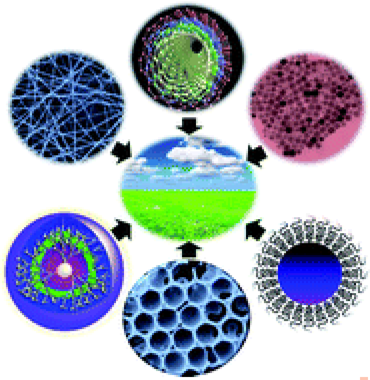

بسم الله الرحمن الرحيم

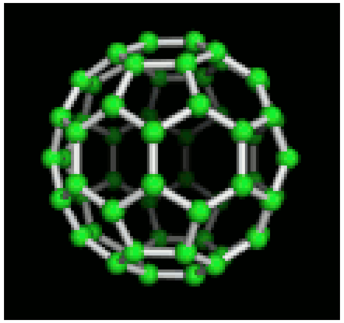
Subject: Nanotechnology & Nanostructures (Lecture # 12)

Prof .Dr. Zohra Nazir Kayani

Physics Department

LAHORE COLLEGE FOR WOMEN, UNIVERSITY, LAHORE





Properties of Nano materials

3. Optical Properties

•Because of their role in quantum dots, nanoparticles made of the elements, which are normal constituents of semiconductors.

•The most striking property of nanoparticles made of semiconducting elements is the pronounced changes in their optical properties compared to those of the bulk material.

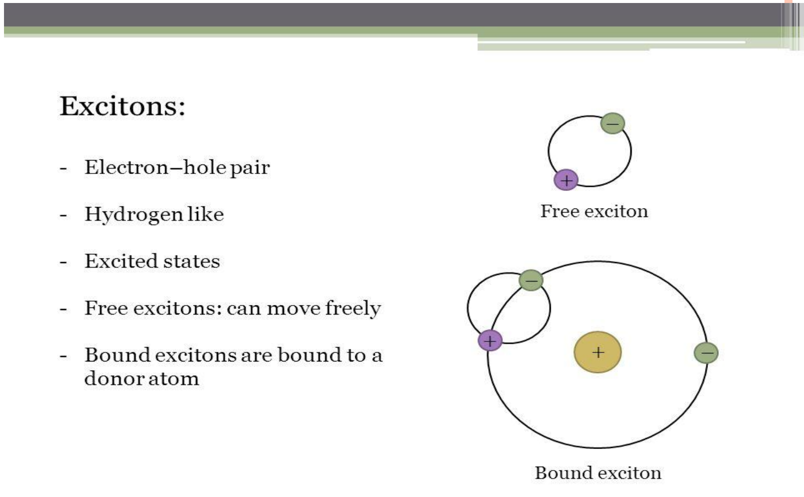
•There is a significant **shift in the optical absorption spectra** toward the blue (shorter wavelength) as the particle size is reduced.

•In a bulk semiconductor a bound electron-hole pair can be produced by a photon having energy greater than that of the band gap of the material.

•Because of the coulomb attraction between the positive hole and the negative electron, the bound pair, called an exciton is formed that can move through the lattice.

•The separation between the hole and the electron is many lattice parameters.

•The existence of the exciton has a strong influence on the electronic properties of the semiconductor and its optical absorption. The exciton can be modeled as a hydrogen-like atom.



- When the size of the nanoparticle becomes smaller than or comparable to the radius of the orbit of the electron-hole pair, there arise two situations:

• The weak-confinement
• The strong-confinement regimes.

- In the weak regime, the particle radius is larger than the radius of the electron-hole pair, but the range of motion of the exciton is limited which causes a blue shift of the absorption spectrum.

- When the particle radius is smaller than the radius of the electron-hole pair, the motion of the electron and the hole become independent, and the exciton does not exist.

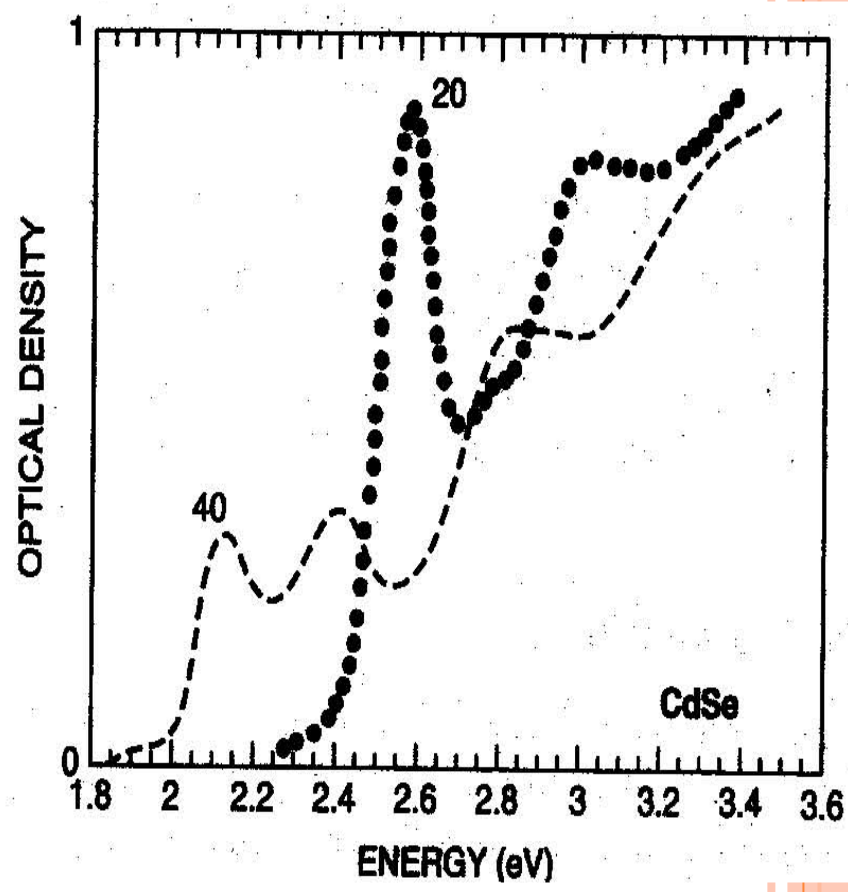
- The hole and the electron have their own set of energy levels. Here there is also a blue shift, and the emergence of a new set of absorption lines.

•Figure shows the optical absorption spectra of a CdSe nanoparticle at two different sizes measured at 10K.

•The lowest energy absorption region (the absorption edge) is shifted to higher energy as the particle size decreases. Since the absorption edge is due to the band gap, this means that the band gap increases as particle size decreases.

•The intensity of the absorption increases as the particle size is reduced. The higher energy peaks are associated with the exciton and they shift to higher energies with the decrease in particle size.

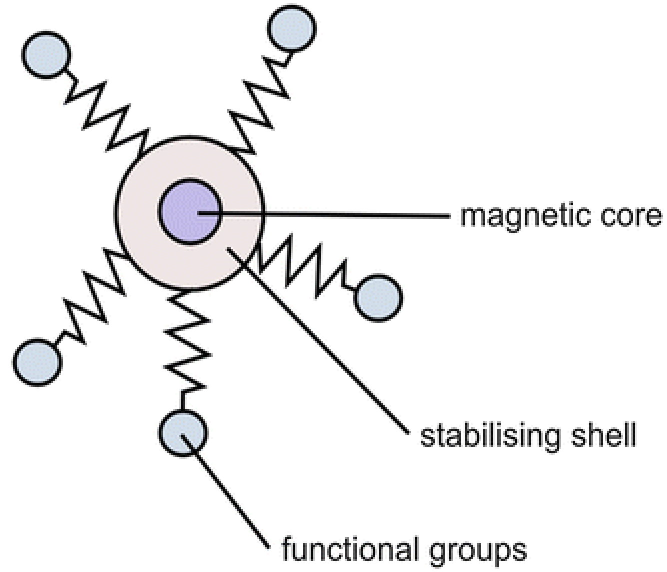
•These effects are a result of the confinement of the exciton. Essentially, as the particle size is reduced, the hole and the electron are forced closer together and the separation between the energy levels changes.

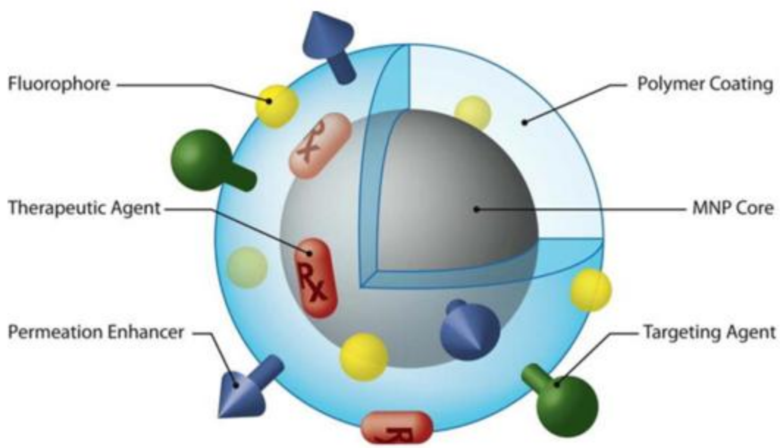


4. Magnetic Properties

Magnetic nanoparticle carriers consist of three functional parts:

- a magnetic core
- a surface coating
- a functionalized outer coating



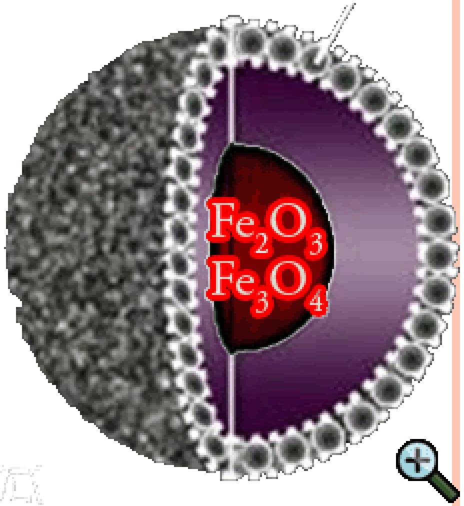


❑At the center of the carrier is the superparamagnetic core which allows for the magnetic manipulation of the particle in the presence of an external magnetic field.

❑ The composition of the magnetic core is dependent on the application.

❑ For example, magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_3) with high oxidative stability are currently the only accepted nontoxic magnetic materials for medical applications.

❑Magnetic cores consisting of materials such as cobalt, nickel, and neodymium-iron-boron may offer improved magnetic properties and however, these materials may be susceptible to oxidation or be toxic for use in the human body.

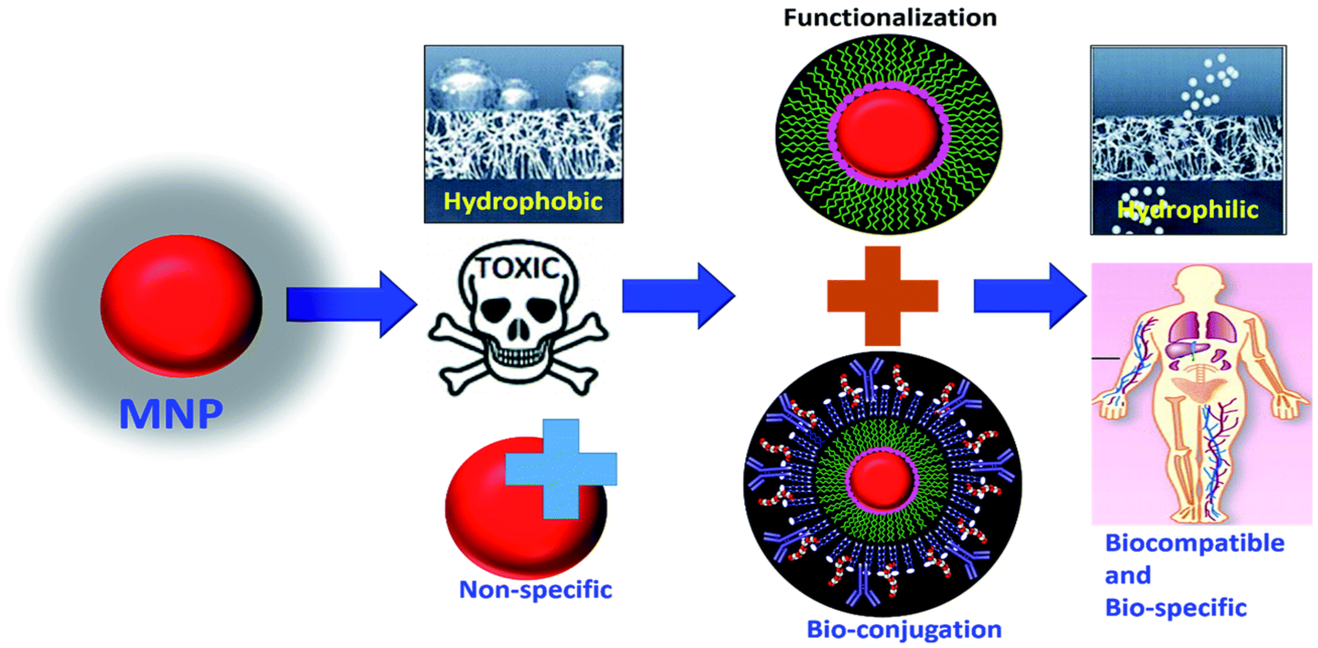


❑By virtue of their smaller size, magnetic nanoparticles are able to overcome the influence of the gravitational field, magnetic field gradient, and the potential magnetic agglomeration which could result when particles come into contact with one another.

❑Particles may be attracted to one another as a result of London-type van der Waals attractive forces.

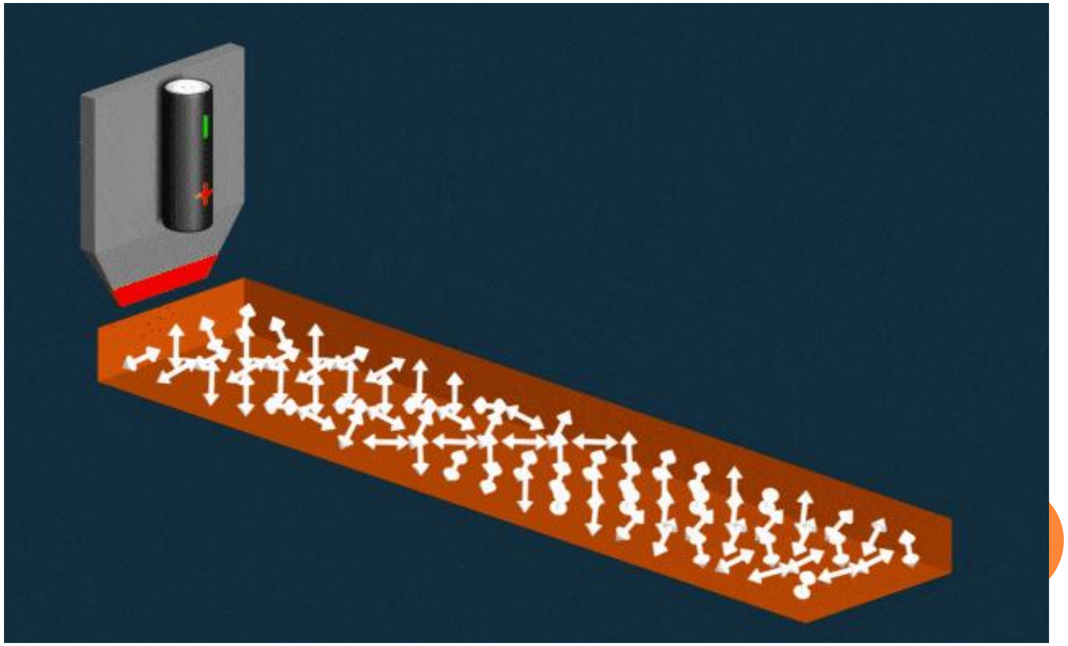
❑In order to minimize such interactions of the particle with the system environment, to ensure stability, and to prevent agglomeration, a surface coating may be required to provide steric repulsion.

❑ The functionalized outer coating may be a component such as a molecule or a ligand for scavenging of metal ions.



Ferromagnetic materials:

Ferromagnetic materials are subdivided into areas known as domains. In an unmagnetized sample, the moments of these domains are randomly orientated, but tend to align themselves in the direction of an external applied magnetic field.



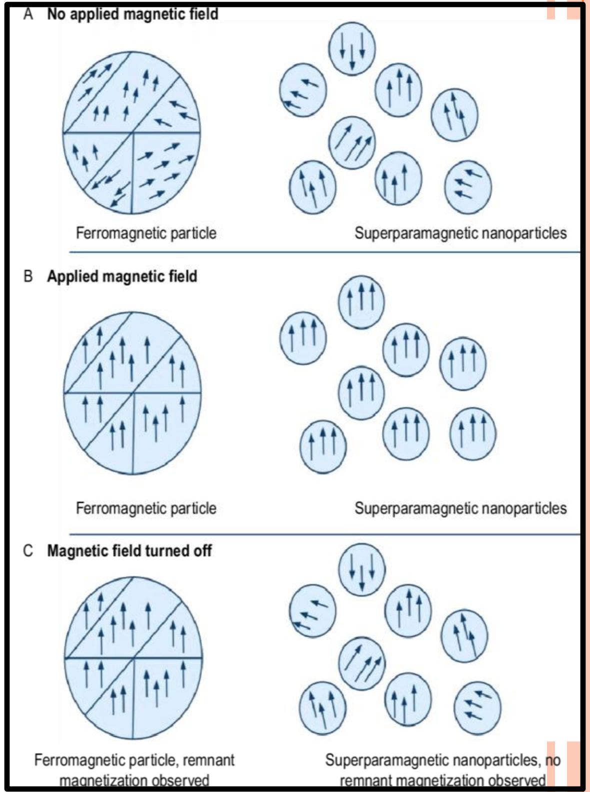
•As the particle size approaches a certain minimum critical size, often in the nanoscale range, the formation of domain walls becomes energetically unfavorable.

• Changes in magnetization occur through the rotation of spins rather than through the motion of domain walls.

• Particles exhibiting these properties are called single domain. As particle size is decreased further, spins are affected by thermal fluctuations and the particles become **super paramagnetic**.

• This super paramagnetic property of materials is useful in that individual particles become magnetized only when exposed to an external magnetic field, but exhibit no remanent magnetization when the field is removed.

•In addition, the particle size provides a large surface area for functionalization which lends itself to applications of small dimensions of interest.



Other properties

•The **magnetic behavior** of bulk ferromagnetic material made of nano sized grains is quite different from the same material made with conventional grain sizes.

•The **inherent chemical reactivity** of nano particles depends on the number of atoms in the cluster. It might be expected that such behavior would also be manifested in bulk materials made of nano structured grains providing a possible way to protect against corrosion and the detrimental effects of oxidation, such as the formation of the black silver oxide coating on silver.

•The **melting temperature** of nano structured materials is also affected by grain size. Melting temperature of nano structured materials decreases with the decrease in grain size.

Other properties

•In the **superconducting phase**, there is a maximum current that a material can carry and the maximum value is called the critical current. When the current exceeds that value, the superconducting state is removed and the material returns to its normal resistance.

•The **optical absorption properties** of nanoparticles determined by transitions to excited states, depend on their size and structure. In principle, it should therefore be possible to engineer the optical properties of bulk nanostructured materials.

•The mechanical, electrical, thermal, optical and catalytic properties of **nanocomposites** depend upon the component materials.

THANK YOU