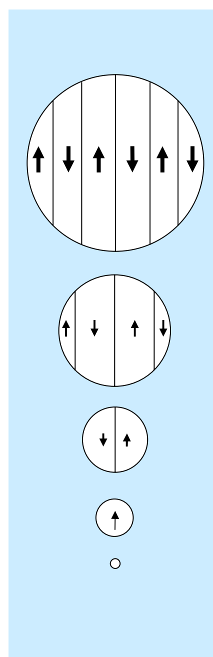
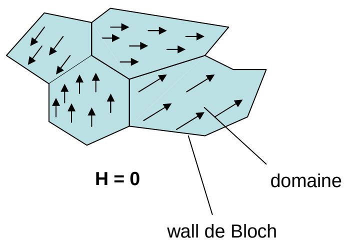
SUPERPARAMAGNETISM

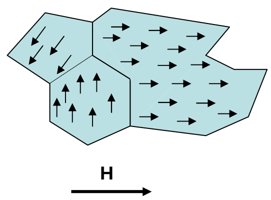
Limits and Applications



BASIS FERROMAGNETISM

Ferro-magnetisme:





Materials: Fe, Co, Ni, Gd

Spins of unfilled d-bands spontaneously align parallel inside a *domain* below a critical temperature T_C (Curie)

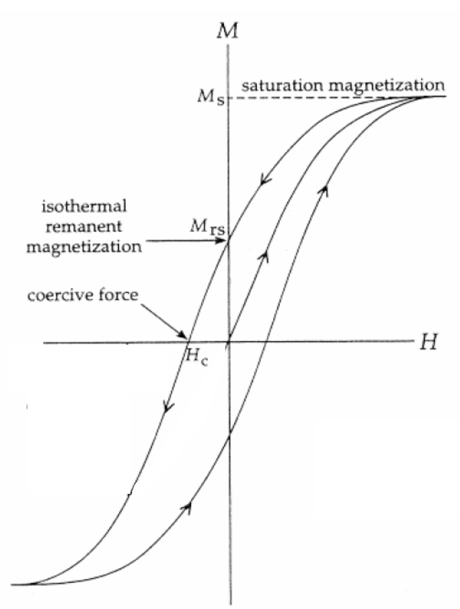
Laws:

$$B = H + 4\pi \cdot \chi \cdot H$$

$$M = \chi \cdot H$$

$$\chi = Susceptibility$$

HYSTERESIS LOOP OF FERROMAGNETIC MATERIALS



$$\mathrm{M} = \chi \cdot \mathrm{H}$$

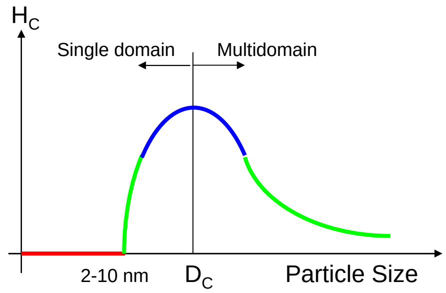
$$\chi = \mathrm{susceptibility}$$

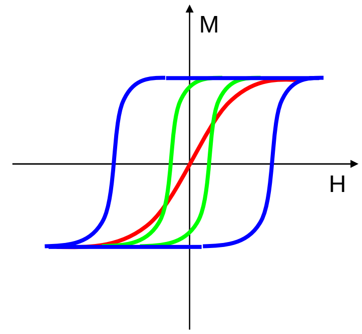
Hard Magnets:

H_C and M_{rs} have high values

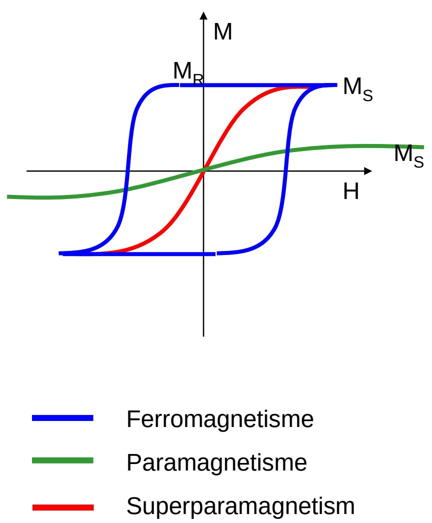
SUPERPARAMAGNETISM - A SIZE EFFECT

Magnetic Properties of Nanostructured Materials:





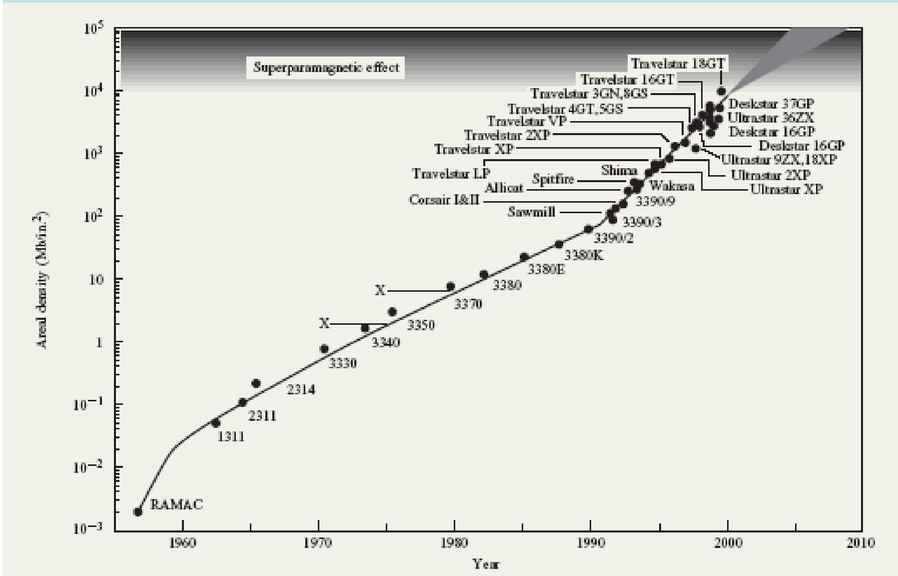
SUPERPARAMAGNETISM - A SIZE EFFECT



Superparamagnetisme:

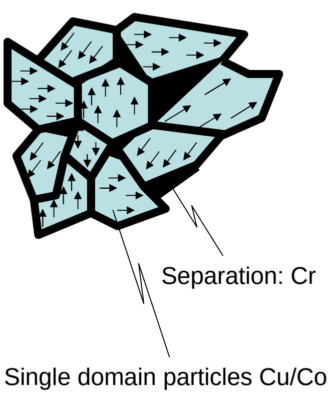
- high saturation magnetisation M_S
- no remanence $M_R = 0$

EVOLUTION OF MAGNETIC DATA STORRAGE



LIMITS AND APPLICATIONS

Magnetic Data Storrage:



Superparamagnetic limit:
min. particle size = **10 nm**

Average over a **large number of particles / bit:**

- Inconsistent switching
- randomly segregated grains:
  - variation in grain size
  - variation in coercivity
  - variation in domain structure

=> statistical noise

min **1000 particles / 1bit**

=> 0,15 Gbit / cm²

ULTIMATE GOAL: 1 particle / bit

=> 10 – 37 Gbit / cm²

LE FONCTIONNEMENT

Solutions to minimize bit size:

- Large crystalline anisotropy -> higher switching barrier
- Single domain nanoparticles -> high M_s , high H_C
- Multilayered Structures -> control of orientation of segregated grains
- perpendicular recording -> demagnetisation field does not destabilize the written domains
- Array of isolated single domain dots produced by e-beam lithography -> uniform switching properties

APPLICATIONS OF SUPERPARAMAGNETISM

Biomedical applications

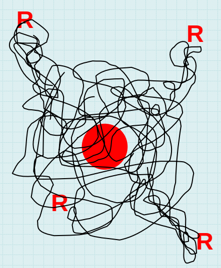
- **Detection**: MRI Magnetic Resonance Imaging
- **Separation**: Cell-, DNA-, protein- separation, RNA fishing
- **Treatment**: Drug delivery, hyperthermia, magnetofaction

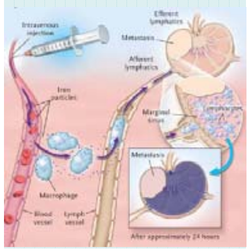
Other applications:

- **Ferrofluid:** Tunable viscosity
- **Sensors**: high sensitivity (GMR, BARCIII)
- Self - Assambling

SPION = S uperparamagnetic I on O xide N anoparticle

Drug Delivery:





Particles with attached drug can be injected and guided through the body by application of an external field.

??? WHY SUPERPARAMAGNETIC PARTICLES ???

Size of the superparamagnetic particle:

Magnetic active core = 2-3 nm
Coating (polymer, proteins, functional rest groups R) ~ 10 nm

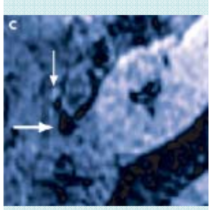
Size of cell = 10 – 100 µm
virus = 20 – 450 nm
protein = 5 – 50 nm
gene = 2* (10 - 100) nm^2

Design of the particle:

- **Attachment of R -> Particles entre the cells**
  - **Particles can be recognized by the organism**
  - **Drugs can be attached to the particle**
  - **R influences the toxicity for the organism**

APPLICATIONS

Hyperthermia

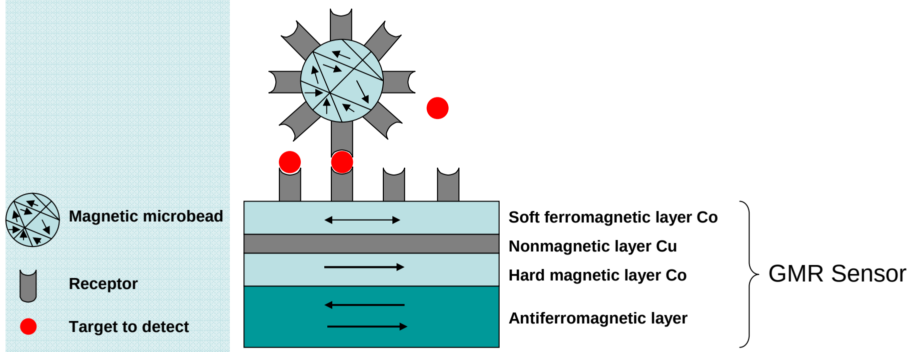


Therapeutic effect on several types of tumours

- Injection of superparamagnetic nanoparticles
- translocation of the particles to the tumour
- uptake of the nanoparticles by cancerous cells
- application of an external alternative magnet field
  - –> provides energy for the magnetic moments to change magnetisation direction
  - –> Superparamagnetic relaxation: dissipated energy = heat
- Cancerous cells have higher temperature senstivity than healthy cells
- No danger of thrombosis, no remanent magnetisation!

BARC III Sensor

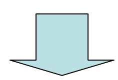
- GMR – sensor array = high sensitivity
- Application of Receptor molecules on GMR and microbead
- Solution of microbeads and target molecules
- DC field to carry not attached beads away
- AC field -> Magnetisation of the beads -> sensing field is generated.
- Measure the electric resistance and compare to a reference GMR array



BARC III Sensor

Magnetic bead criteria:

- High magnetisation to maximize the response of the sensor
- No clustering -> No remanent magnetisation!



Microbeads composed of γ-Fe_2O_3 and Fe_3O_4 superparamagnetic nanoparticles < 20nm dispersed in a polymer matrix.