

**Nano structured materials-synthesis, properties, self assembly and applications
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Module 4 (Lecture 6, 7 and 8)

Problem :

Magnetic properties 1:

1. What is magnetic dipole? Draw a schematic diagram.
2. What is magnetic force? Write the relation between magnetic force and magnetic field when the field is at angle of Θ with charged particle.
3. What is the relation between M and H? Draw the different types of magnetic behavior (M vs. H curve) with examples.
4. What is magnetic susceptibility (χ)?
5. Draw the magnetic susceptibility vs. temperature curve for different magnetic materials.
6. Why do magnetic domains form in magnetic materials?
7. What is magneto-optic Kerr effect?

Magnetic properties 2:

1. Draw magnetization curve in presence of applied field in case of both magnetically hard and soft materials.
2. Draw and explain the magnetic domain structure in the initial magnetization curve in magnetic hysteresis.
3. What are the different types of magnetic hysteresis?
4. Define superparamagnetism with example.
5. What is blocking temperature? How does it depend on the size of the particles?
6. What is relaxation time and how does it depend on the blocking temperature?

Magnetic properties 3:

1. What are the applications of magnetic nanoparticles?
2. How does MRI contrast agent work? Explain with schematic diagram.
3. Give an example of T1 and T2 contrast agents.
4. What is mechanism of heavy metal ions separation from waste water using magnetic particles?

Module 4, Lecture 6, 7 and 8

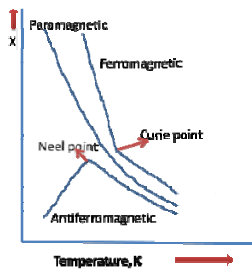
Solution:

Magnetic properties 1:

1. A magnetic dipole is the two opposite poles in a bar magnet where magnetic lines of force move from N pole to S pole. It is simply a current loop which creates and responds to magnetic fields. Figure, see Module 4, Lecture 6 first slide.
2. The force experienced by a charge in a magnet field is called magnetic force.

$$F = q v B \sin \theta$$

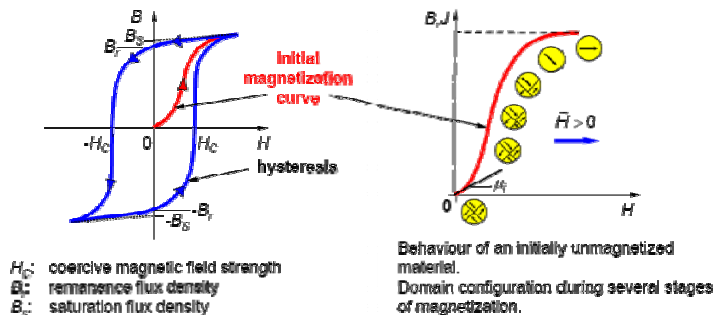
3. $M = \chi_m H$, for the curves, see Module 4, Lecture 6, at 13:35 mins.
4. Ratio of the induced magnetization to an inducing magnetic field or M/H .
- 5.



6. To minimize outer field of the magnetic material or to minimize magnetostatic energy.
7. Magneto-optic Kerr effect is the rotation of the polarization of light reflected from a magnetized surface.

Magnetic properties 2:

1. See module 4, lecture 7, at 8:02 mins, draw similar curve with higher area for magnetically hard and draw similar curve with small area for magnetically soft materials.
- 2.



Domain structures of the initial magnetization curve as drawn inside yellow circles.

3. See module 4, lecture 7, at 14:01 mins

- In nanostructures, thermal energy is not sufficient to overcome spin-spin coupling energy resulting random orientations of magnetic spins. This leads to zero remanent magnetization and zero coercivity showing paramagnetic behavior. This is called superparamagnetism.
- The transition temperature from ferromagnetism to superparamagnetism with no hysteresis behavior is called as the blocking temperature (T_b). $T_b = KV/25k$,
 K is the anisotropy energy (20'000 J/m³ for iron oxide)
 V the volume of the particle
 k is the Boltzmann constant.
 It depends on the volume of the particles means it depends on the size. T_b will increase with size of the particles.
- The time required to achieve zero magnetization after removing the external magnetic field

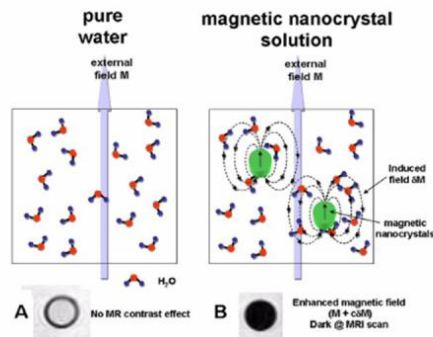
$$\tau = \tau_0 \exp (KV/ k T)$$

$$\tau = \tau_0 \exp (25T_b/ T) \text{ as } T_b = KV/25k,$$

Magnetic properties 3:

- MRI contrast agents
 - Magnetic hyperthermia agents
 - Data storage
 - Magnetic separation (water treatment)
 - In vivo detection of biological targets

2.



Enhanced magnetic field due to presence of magnetic nanocrystals leads to decrease in the spin-spin relaxation time (T_2) of the proton resulting MR image as dark.

- Gd^{3+} -chelates as T1, and Superparamagnetic iron oxide (SPIO) as T2 agents.

4. Heavy metals adsorbed on the functionalized magnetic nanoparticles can be easily recovered by utilizing magnetic separation. Example Humic acid functionalized Fe₃O₄ nanoparticles.