# Physics of Nanoparticles

Engineering Physics
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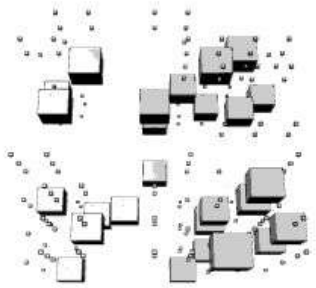
FE HOD
SKNSITS



# Syllabus

- *Introduction*
- *Nanoparticles*
- *Properties of nanoparticles (optical, electrical, magnetic, structural, mechanical)*
- *Brief discussion of different methods of synthesis of nanoparticles.*
- *Synthesis of colloids*
- *Growth of nanoparticles*
- *Synthesis of metal nanoparticles by colloidal route*
- *Applications of nanotechnology*

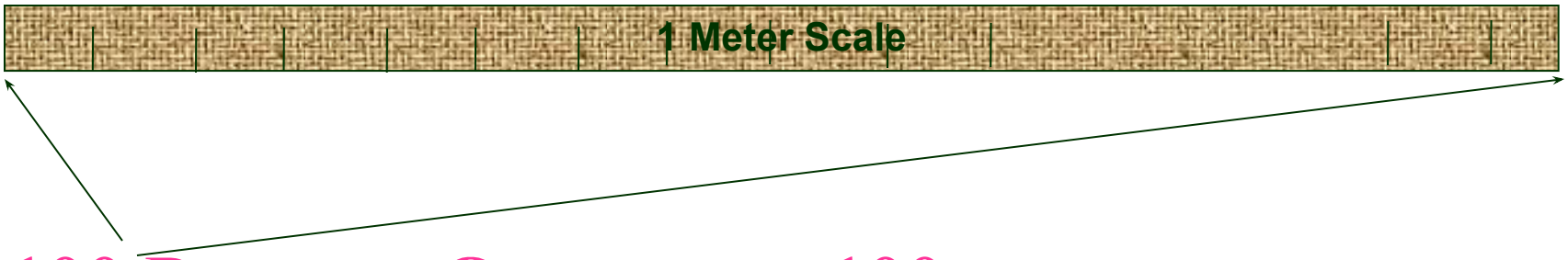

# What is ‘nano’?

**nano**

# *'Nano' : A Greek word for Dwarfs which means smaller things.*

**"Nano" = one BILLIONTH**

# “Nano” = one BILLIONTH




100 Parts → One part = 100 cm

1000 parts → One part = 1 mm

1000000000 parts → One part = 1 nm

**1 nm = 1/1,000,000,000 of a meter**

# How small is the Nanoscale ?

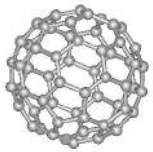
12,756 Km

$1.27 \times 10^{7}$ m

22 cm

0.22 m

Fullerenes $C_{60}$



0.7 nm

$0.7 \times 10^{-9}$ m

10 millions times smaller

1 billion times smaller

# Nanotechnology is……

**Creation of Functional Materials, Devices & Systems**
**Through**
**Control of Nanoscale Materials**
**(1 to 100 nm)**
**exploiting**
**Novel Properties & Phenomenon**
**At**
**All Length Scales !**

## Lycurgus cup:

**It appears green in reflected light, but appears red when light is incident from inside, and is transmitted through the glass.**


*(M. Faraday1857)!*



**What is big deal ?**

*Smaller things like atoms behave differently than the same stuff behaves when it is bigger.*

**i.e., Size controls the nanotechnology equation !!**

# Nanoparticles

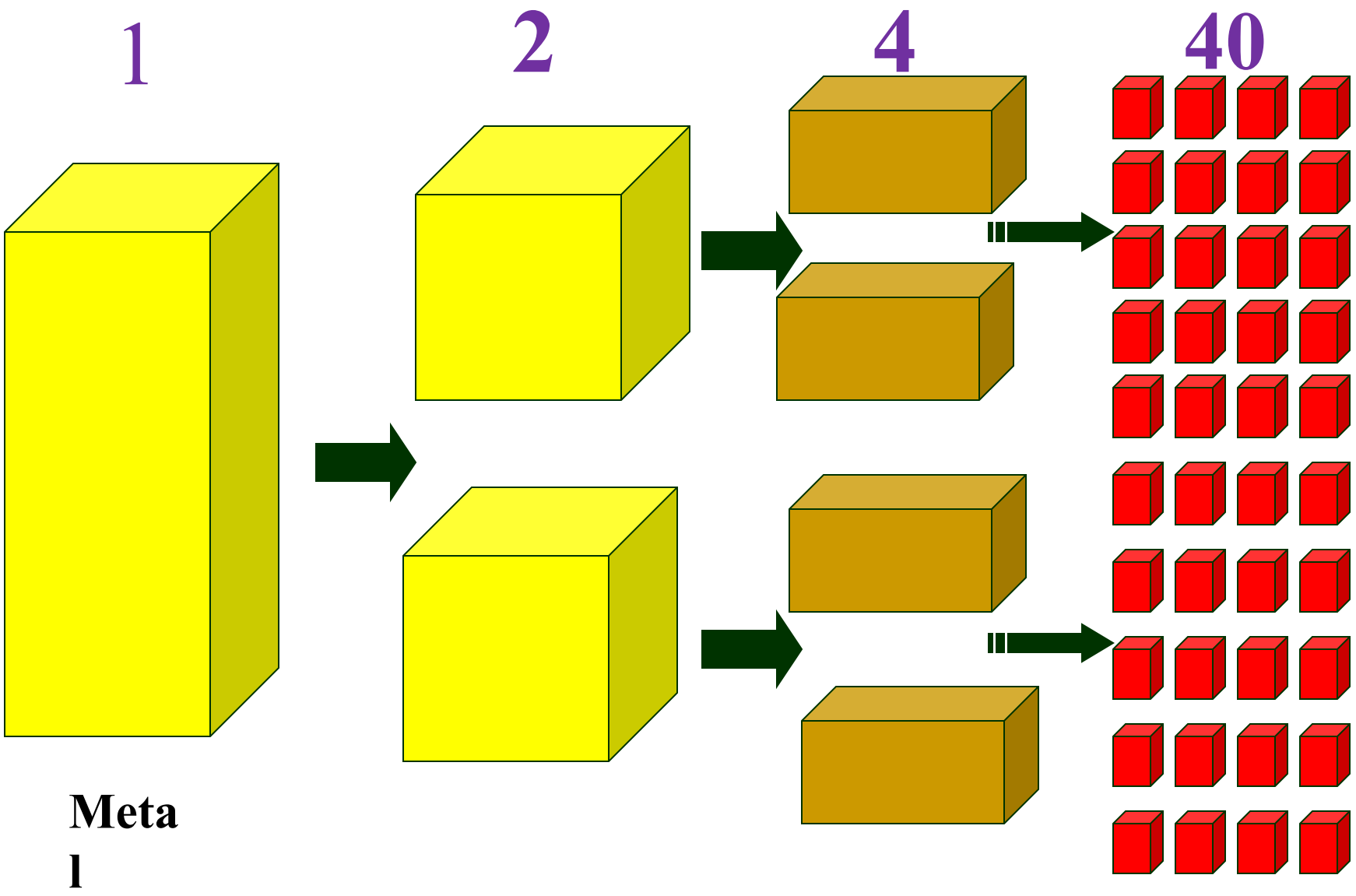
- These are the particles having dimensions less than 100 nm.

***Properties of nanometers can be uniquely different from properties of materials in bigger bulk forms.***

**As numbers of chunks increases, surface area increases !**

**More area to work**

**More Research !!!**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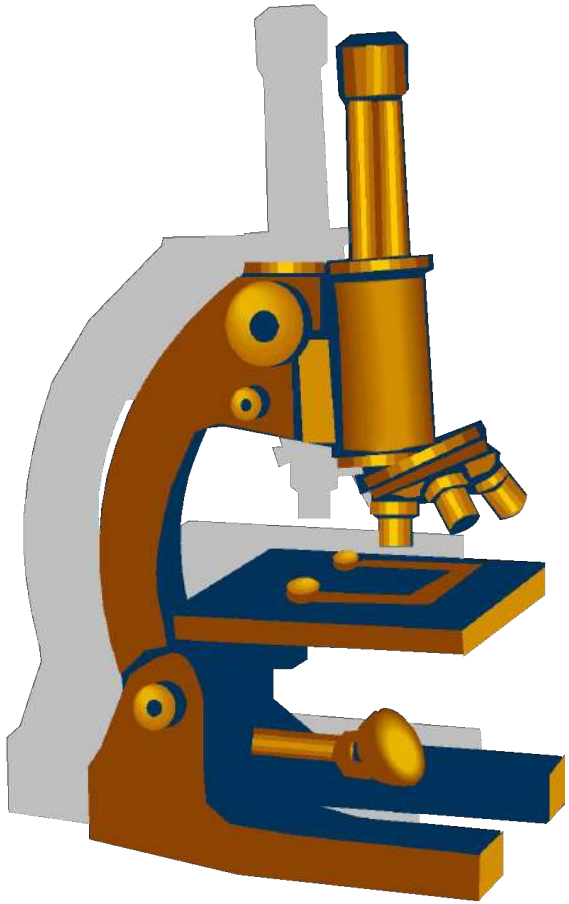
# Properties of Nanoparticles



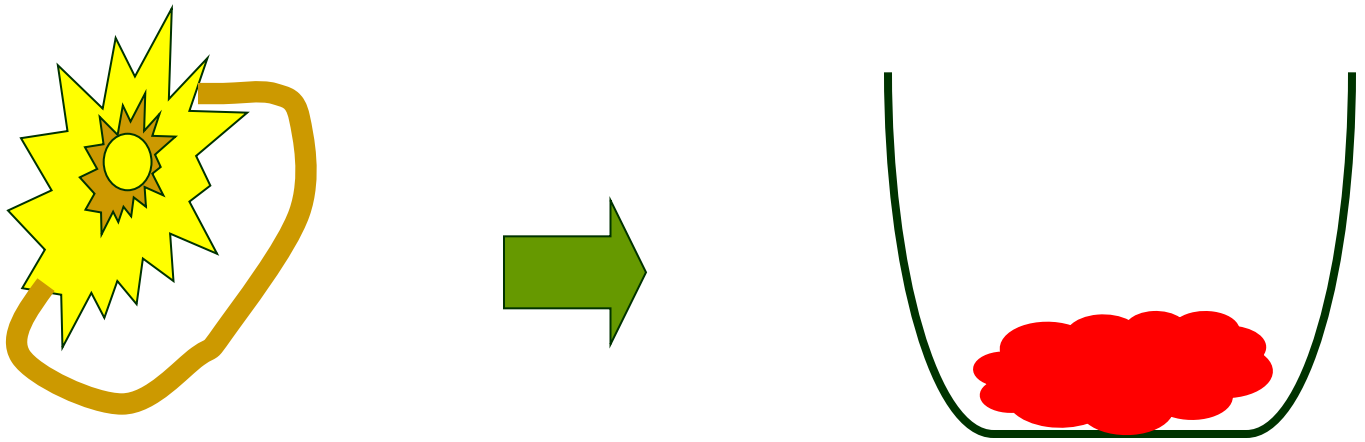
- Optical
- Electrical
- Magnetic
- Structural
- Mechanical

# 1)
# Optical property

# Optical property

- The colour of nanoparticles are different from colour of bulk material.

**Exa.: When nanoparticles of gold are formed, they give bright red colour instead of yellow as it appears in bulk form.**



# Mie's formula

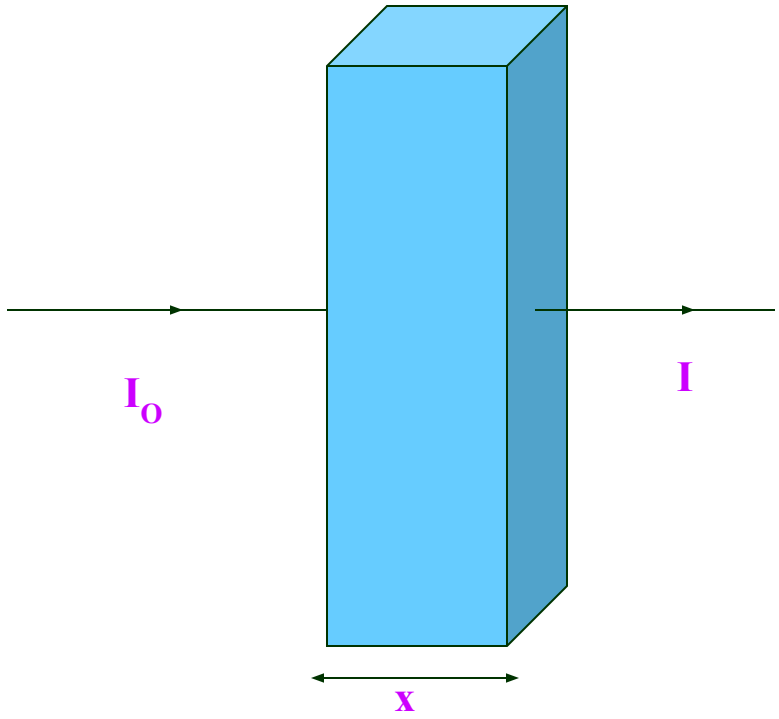
When a beam of light of intensity Io & wavelength λ passes through a medium, then, the transmitted intensity is given by

$$I = I_o e^{-\mu x}$$

μ = extinction coefficient depends upon no of particles in medium,

= (N/V) $C_{Ext}$ where N is number & V is volume of particles, $C_{Ext}$ is extinction coefficient.

x = Thickness of material

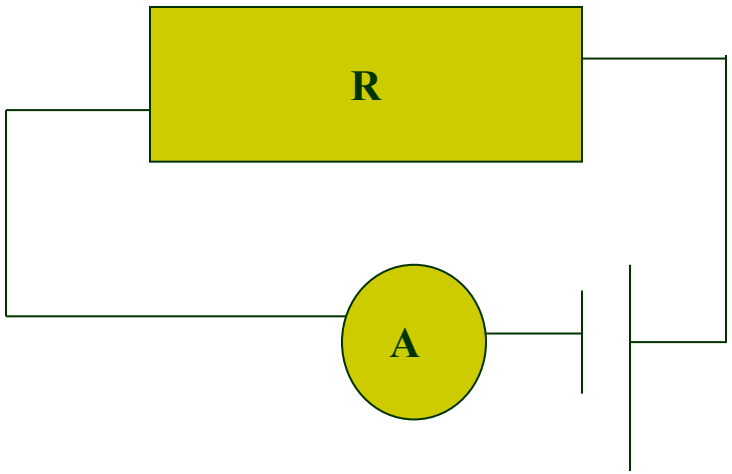


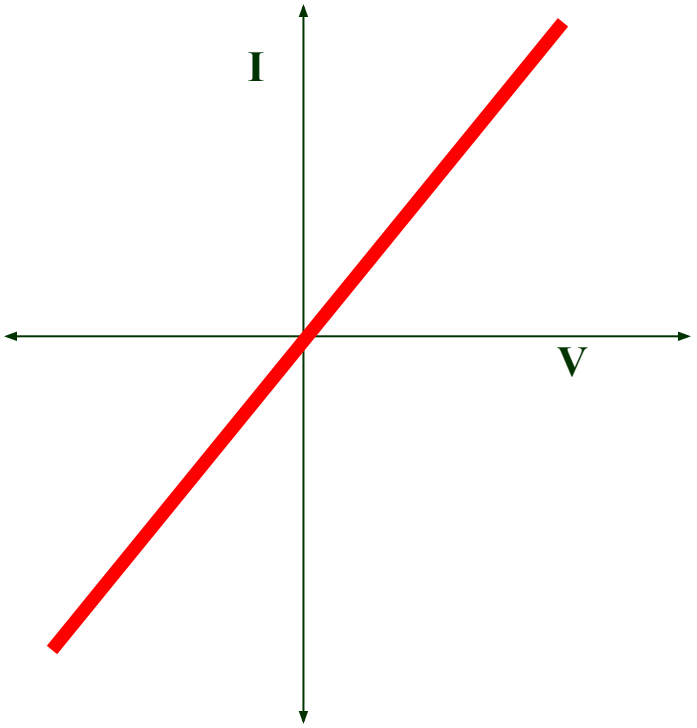

**When light is passed through the medium ,a fraction is absorbed and the part is scattered hence the extinction cross section is the sum of absorption extinction and scattered extinction cross section.**

**The scattering coefficient the light depends on wavelength λ and the absorption coefficient depends inversely on the volume of colloidal particles i.e. 1/V.**

# 2)
# Electrical properties

# Bulk Material



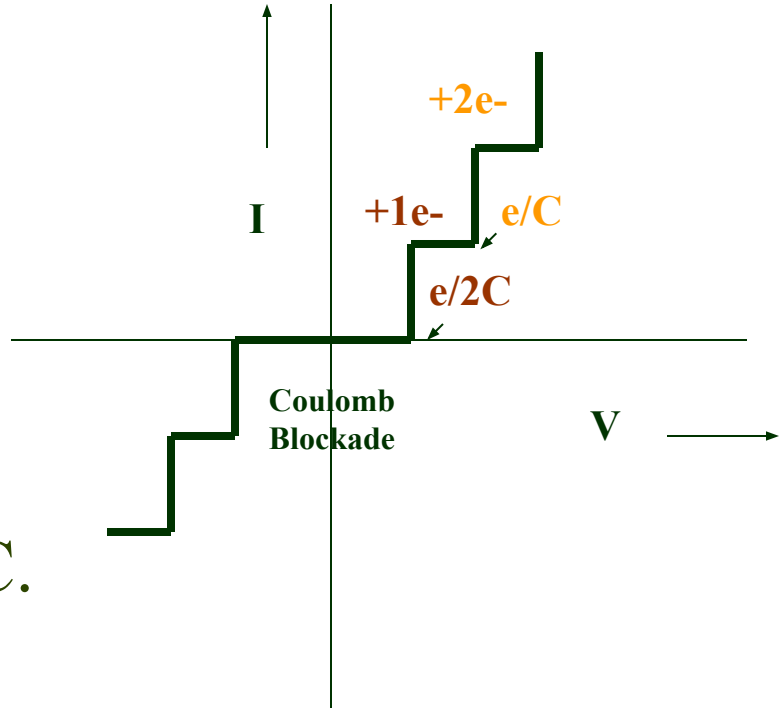



# Electrical properties of Nano material:

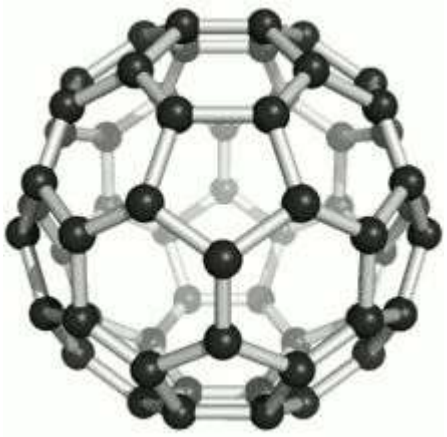
1) IV graph for nanoparticles is as shown in figure ( known as Coulomb staircase).

2) Electrons are transferred when the voltage is ±e/2C. (E = e/2C is electrostatic energy of capacitor)

3) The zero current region is known as Coulomb Blockade.



# 3)
# Structural properties



# Structural properties

- Nanostructures are not just fragments of bulk materials, they are different in bonds, bond strength & hence having different lattice parameters.
- They do not have the same structure or atomic arrangement as a bulk.

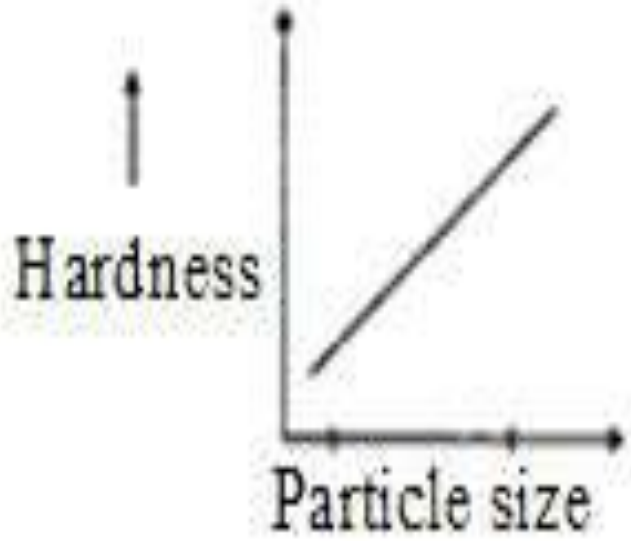
Fig.:

# 5)
# Mechanical Properties

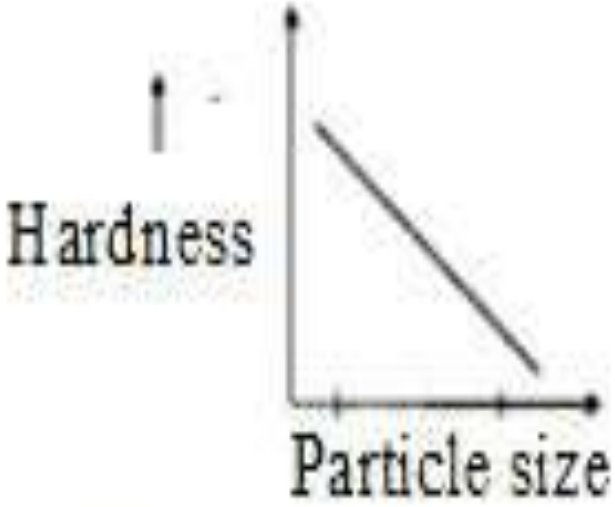
# Mechanical Properties

- Properties like elasticity, hardness, ductility, depends upon composition and the bonds between the atoms.
- The presence of impurities and imperfections in the crystalline form change these properties.
- For nano material, the material tends to form a single crystal, which are highly pure and free of imperfections.

**Exa.:** For bulk material, the hardness increases linearly with the grain size. But in nano the hardness increases linearly with decrease of the particle size.

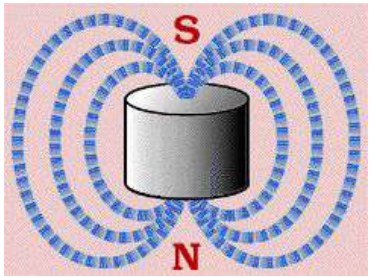



Hardness vs size in Bulk Material



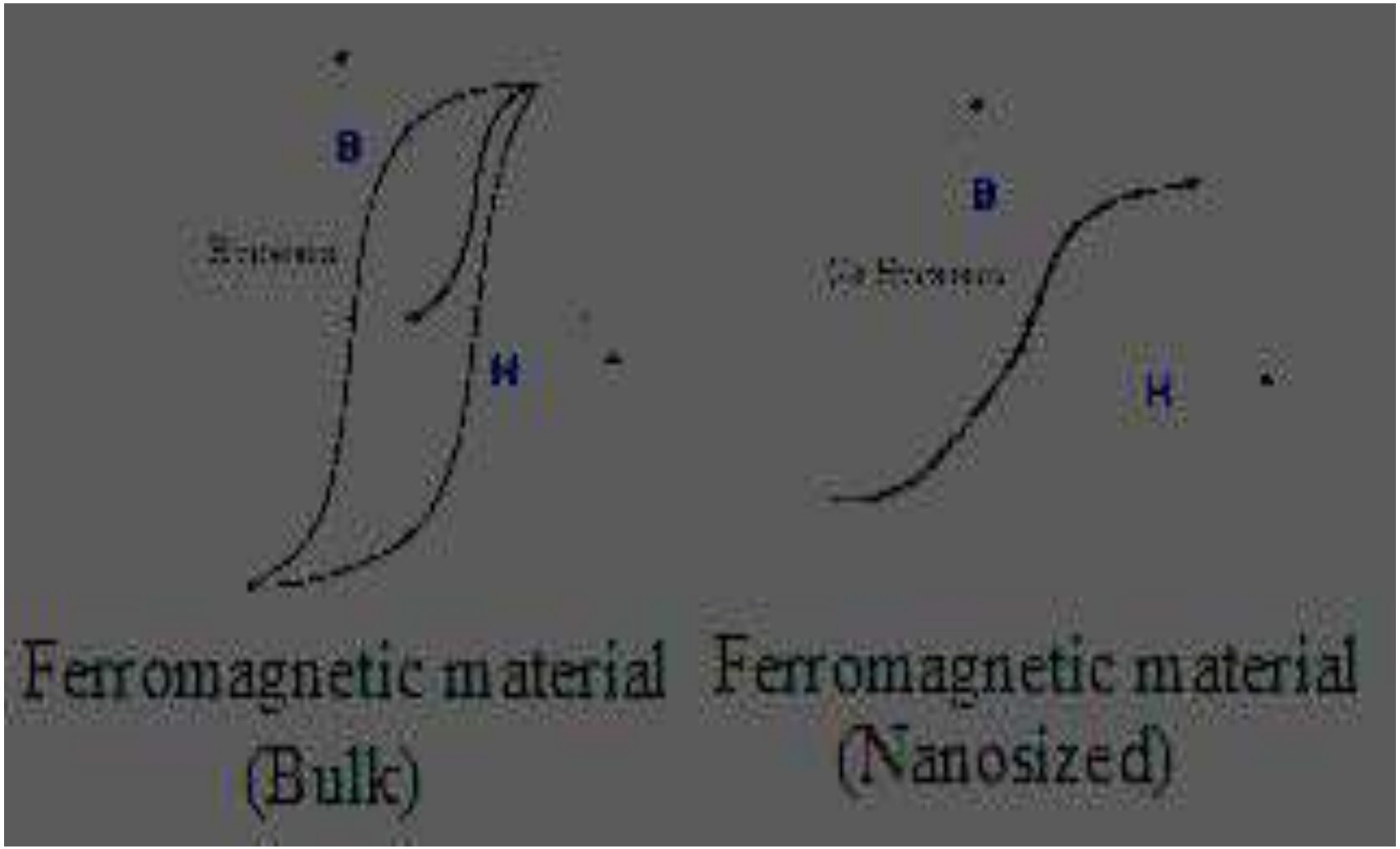

Hardness vs size in in Nanomaterial

# 6)
# Magnetic Properties



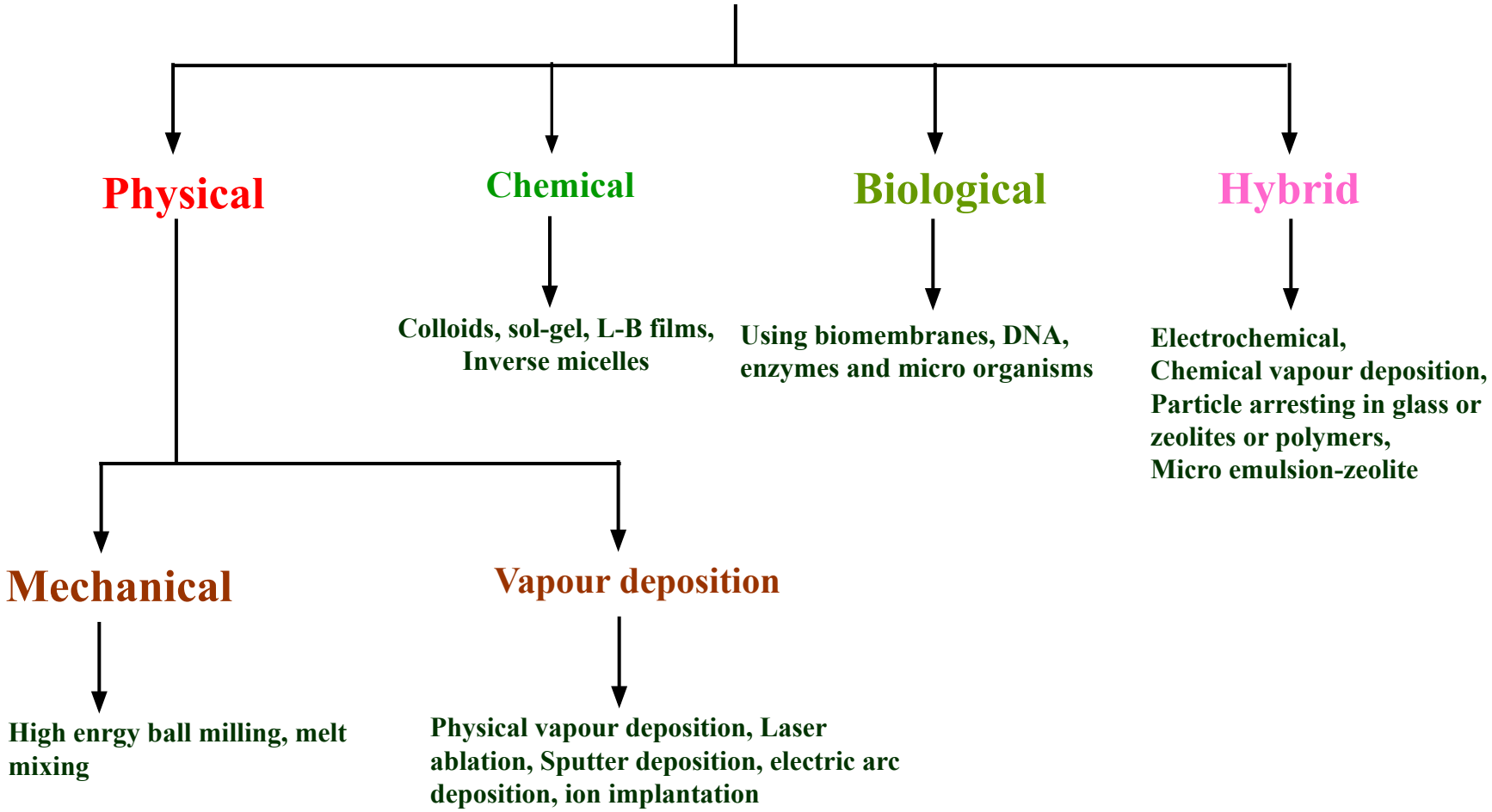
# Magnetic Properties

1. In bulk material, magnetism is due to magnetic moments.
2. At nanoscale, material behaves as single domain. The single domain doesn't show coercivity or hysteresis. These type of particles are known as superparamagnetic particles.

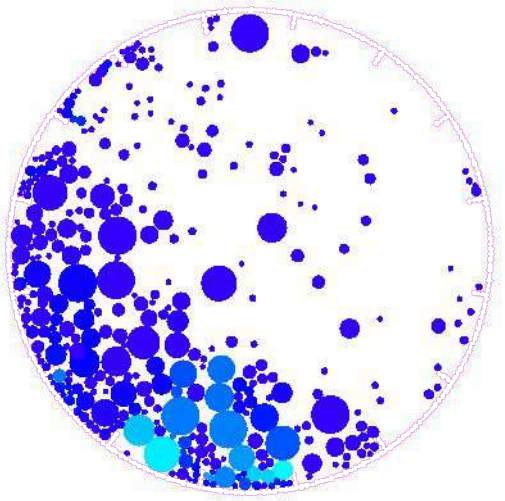

B
H
Ferromagnetic material
(Bulk)
B
H
Ferromagnetic material
(Nanosized)

# *Synthesis of Nanomaterials*

# Synthesis



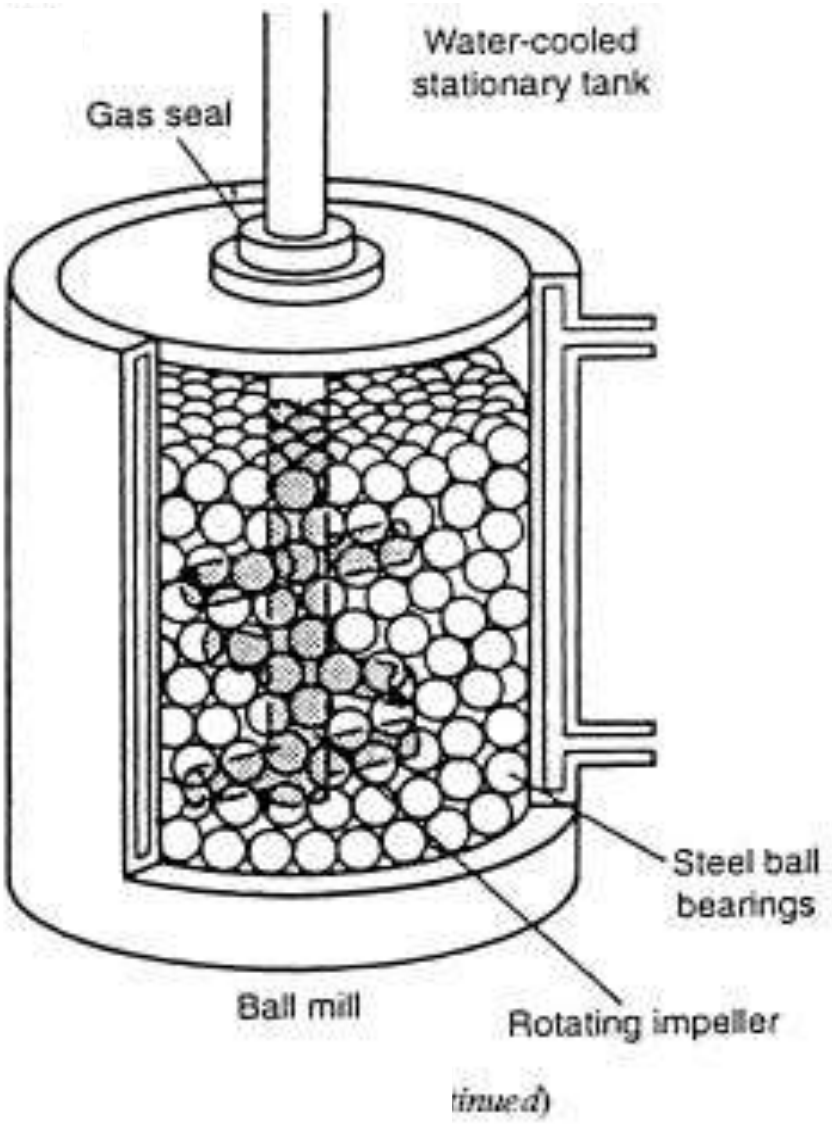
# Mechanical Synthesis of nanoparticles



# Ball mill

***Simplest method to make Powdered form of nanoparticles.***

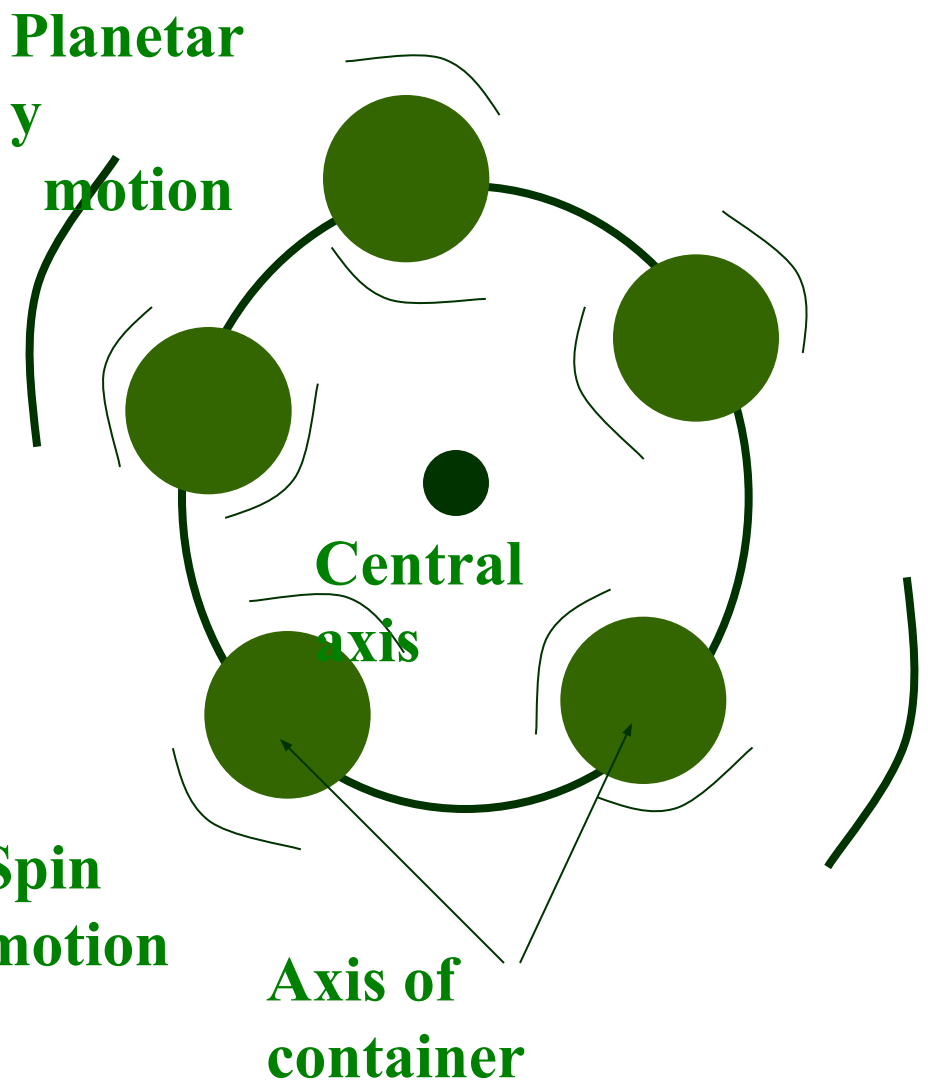
1) Put steel balls along with bulk material (2:1 ratio).
2) Rotate axis to get smaller grain sized particles.
3) Use liquid nitrogen to dissipate the heat generated

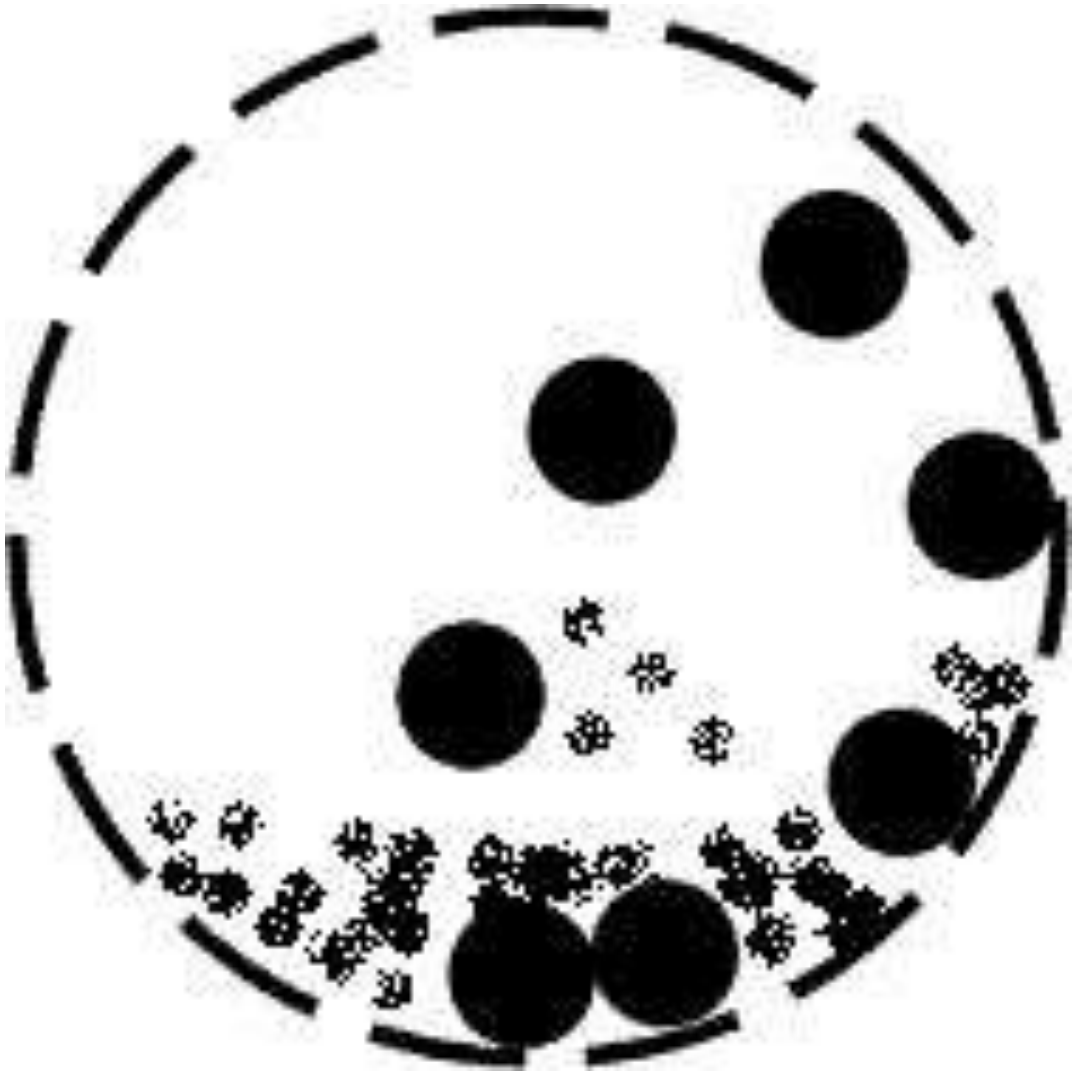


# Physics Of Mill :

Due to rotation of axis, material is forced to the walls & pressed against the walls due to centrifugal force.

But due to motion of container around its own axis , material is forced to other region of the container.

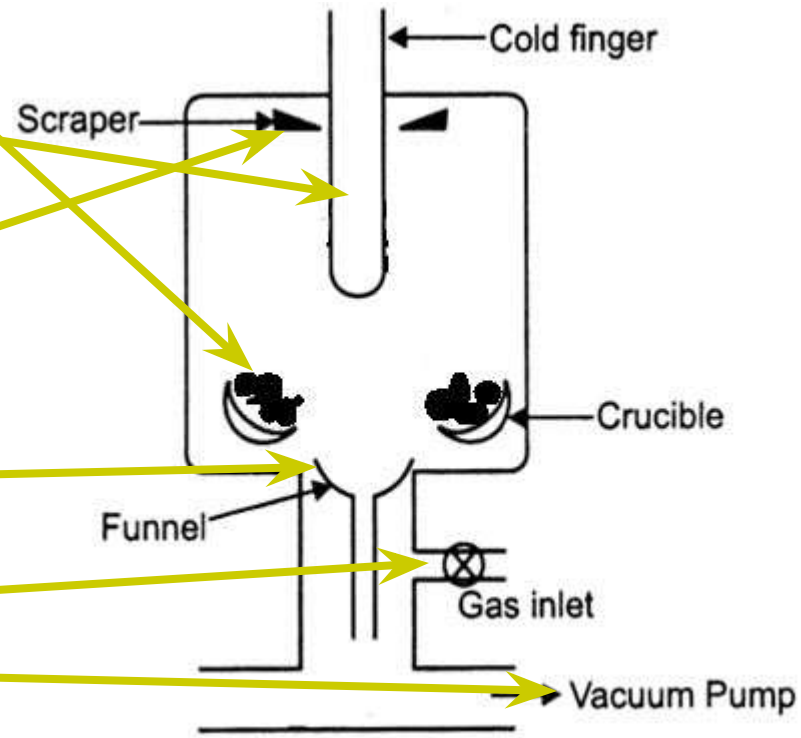




# Physical vapour deposition

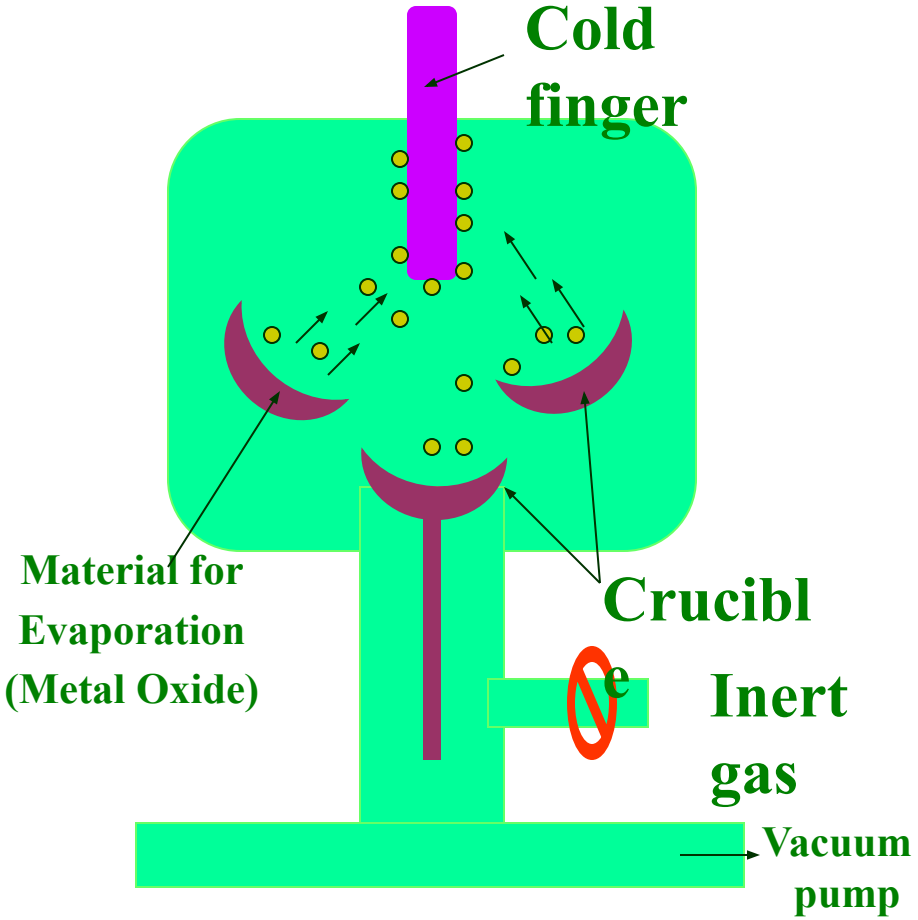
# Physical vapor deposition

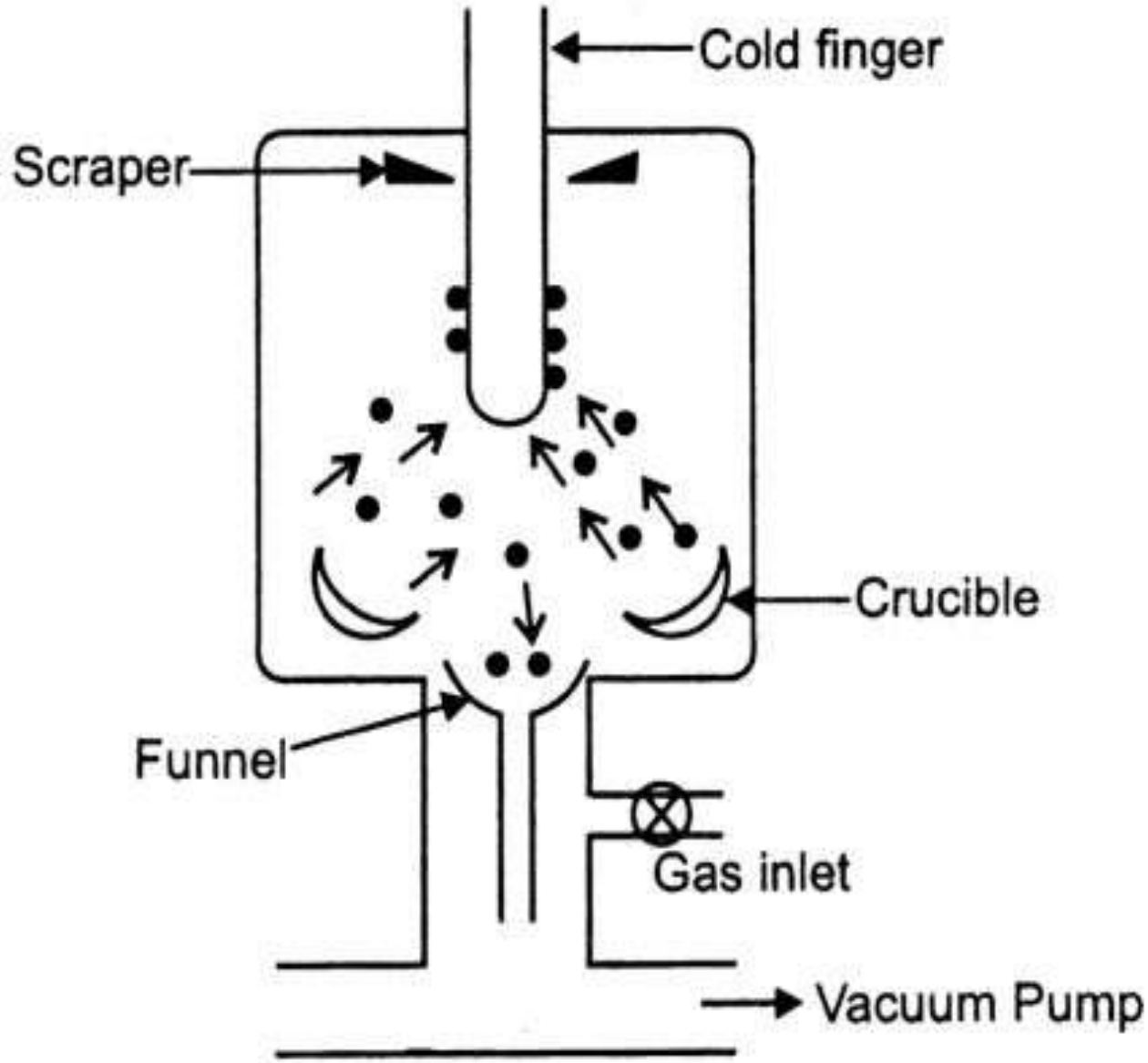
- Material to be synthesized kept in heated crucible,
- Cold finger consisting liquid nitrogen,
- Scraper to scrap condensed nanoparticles,
- Funnel to collect nanoparticles,
- Inlet for reactive gas and
- Pump to create vacuum.



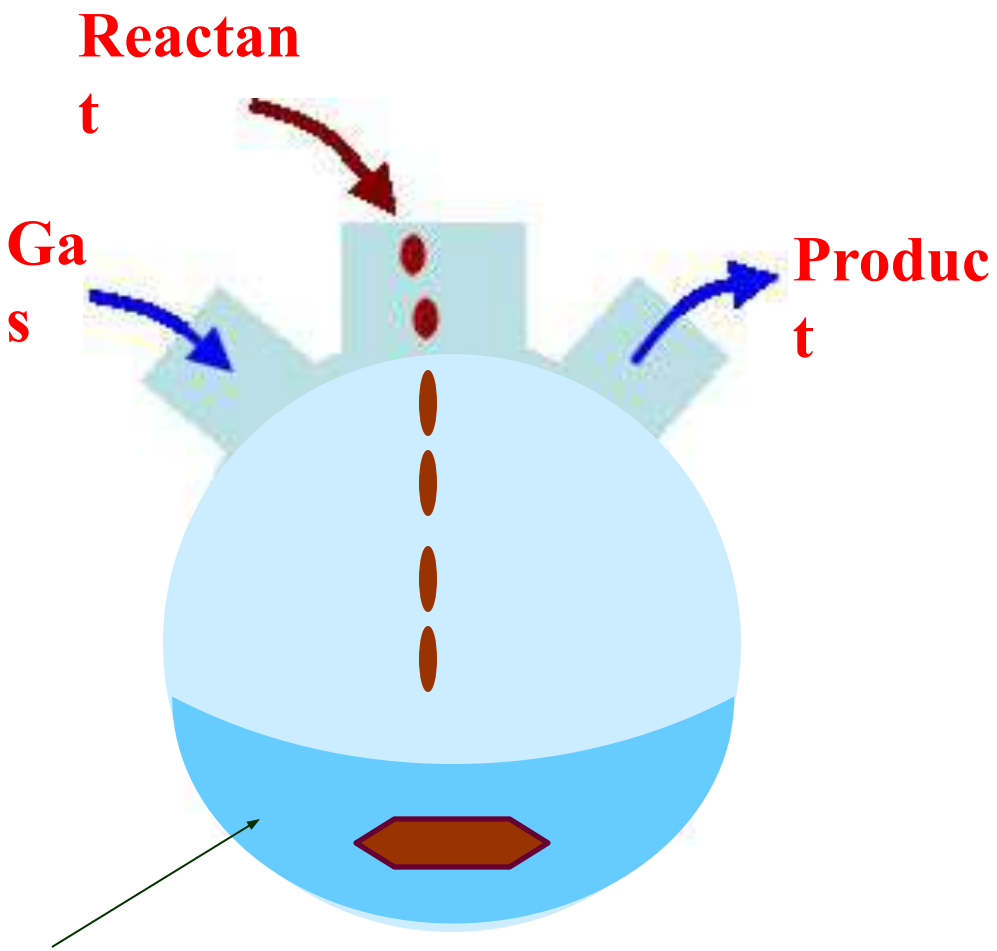
# Physical vapour deposition

- The evaporated atoms & clusters tend to form bigger particles by collisions
- These particles condense on the cold finger.
- While moving from source to cold finger, the particles grow, hence distance between source to cold fingers will decide the particle size.
- The size, shape and phase of particles depend on the gas pressure inside the chamber.





# Chemical methods



# Colloids:

These are clusters of material containing $10^7$ molecules.

It is a mixture with properties between those of solution & fine suspension.

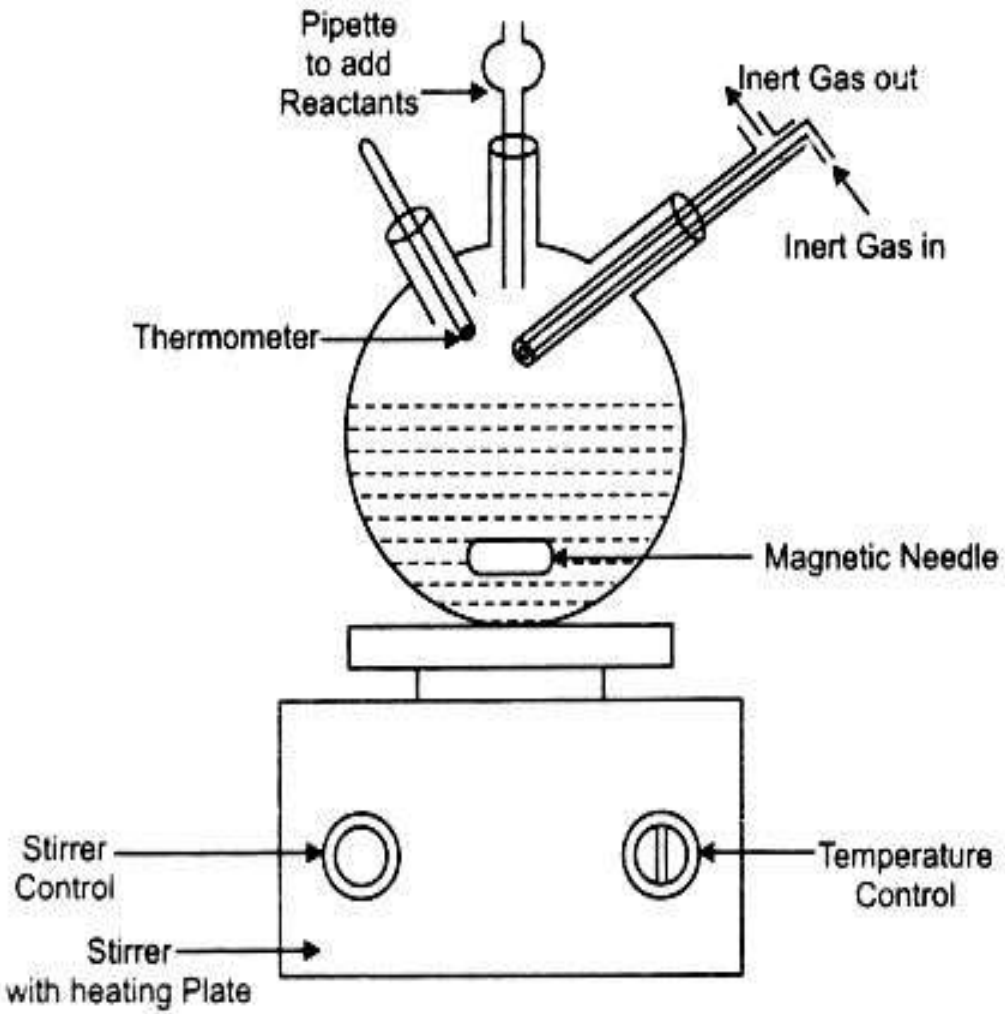
It has different sizes in the form of rods, tubes, plates, etc. in the range 1nm to 100 nm.

# Chemical (Colloidal) Synthesis of Nanoparticles

# Synthesis of colloidal particles

Apparatus :

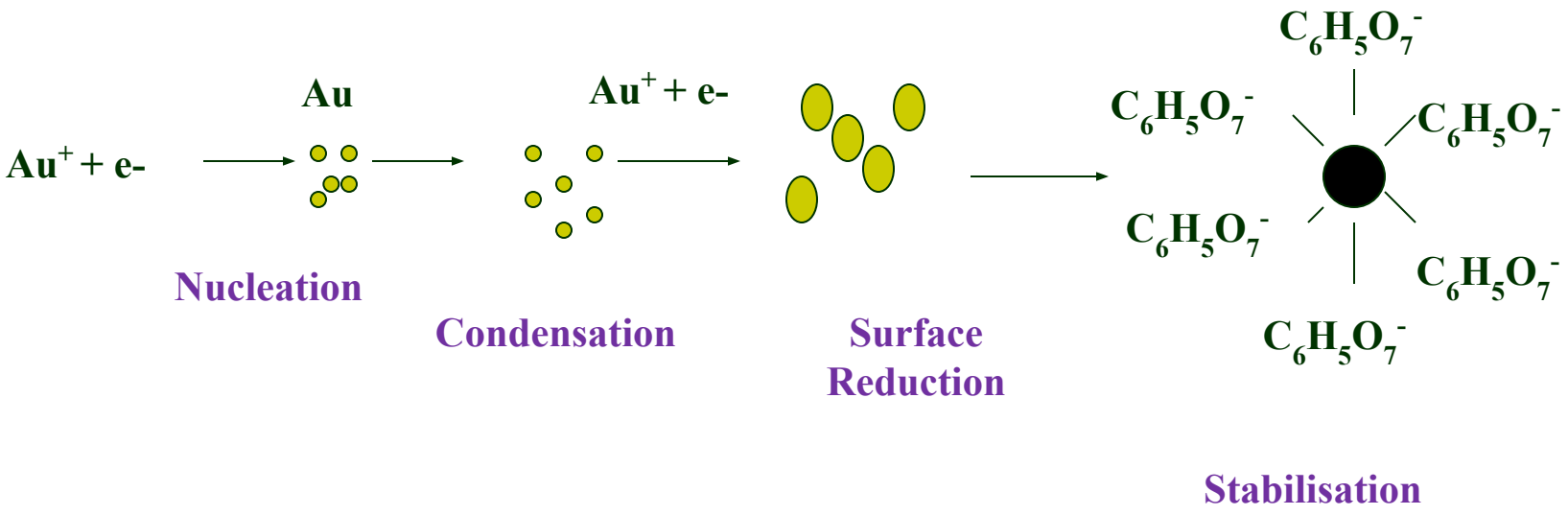
- **Glass reactor for chemical reaction, three Inlets for gas (argon or nitrogen), reactants & thermometer, pH meter, teflon coated magnetic needle, etc.**
- The product can be suitably removed.
- The reaction is usually carried out under inert atmosphere like argon or nitrogen gas so as to avoid any uncontrolled oxidation of the products.
- The Teflon coated magnetic needle is also provided to stir the reactants during the reaction.



# Exa.: Synthesis of Gold nanoparticles by colloidal route

Chloroauric acid + Trisodium citrate ► Gold Nanoparticle +Other product

The Gold nanoparticles are formed by nucleation & condensation.



# Growth of nanoparticles

## LaMer diagram:

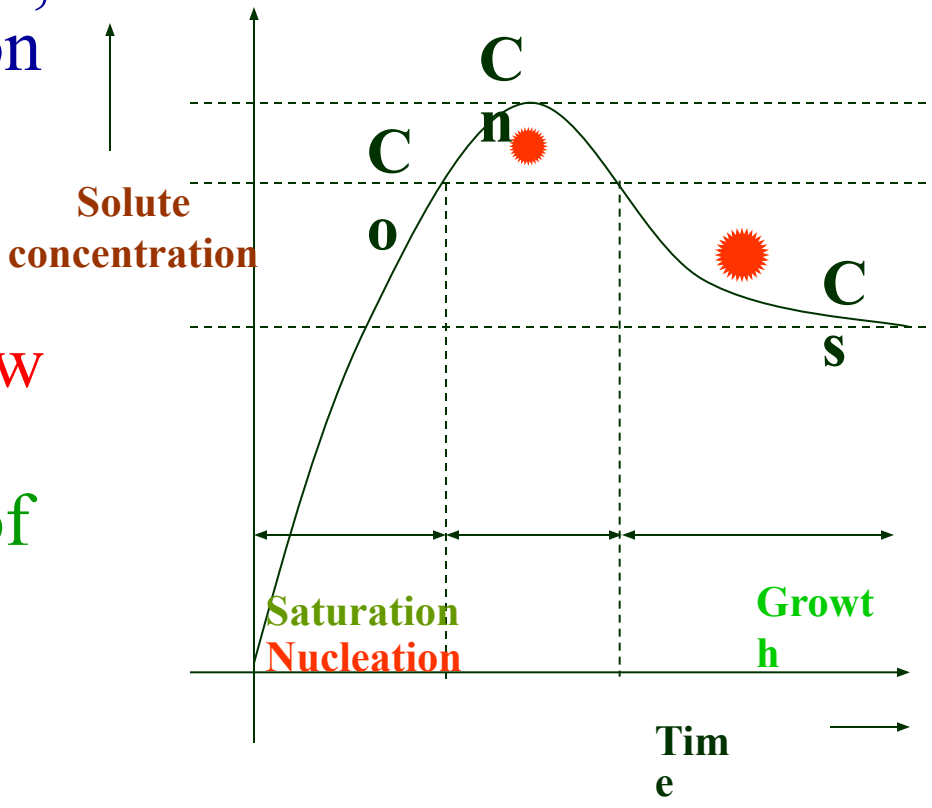
*(Nucleation & Growth Behaviour)*

As concentration increases, at Co, nucleus formation begins.

At concentration Co, nucleation begins.

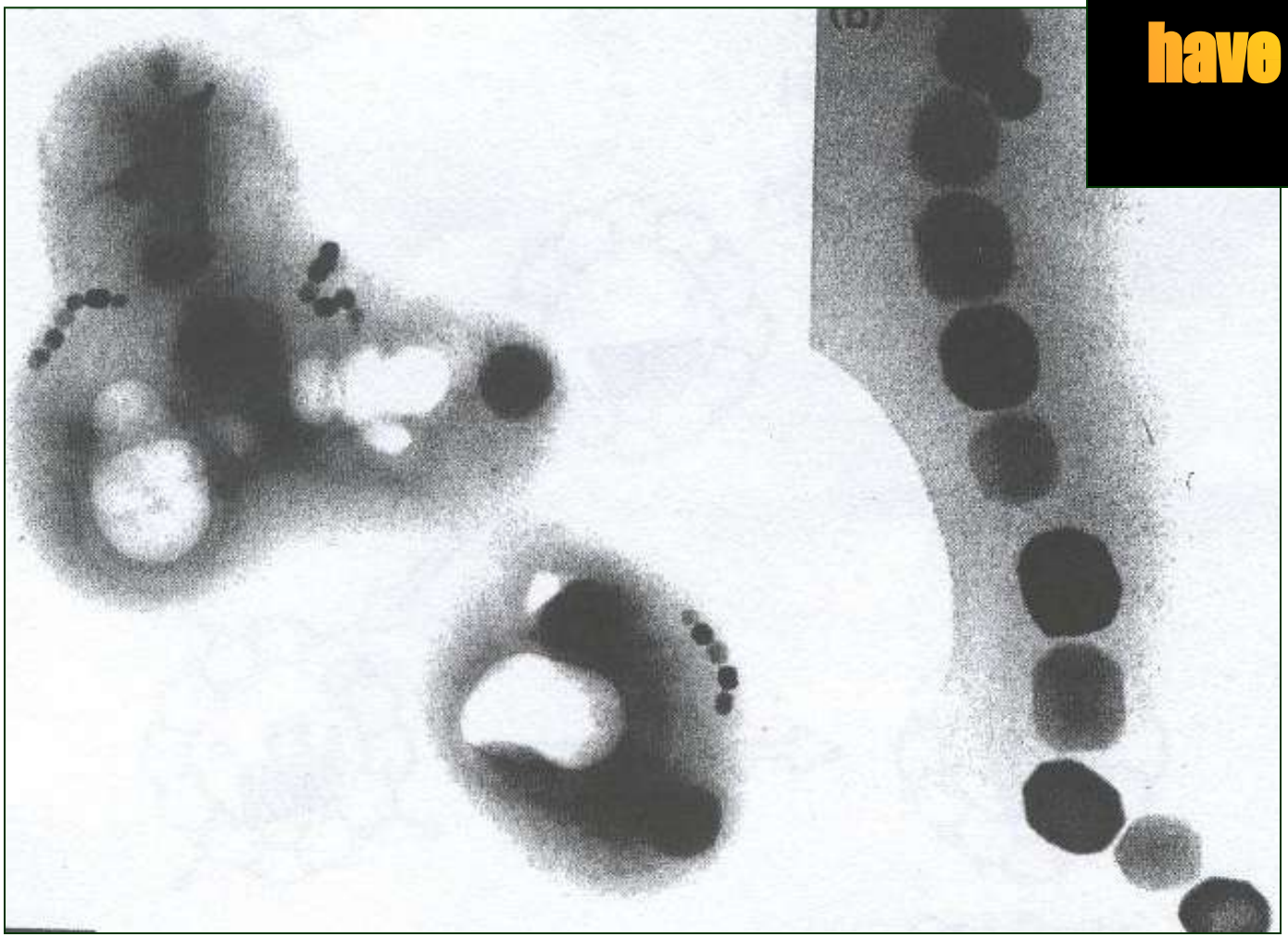
After saturation, No new nuclei can be formed.

After nucleation growth of nanoparticles begins.



# Biological Synthesis

# Biological route

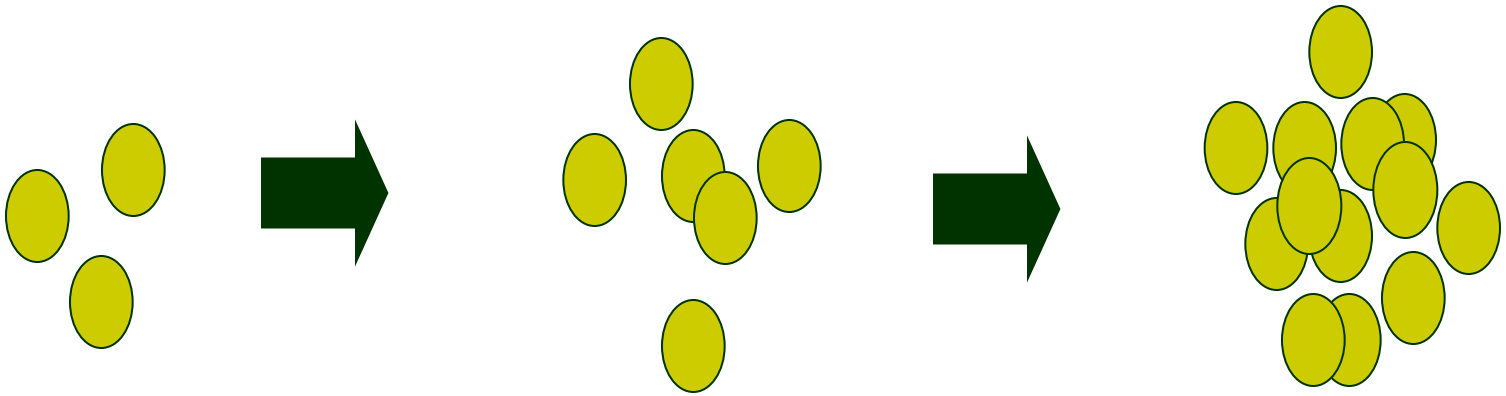


**Some Birds, Swimming Creatures, Bacteria have Nanomagnets**

# Types of Growth of nanoparticles

# Aggregation
## (number of separate things brought together)

**Aggregation also reduces free energy & may also take place during growth.**



**The Ostwald ripening & Aggregation are competing processes.**

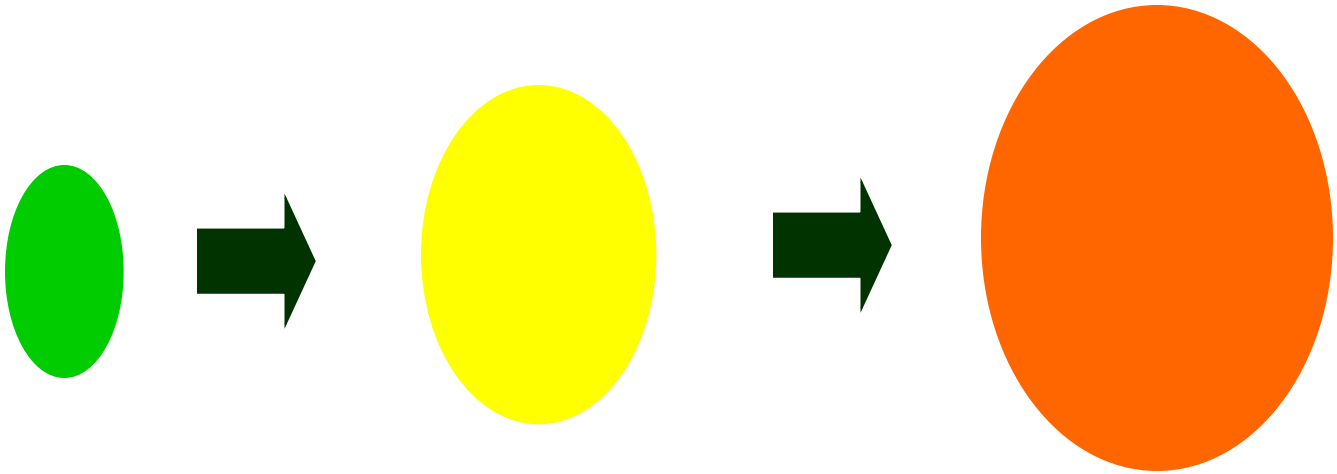
# Ostwald ripening

## To make or become ripe

# Ostwald ripening

**To make or become ripe :**

**Since the larger particles have lower surface energy, hence they are more stable & grow at the expanse of smaller particles.This growth is known as Ostwald ripening .**



# Self Assembly process

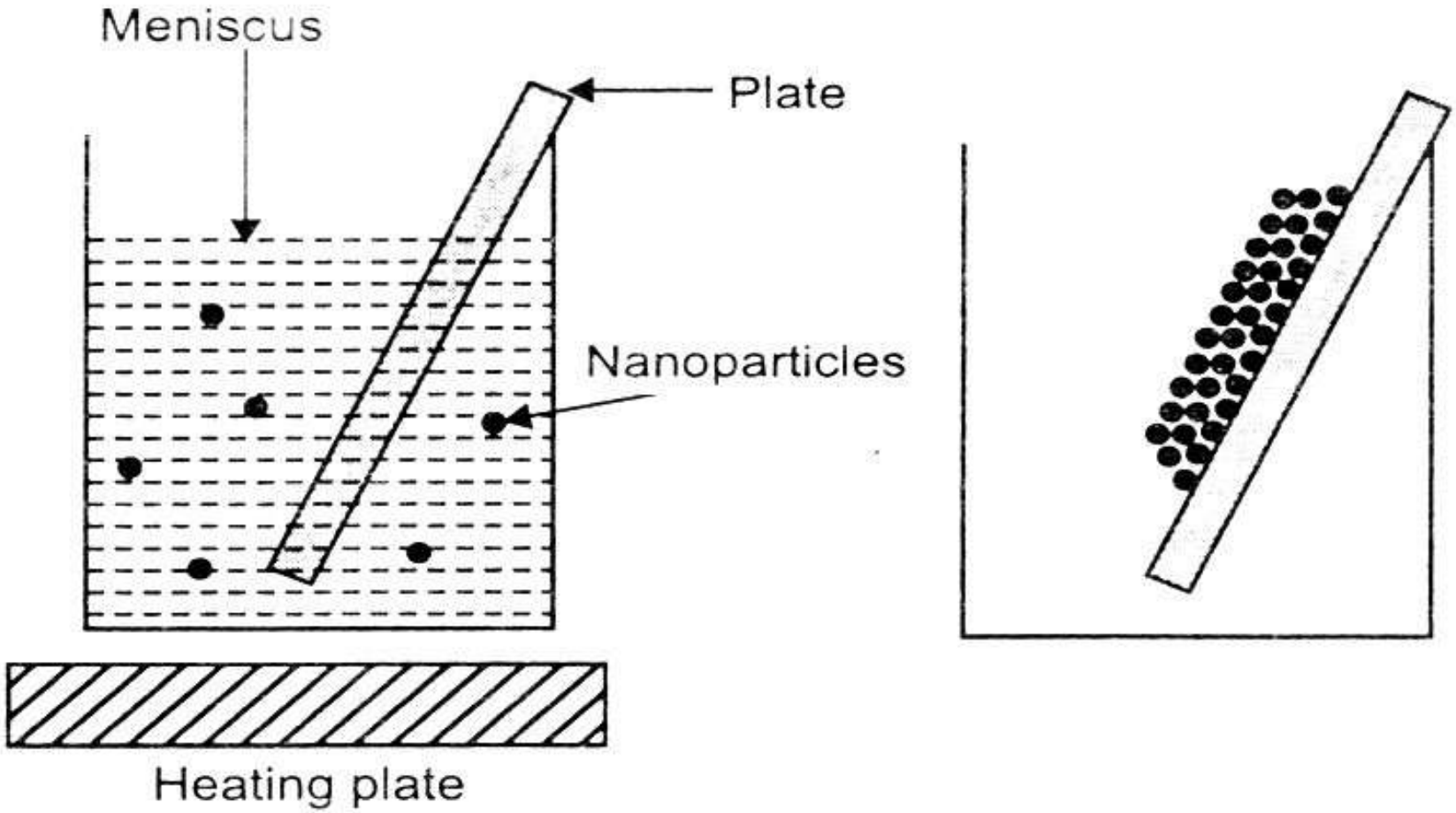
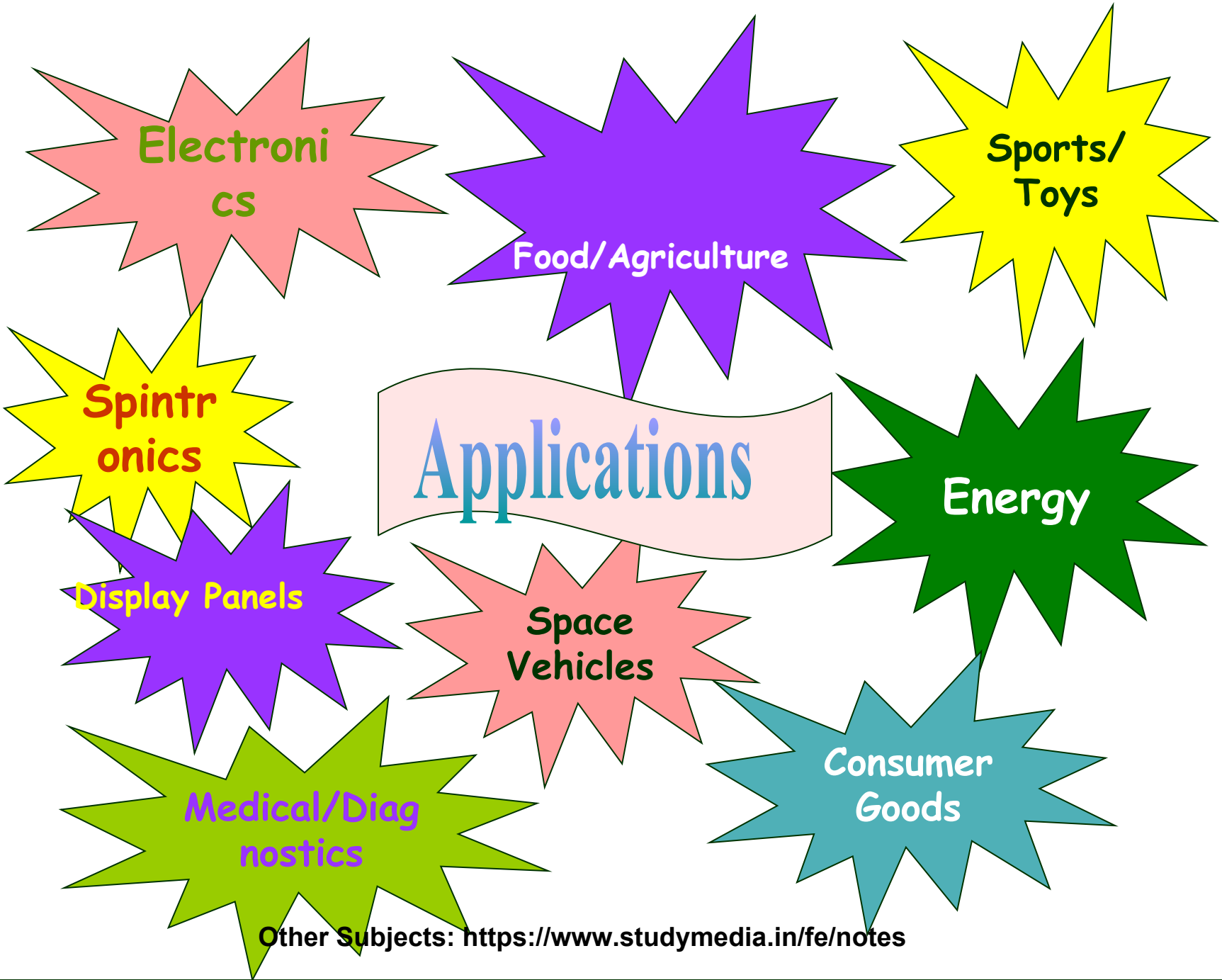
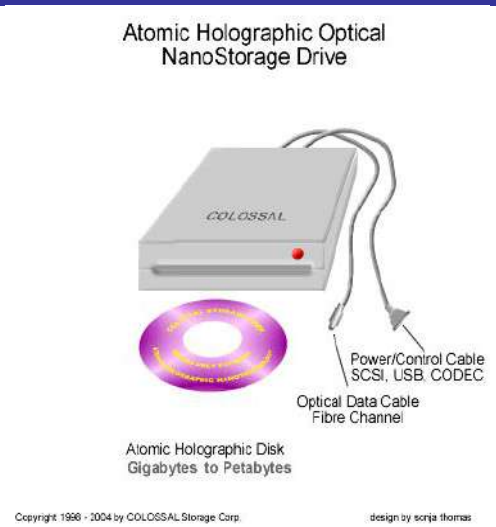


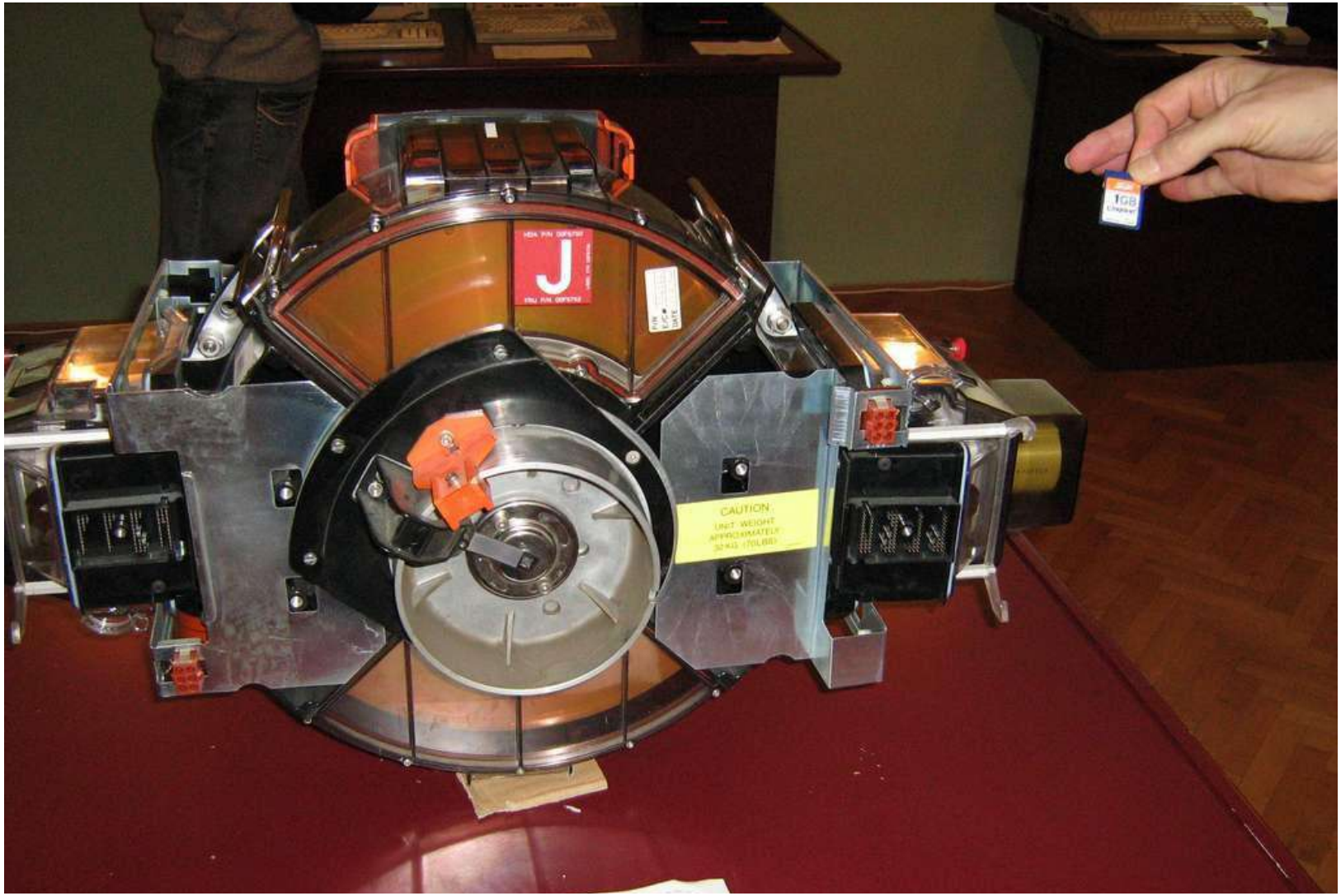

**Fig. : Self-assembly process**

# Applications



# 1)Nanotechnology in Electronics






# 1 GB…20 yrs before an……..now

# Communication, Fast Computers with Large Data Storage Capacity

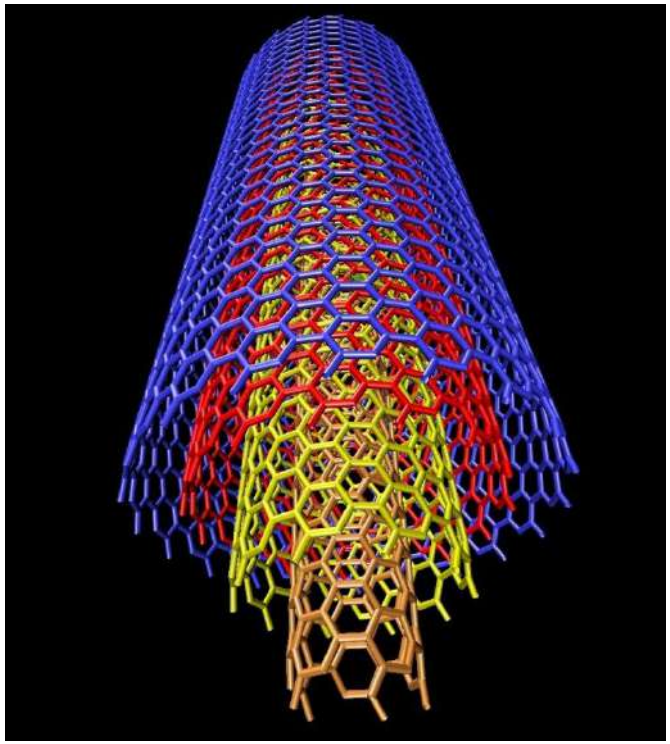

# *Flat Panel Displays*


**Bridgestone engineers developed this Quick Response Liquid Powder Display, a flexible digital screen, using nanotechnology.**

# Intelligent/ Smart Materials

**Other potential applications include intelligent materials that can sense external stimuli and adapt to changes in the environment.**

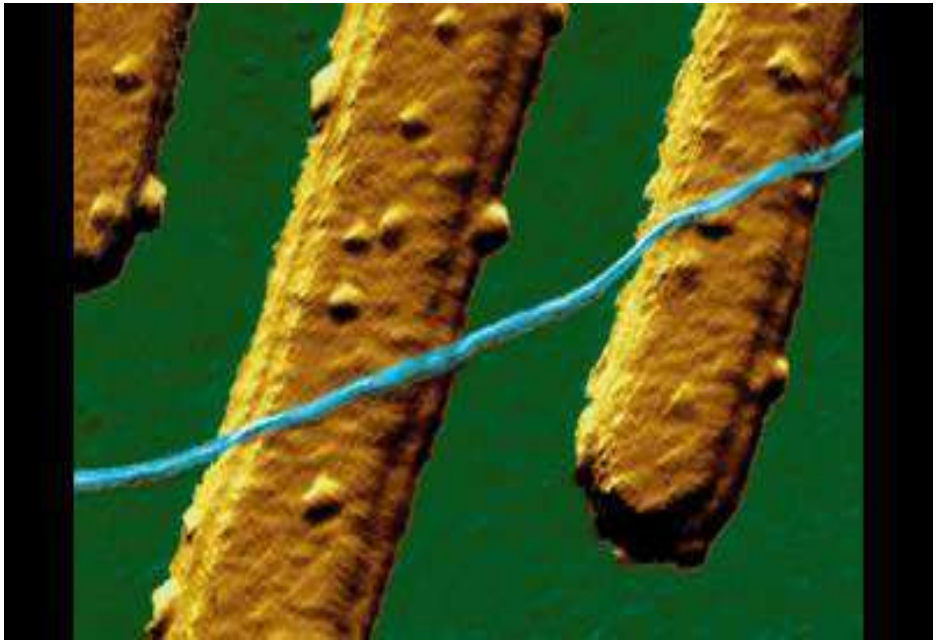
**Smart materials can potentially sense disturba**
**reactions in the body far beyond current hum**



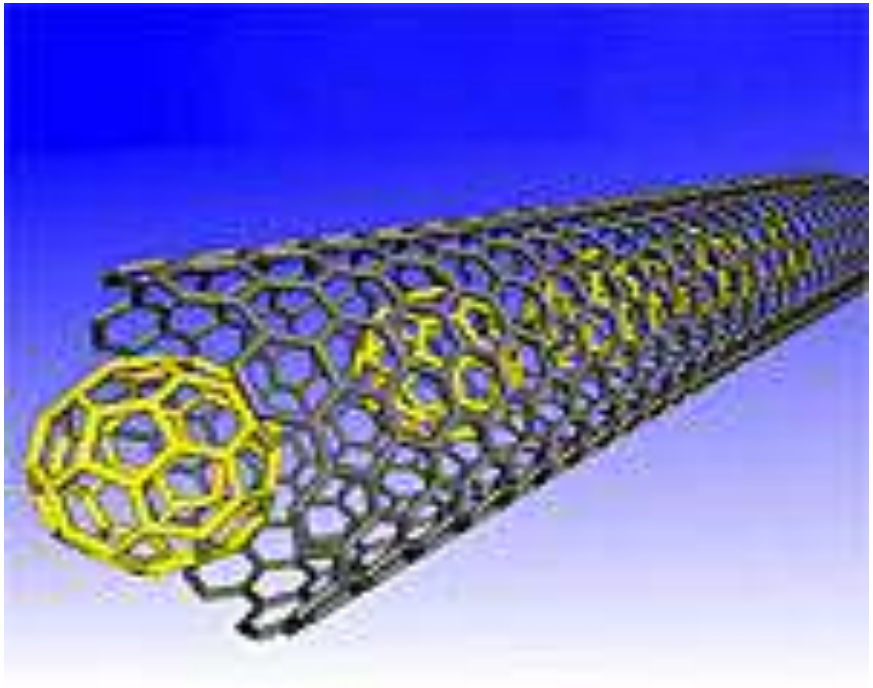
# CARBON NANOTUBE TVs

**In these TVs, nanotubes shoot electrons at a screen to create a picture. Functionally, they are similar to traditional CRT (cathode-ray tube) televisions, which still provide the best picture, but are slim, like LCD (liquid crystal display) or plasma televisions.**

# Electronics Applications



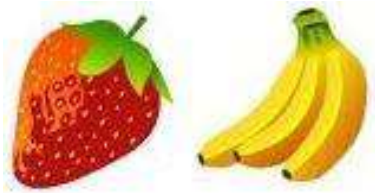
**Nanoelectronics: SWNT transistors**



**Nano peapods: memory devices**

# 2) Nanotechnology in agriculture

# Antimicrobial Packaging:



- Edible food films made with cinnamon or oregano oil, or nano particles of zinc, calcium other materials that kill bacteria.
- Nano-fibers made from lobster shells or organic corn are both antimicrobial and biodegradable.

**Agriculture – better materials for agricultural implements**

**better seeds, control of fertilizers & pesticide**

**Food**

**to get improved yield**

**Food – preservation, testing the quality**

# 3) Nanotechnology in Automobile

# Nanotechnology in Automobile

6) Application

# Nano-particles, wires, tubes ,rods etc …….

Carbon nanotubes based alloys - automobile frames

Nano-scale metal oxide ceramic catalysts - emissions

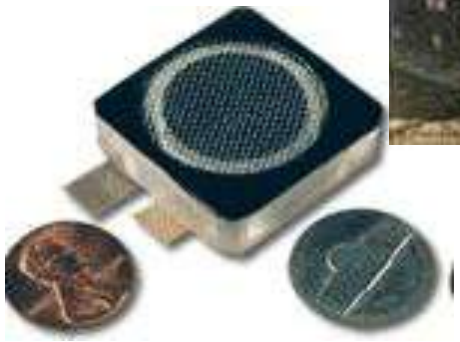
Nano-po wders - paint coatings

nano-polymer composites - electrostatic painting,

Nano-catalysts and membrane technologies - fuel cells

# 2012 global market estimated at $200 billion

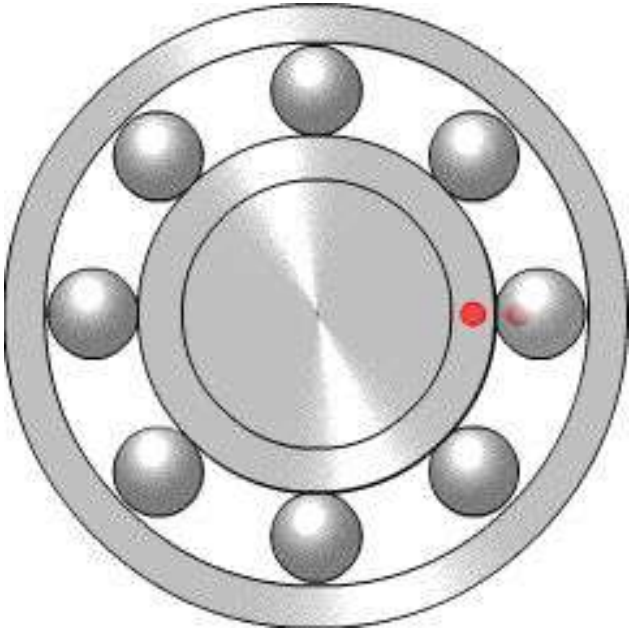
- Automotive
- Power Grid
- Battery Replacement



# Nano Clays


# Bearings

**With 15,342 atoms, this parallel-shaft speed reducer gear is one of the largest nanomechanical devices ever modeled in atomic detail.**



# 4) Nanotechnology in Consumer Goods

# Anti-Fogging Glass

# Nano-Textile

# Cosmetic Industry … particles of ZnO and $TiO_2$

# Cosmetic Industry … particles of ZnO and $TiO_2$



**Sunscreen - Many sunscreens contain nanoparticles of zinc oxide or titanium oxide.**

# Shampoo :

**Nano-emulsians in shampoo encapsulate active ingredients and carry them deeper into hair shafts.**

# Lotus Effect !

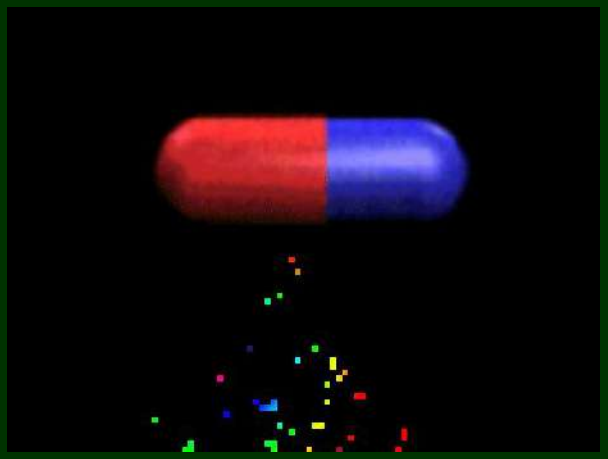
# Nano Shoes

# No need to polish!

# Silver Nanotechnologies in Bed Sheets and Footware!

**Lighter and stronger materials will be of immense use to aircraft manufacturers, leading to increased performance.**

# 5) Nanotechnology in Medical Field



6) Application

# Medical Nanotechnology or Nanomedicine

**Nanomedicine is the application of nanotechnology in medicine, including to cure diseases and repair damaged tissues such as bone, muscle, and nerve**

## Key Goals for Nanomedicine

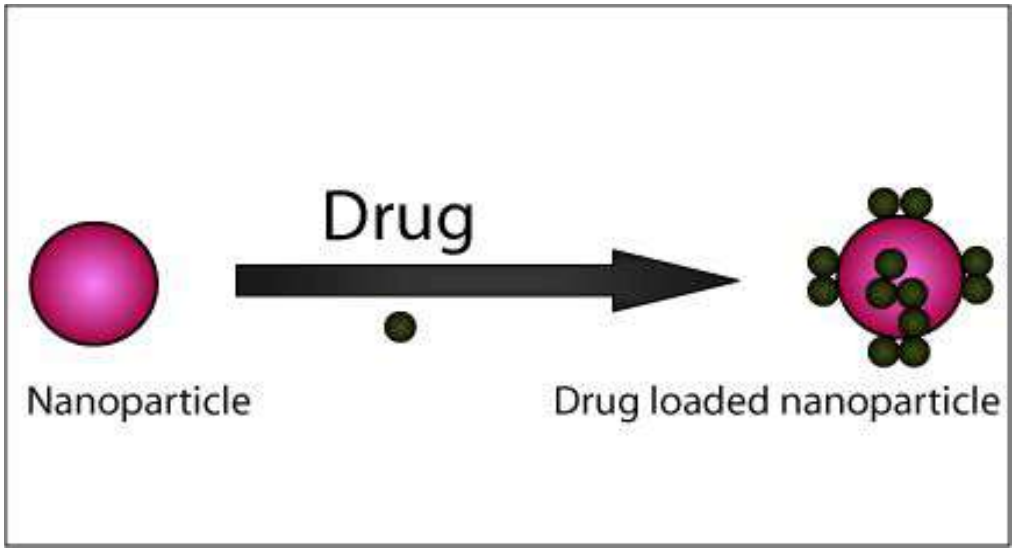
- To develop cure for traditionally incurable diseases (e.g. cancer) through the utilization of nanotechnology
- To provide more effective cure with fewer side effects by means of targeted drug delivery systems

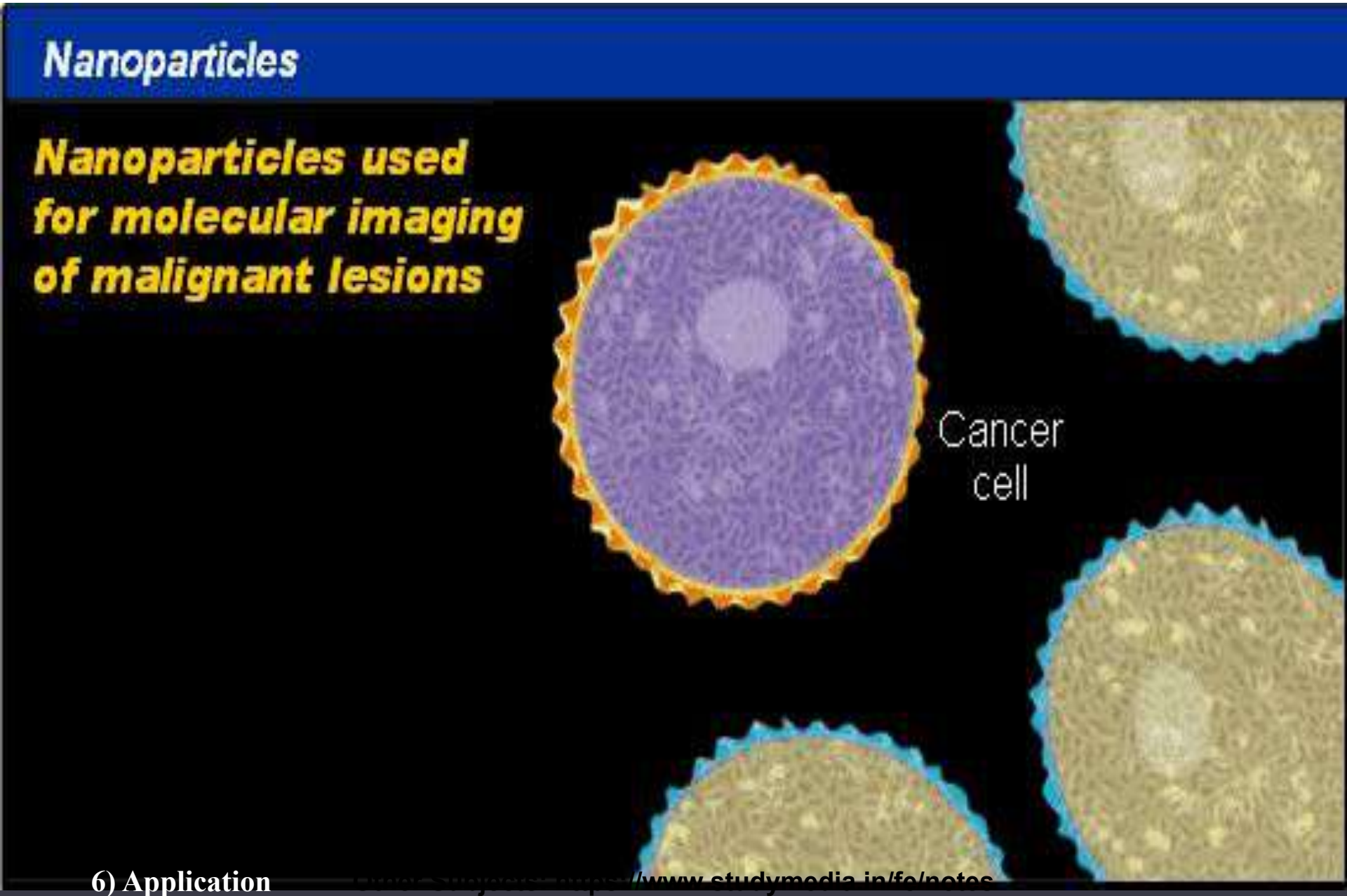
# Antibacterial Clothes:

- Silver nanoparticles in cloth give antibacterial effect.
- They can be used as dressing on wounds.

# Nano Drug Delivery :

- Pills need to go through a long process of digestion in order to be implemented by the body.
- Therefore, scientists believe that structures such as nanotubes could be used someday in delivering drug therapy.
- Their minute size allows quick and easy movement inside the body, as opposed to their slow pill counterparts.

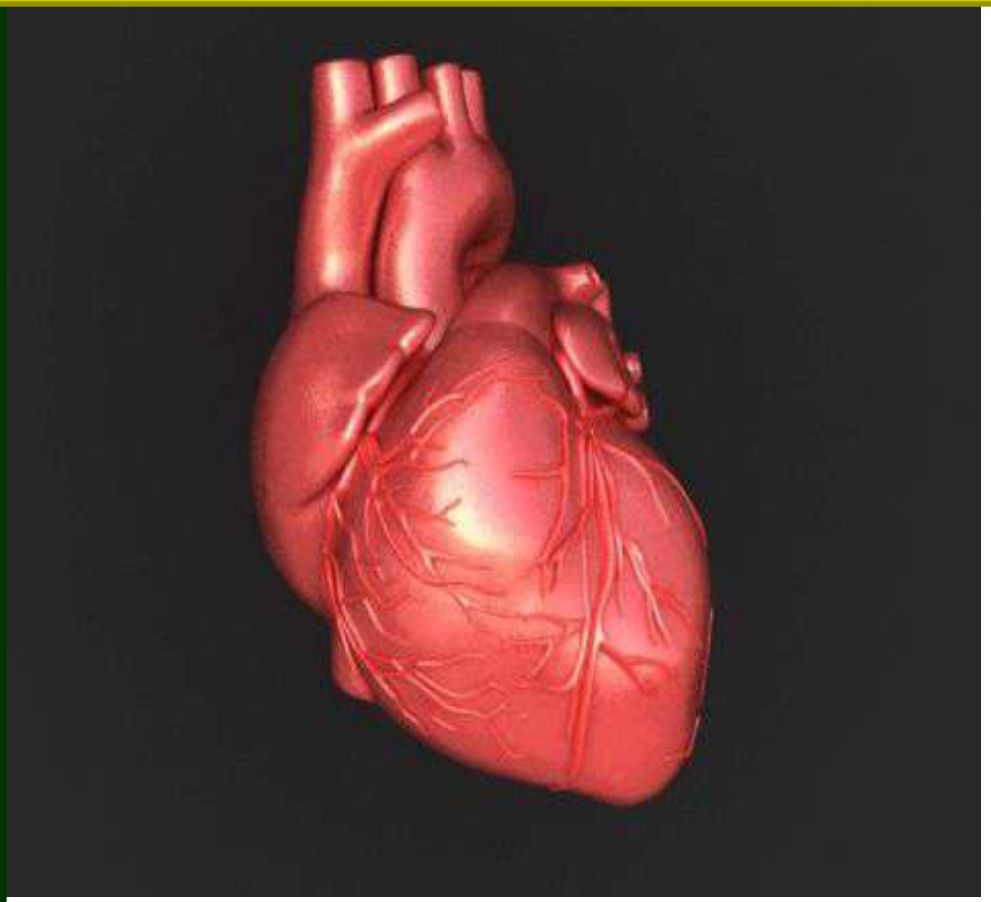





6) Application

# Artificial Heart Valves

**Stents:**
**Nanocrystalline silicon carbide is a candidate material for artificial heart valves primarily because of its low weight, high strength and inertness.**

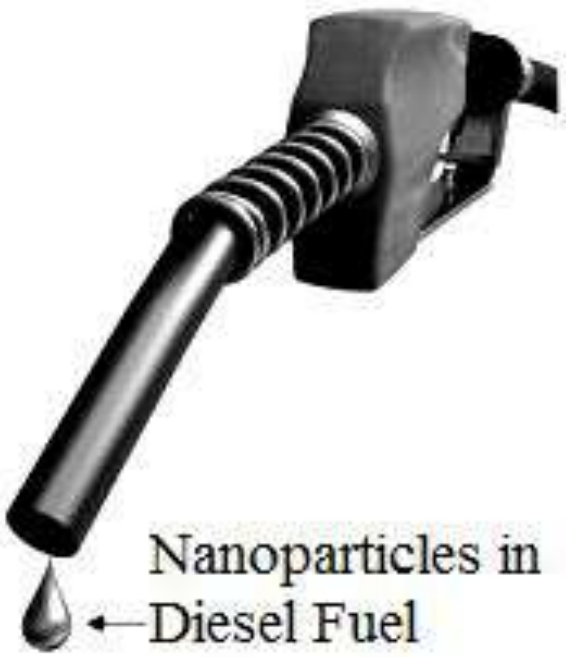


# Energy

**Recycling of batteries:**

The use of batteries with higher energy content or the use of rechargeable batteries using nanomaterials could be helpful for the battery disposal problem.


- **Improved fuel economy:** Addition of nanoparticles to diesel fuel improves fuel economy by reducing the degradation of fuel.



# Thank You !

**Think**
**Nano,**
**Do bulk !!!**