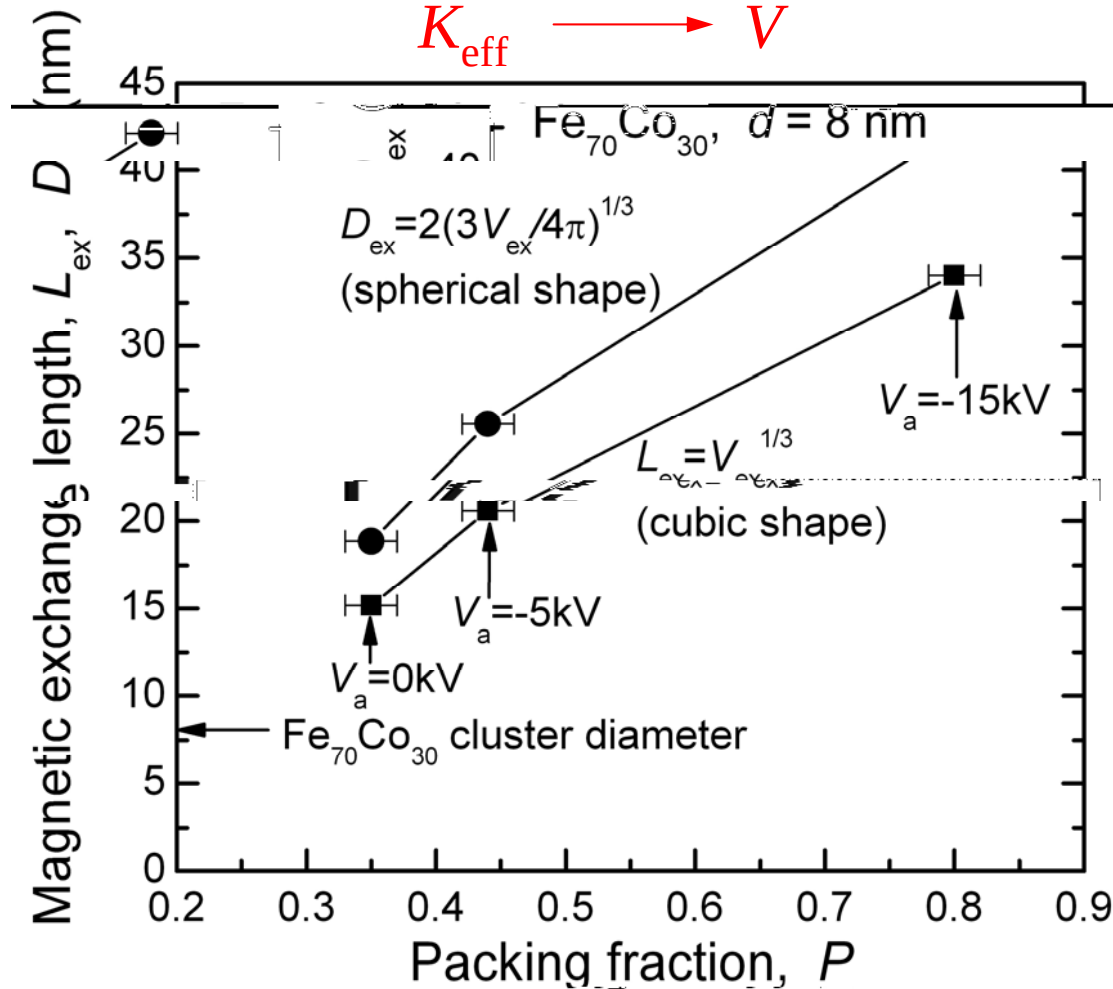




Fe-Co

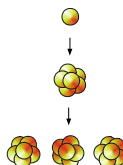
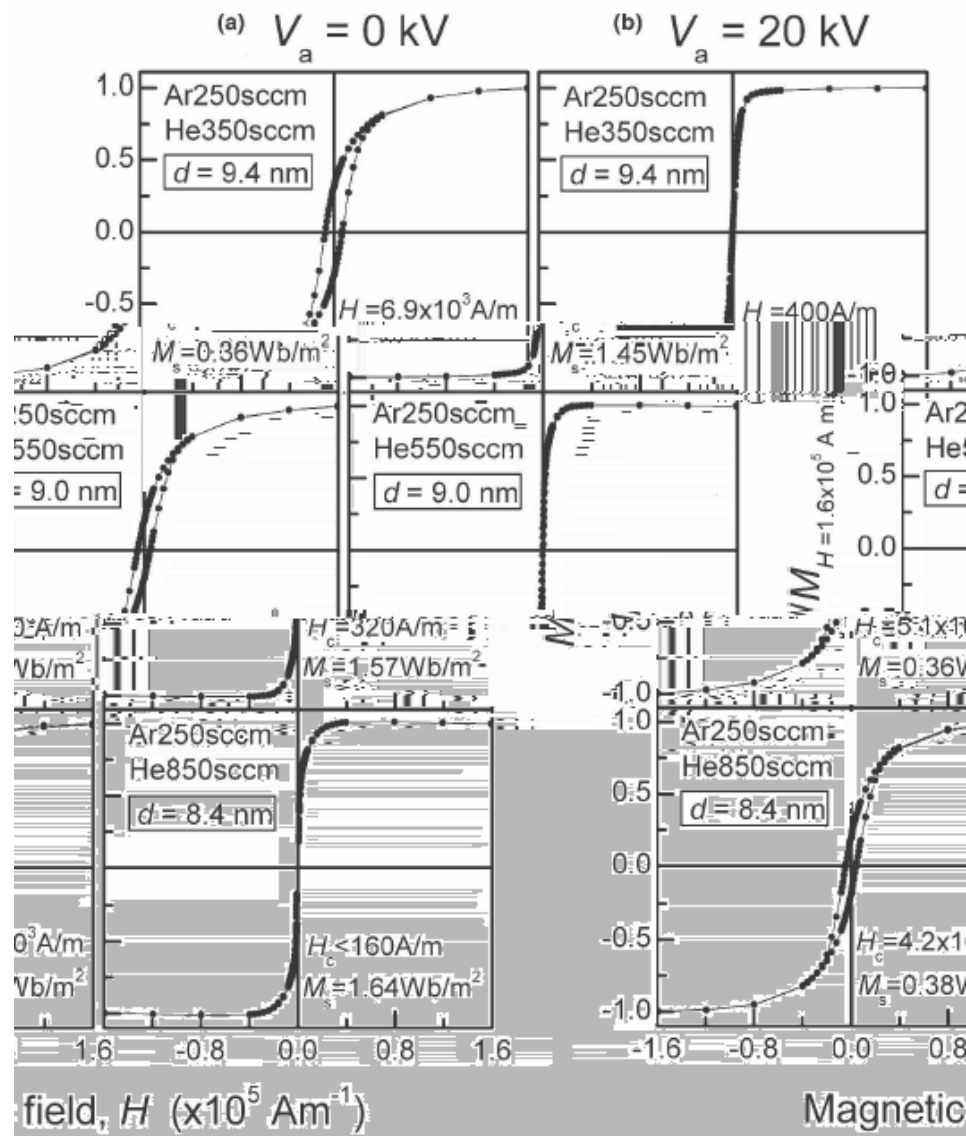
$$H_c = H_{c,0} [1 - (25k_B/K_{\text{eff}} V)^{1/2} (T)^{1/2}]$$

$$K_{\text{eff}} \longrightarrow V$$



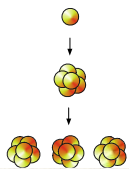
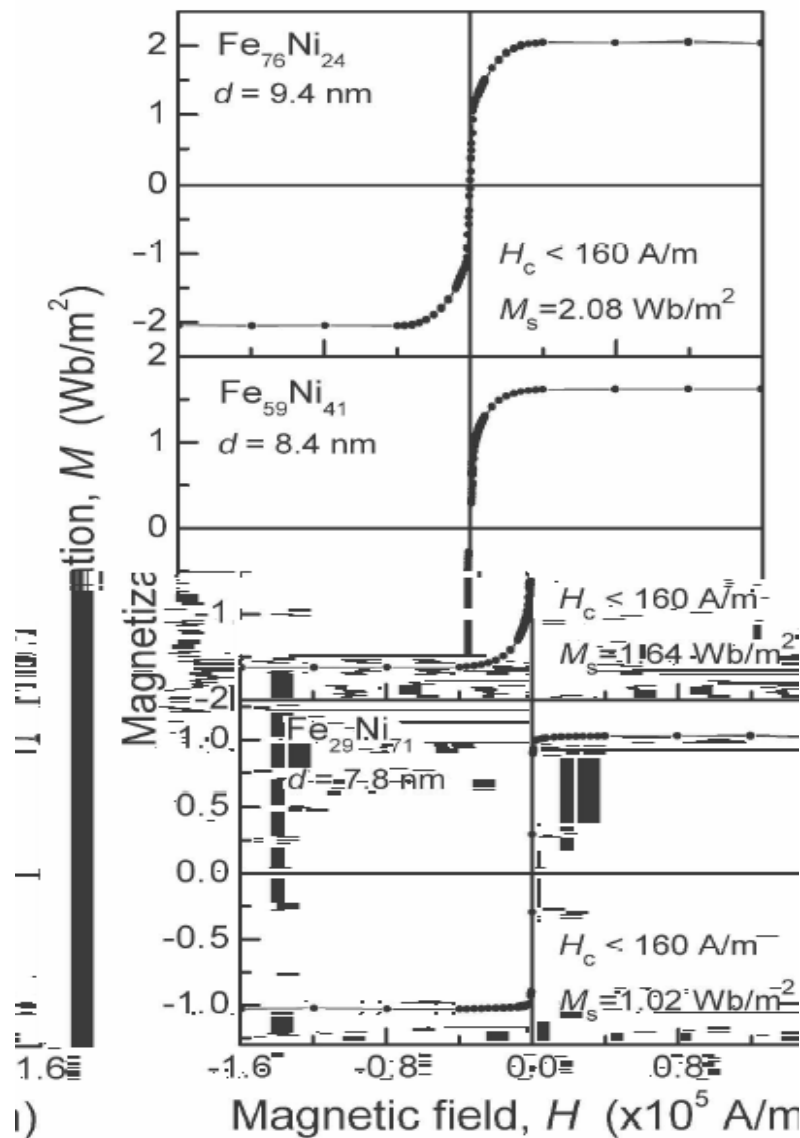


Fe-Ni

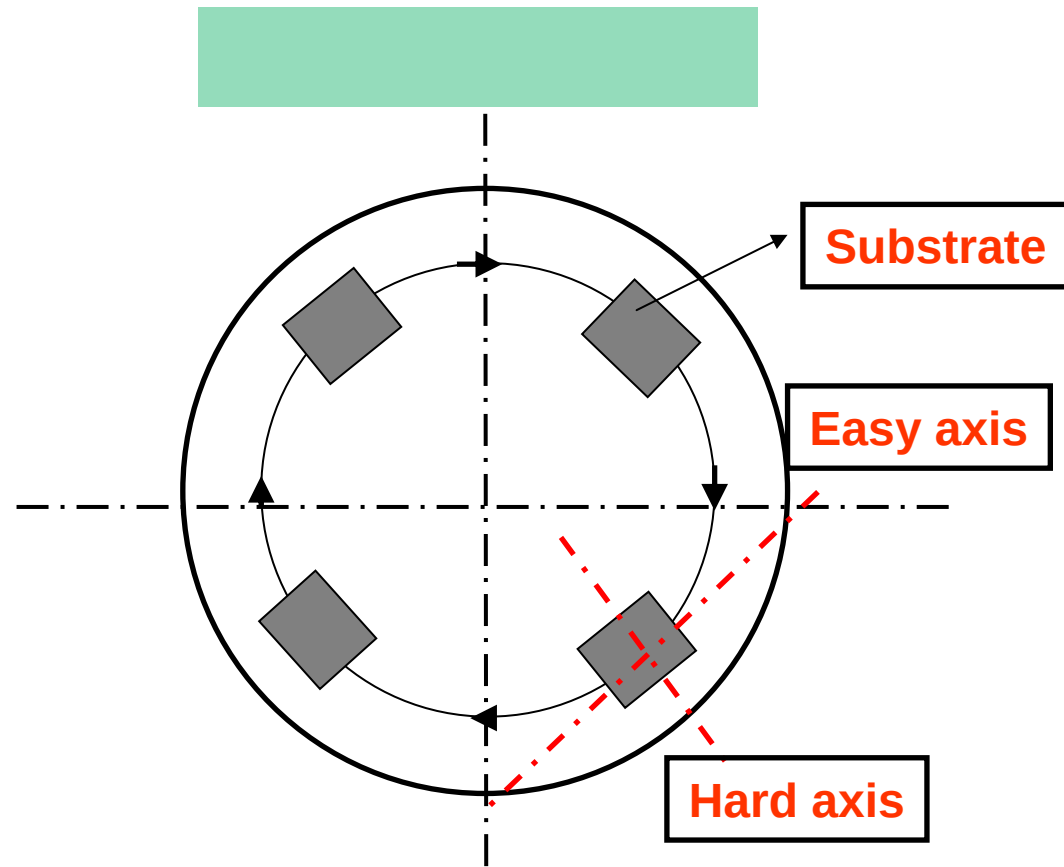
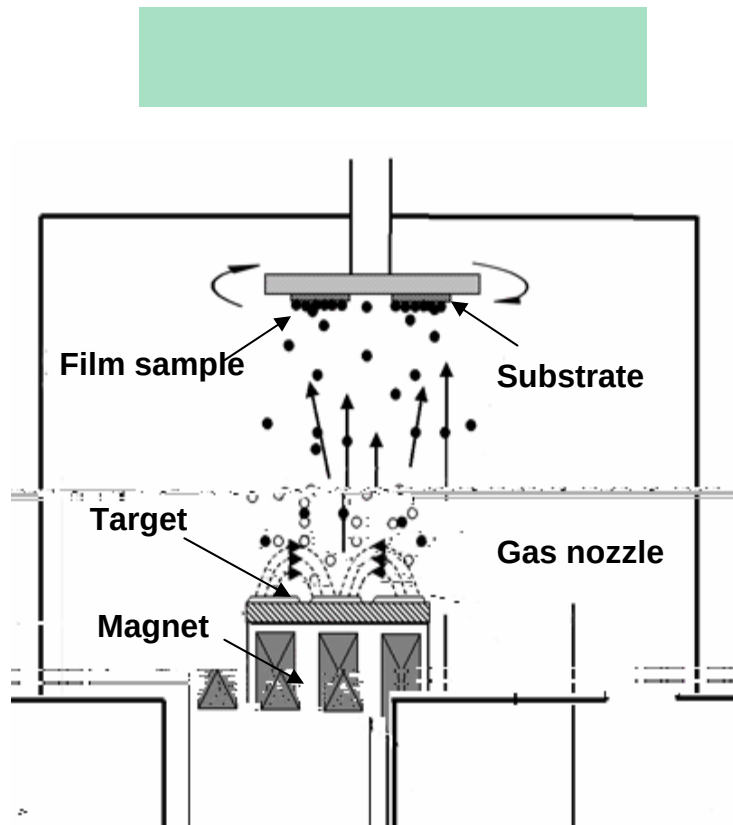




Fe-Ni

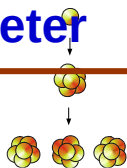






■ $\text{Fe}_{65}\text{Co}_{35}$ O_2

■ XRD SEM EDX Four-probe Surface profiler VSM Permeameter





$\text{Fe}_{65}\text{Co}_{35}-\text{O}$

