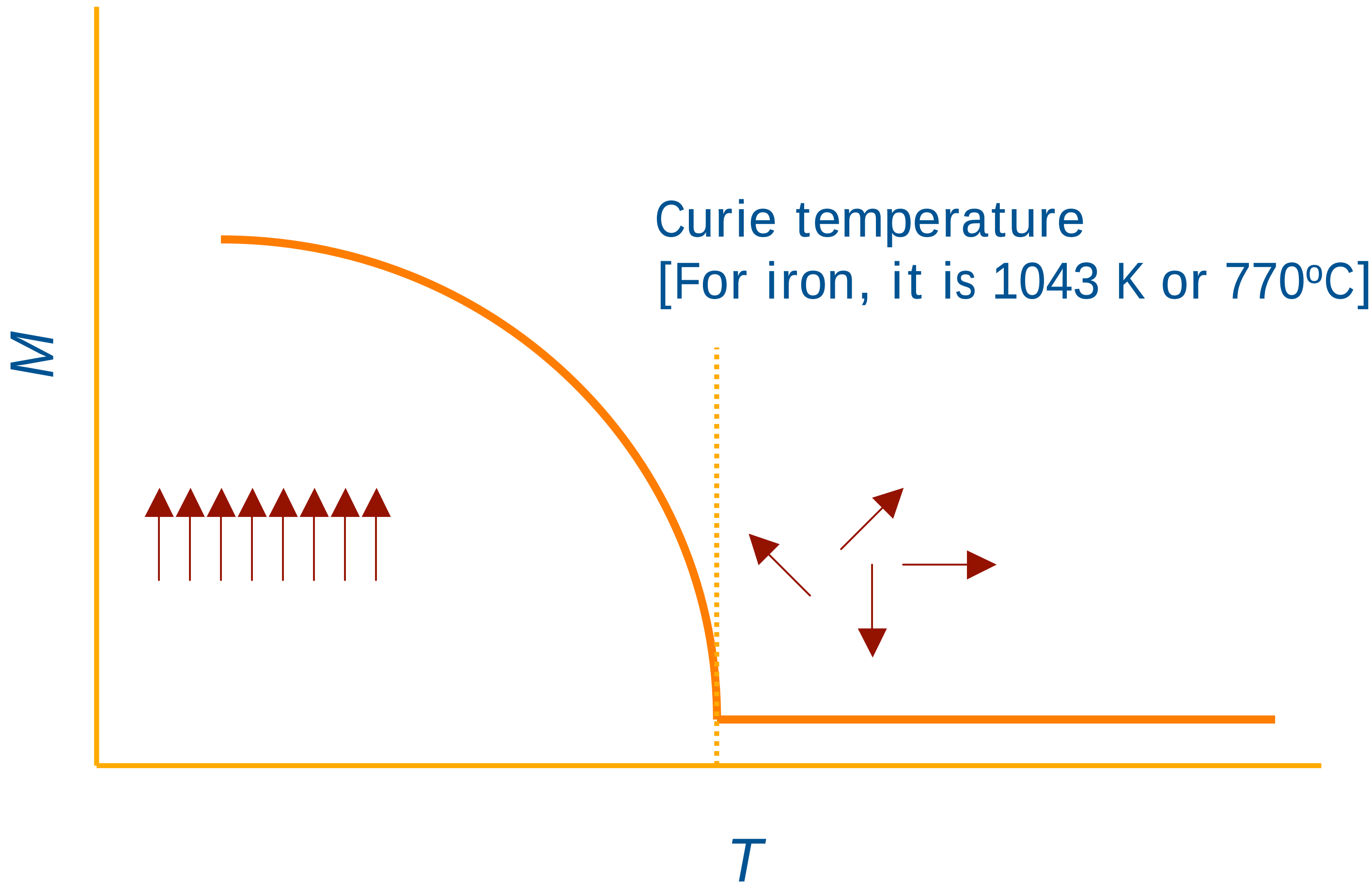
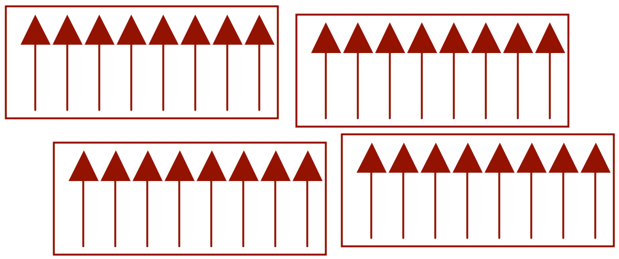
# Magnetic oxides

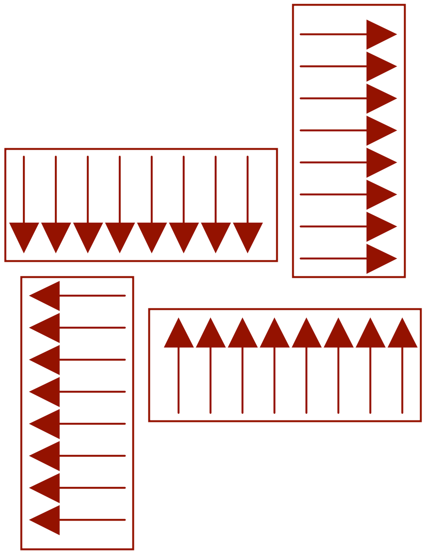



(some) materials are magnetic below their Curie temperatures

Domains are collections of aligned spins (on electrons). They can in turn be aligned (or magnetized) or misaligned (demagnetized)

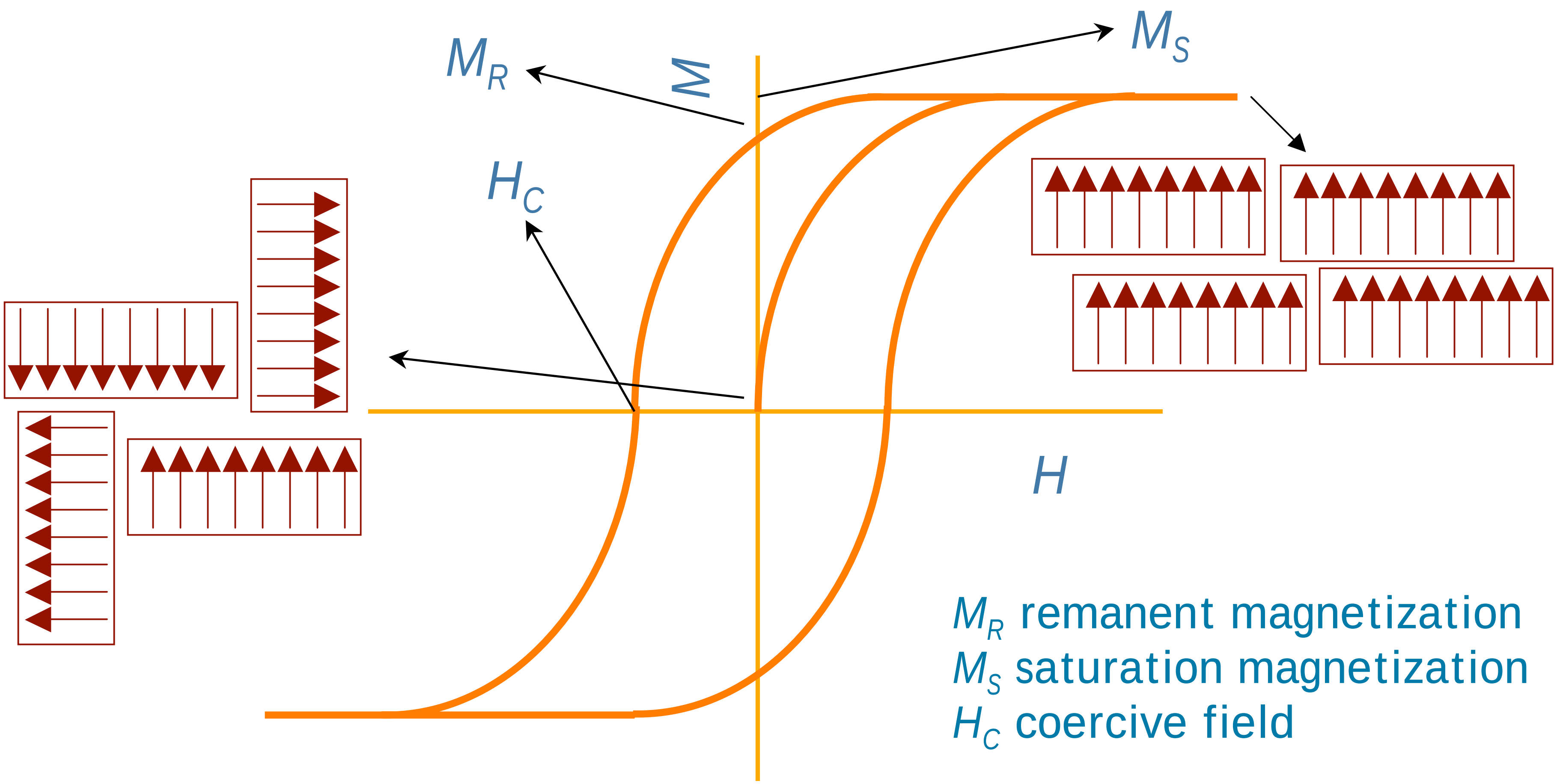


aligned domains (magnetized)



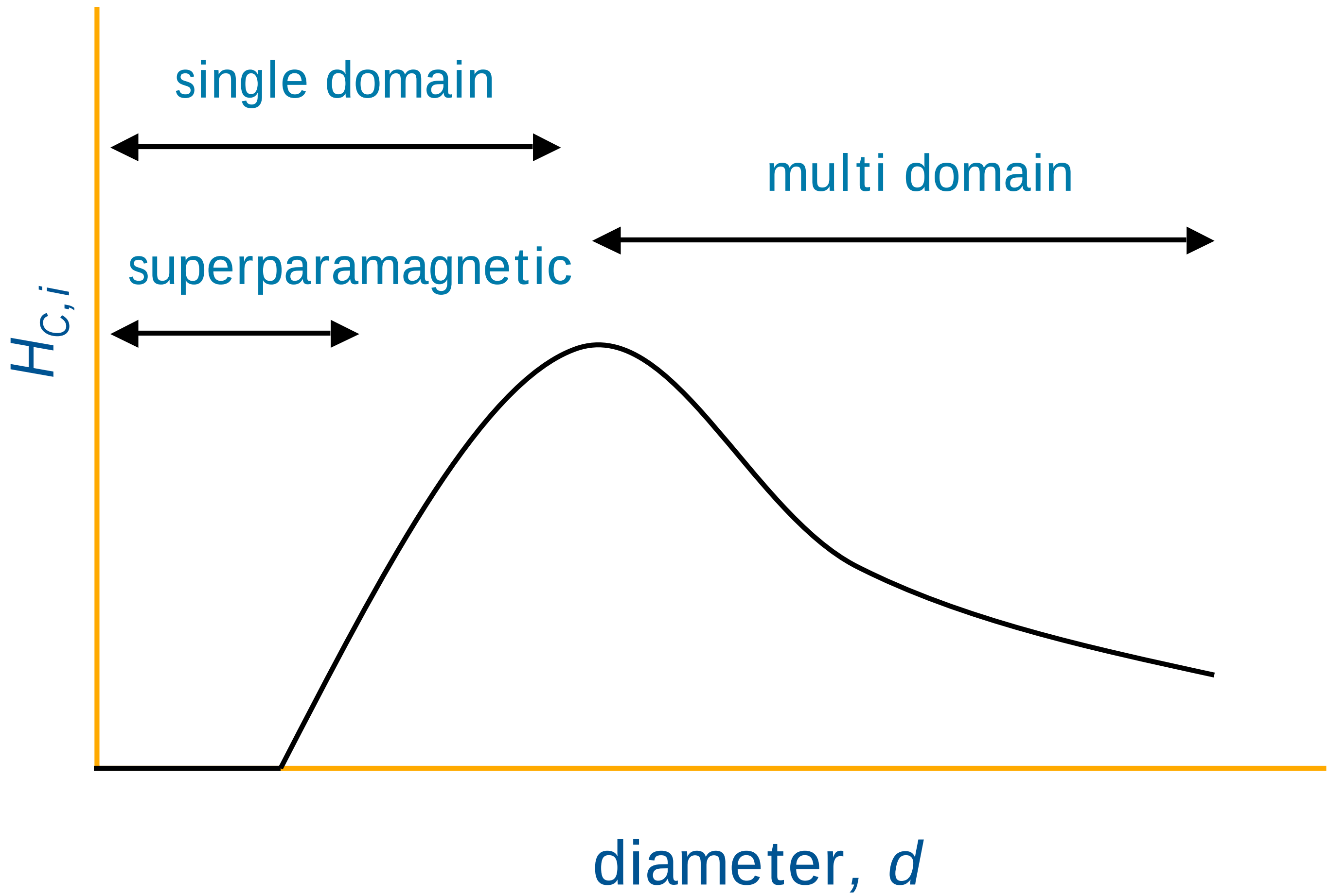
misaligned domains (demagnetized)

Domains also explain hysteresis, and the notion of magnetic memory:




$M_R$ remanent magnetization
$M_S$ saturation magnetization
$H_C$ coercive field

## Size dependence of the magnetic coercivity $H_c$




$H_{C,i}$ : intrinsic coercivity

Cullity, Inroduction to Magnetism and Magnetic Materials, Addison Wesley, 1972.

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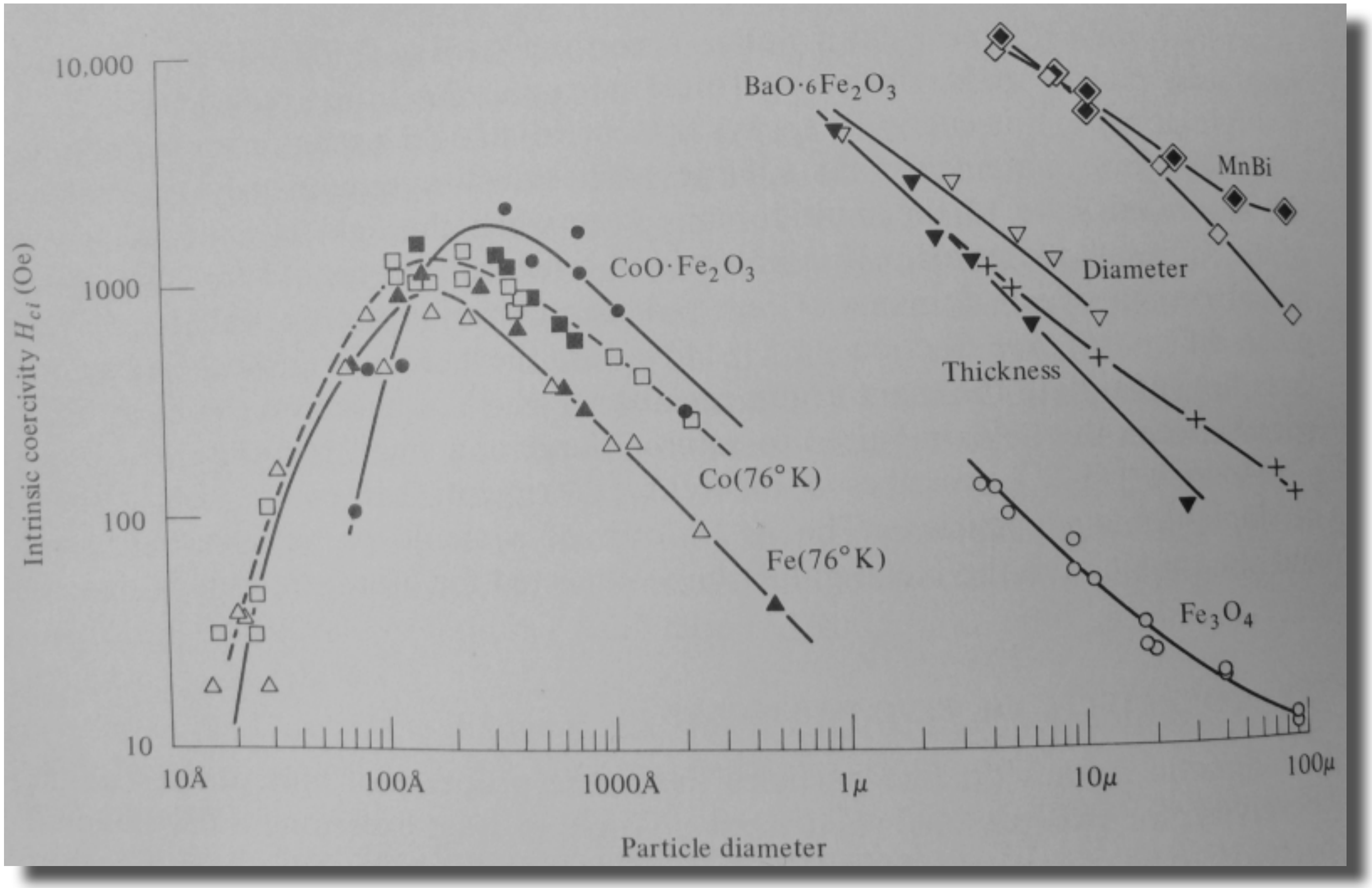
## Size dependence of the magnetic coercivity $H_c$




Cullity, Inroduction to Magnetism and Magnetic Materials, Addison Wesley, 1972.

## Superparamagnetism

As a consequence of the small barrier for spin reversal in small magnetic paticles, the time taken for reversal is strongly temperature dependent and activated.

$$1/\tau = f_0 \exp(-\frac{KV}{k_B T})$$

Where $\tau$ is the relaxation time of the magnetization
$f_0$ is the frequency pre-factor, $V$ the volume,
and $K$ the magnetocrystaline anisotropy.

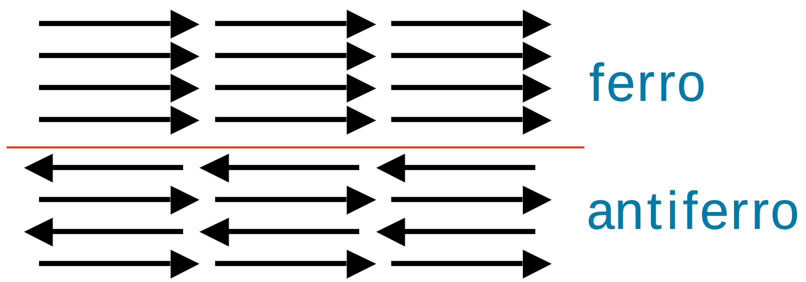
Below a BLOCKING TEMPERATURE, $T_B$, the sample develops magnetic coercivity:

$$T_B = \frac{KV}{25 k_B}$$

Cullity, Inroduction to Magnetism and Magnetic Materials, Addison Wesley, 1972.

Exchange anisotropy (exchange bias):

At the interface:



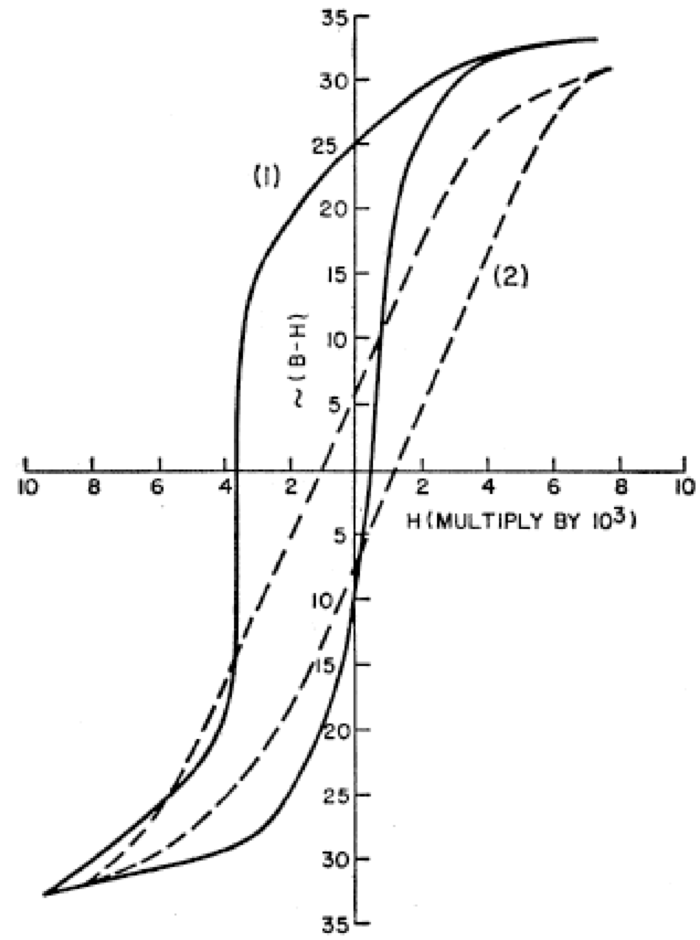




FIG. 1. Hysteresis loops at 77°K of oxide-coated cobalt particles. Solid line curve results from cooling the material in a 10 000 oersted field. The dashed line curve shows the loop when cooled in zero field.

New Magnetic Anisotropy, W. H. Meiklejohn and C. P. Bean, *Phys. Rev.* 1**05** (1957) 904.

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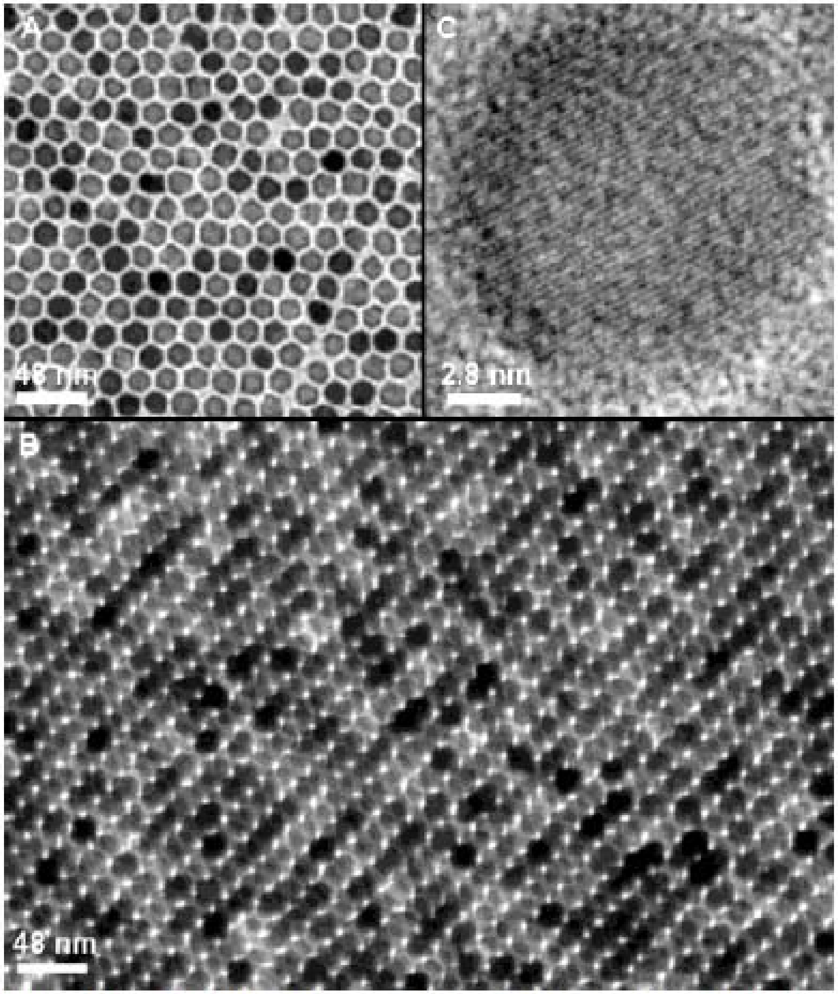



*Figure 1.* TEM bright field image of 16-nm $Fe_3O_4$ nanoparticles deposited from their dodecane dispersion on amorphous carbon surface and dried at 60 °C for 30 min: (A) a monolayer assembly, (B) a multilayer assembly, (C) HRTEM image of a single $Fe_3O_4$ nanoparticle. The images were acquired from a Philips EM 430 at 300 KV.

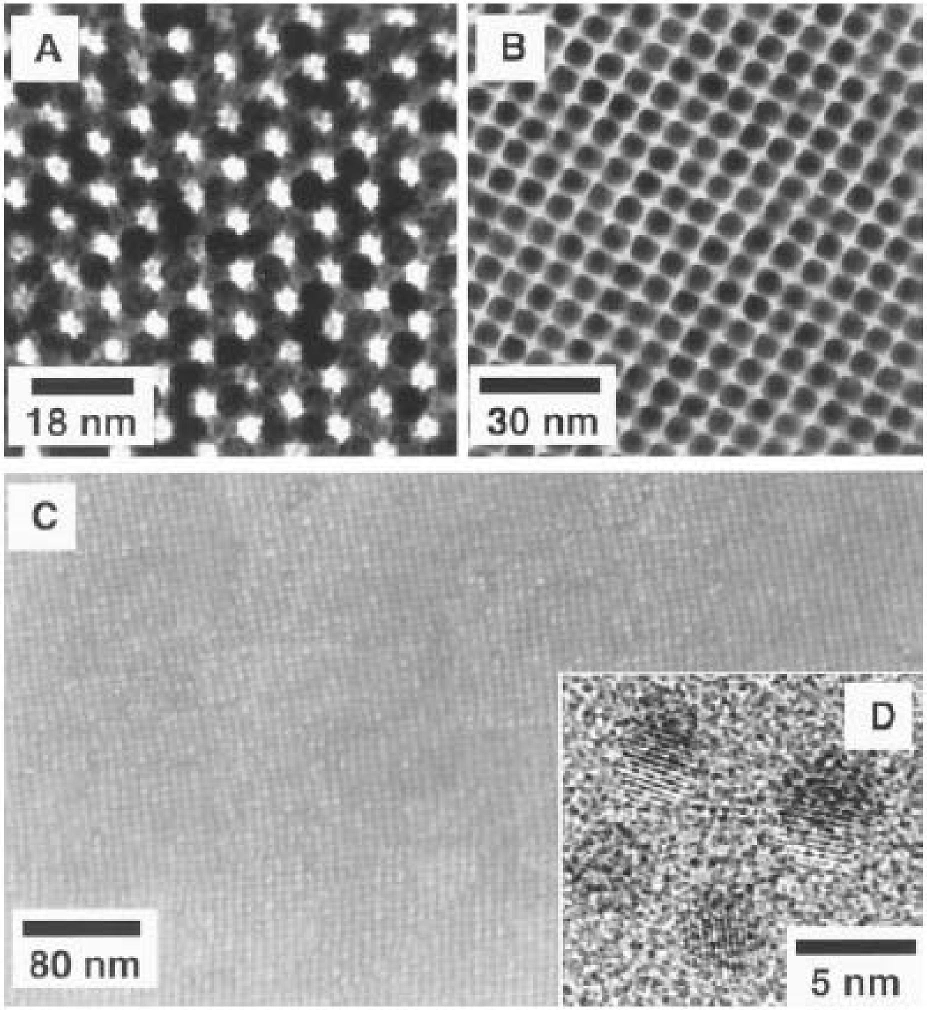
Fe(acac)3 + ROH + RNH2 + RCOOH -> products
The solvent is dibenzyl or diphenyl ether at reflux.

Contrast hydrolytic routes with thermolytic routes.

Size-Controlled Synthesis of Magnetite Nanoparticles, S. Sun and H. Zeng, *J. Am. Chem. Soc.* **124** (2002) 8204

# Magnetic materials (FePt has a very large *K*)

**Fig. 1.** (**A**) TEM micrograph of a 3D assembly of 6-nm as-synthesized $Fe_{50}Pt_{50}$ particles deposited from a hexane/octane (v/v 1/1) dispersion onto a SiO-coated copper grid. (**B**) TEM micrograph of a 3D assembly of 6-nm $Fe_{50}Pt_{50}$ sample after replacing oleic acid/oleyl amine with hexanoic acid/hexylamine. (**C**) HRSEM image of a ~180-nm-thick, 4-nm $Fe_{52}Pt_{48}$ nanocrystal assembly annealed at 560°C for 30 min under 1 atm of $N_2$ gas. (**D**) High-resolution TEM image of 4-nm $Fe_{52}Pt_{48}$ nanocrystals annealed at 560°C for 30 min on a SiO-coated copper grid.




Monodisperse FePt Nanoparticles and Ferromagnetic FePt Nanocrystal Superlattices,
S. Sun, C. B. Murray, D. Weller, L. Folks, A. Moser, *Science*, **287** (2000) 1989.

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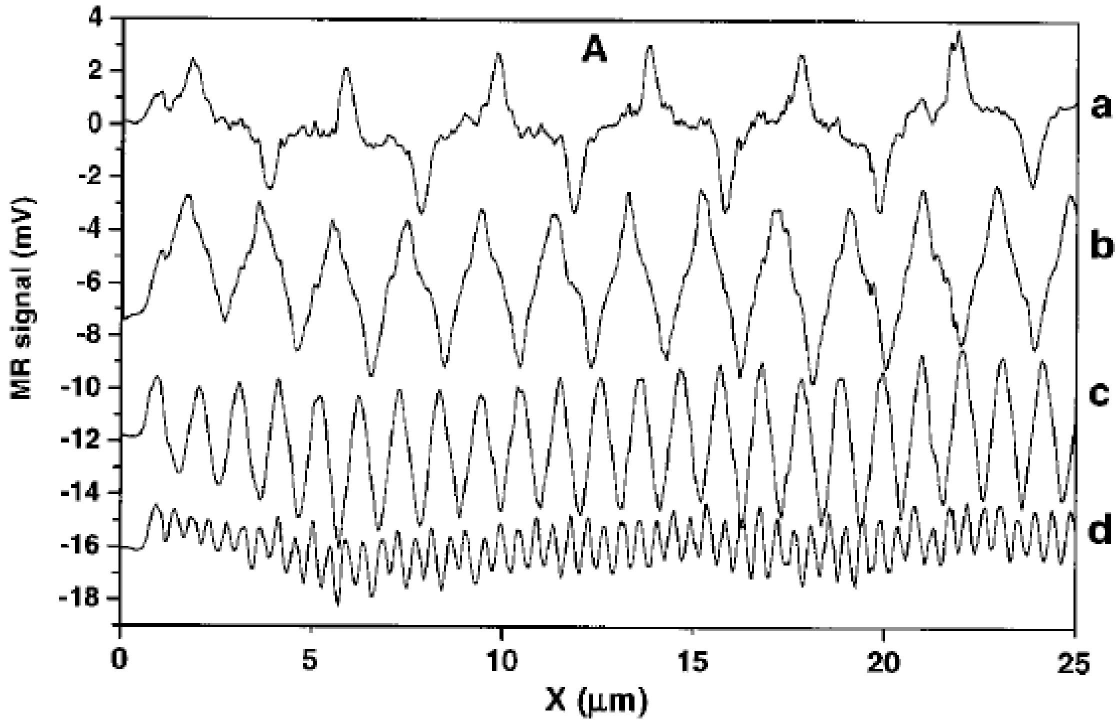


**Fig. 4.** (**A**) Magneto-resistive (MR) read-back signals from written bit transitions in a 120-nm-thick assembly of 4-nm-diameter $Fe_{48}Pt_{52}$ nanocrystals. The individual line scans reveal magnetization reversal transitions at linear densities of (a) 500, (b) 1040, (c) 2140, and (d)

The magnetic superlattice can be used for data storage.

Monodisperse FePt Nanoparticles and Ferromagnetic FePt Nanocrystal Superlattices, S. Sun, C. B. Murray, D. Weller, L. Folks, A. Moser, *Science*, **287** (2000) 1989.

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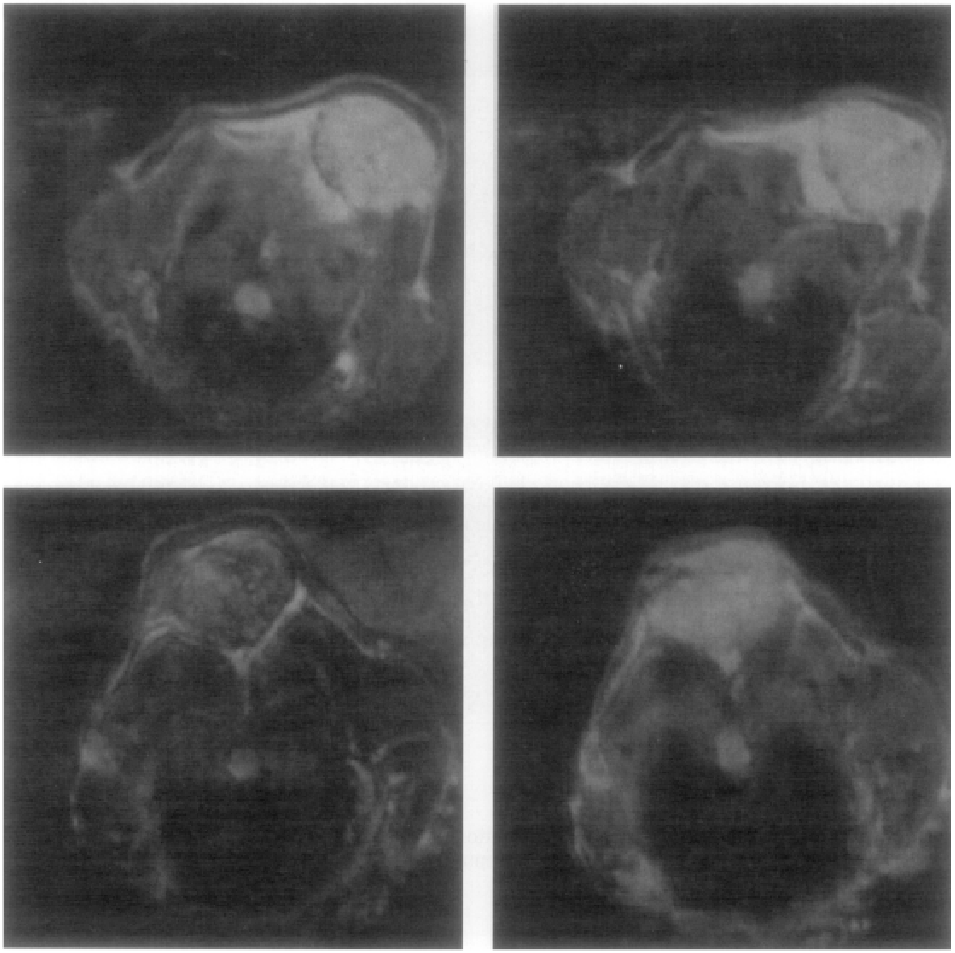

Magnetite nanoparticles are used to enhance MRI contrast in imaging a mouse tumor (the two pictures below were taken with the magnetite contrast agent.

Fig. 6. $T_2$-weighted MRI images of a mouse with a CEA-producing tumor on its back, before (upper two images) and after administration of 300 $\mu$g magnetite-PEKY-AB$_{CEA}$-GPB particles (lower two images). Two neighboring slices are shown from left to right.

In vivo evaluation of magnetite nanoparticles for use as a tumor contrast agent in MRI, Tiefenauer, Schirky, Kuhne, and Andres, *Magn. Resonance Imaging*, **14** (1996) 391.