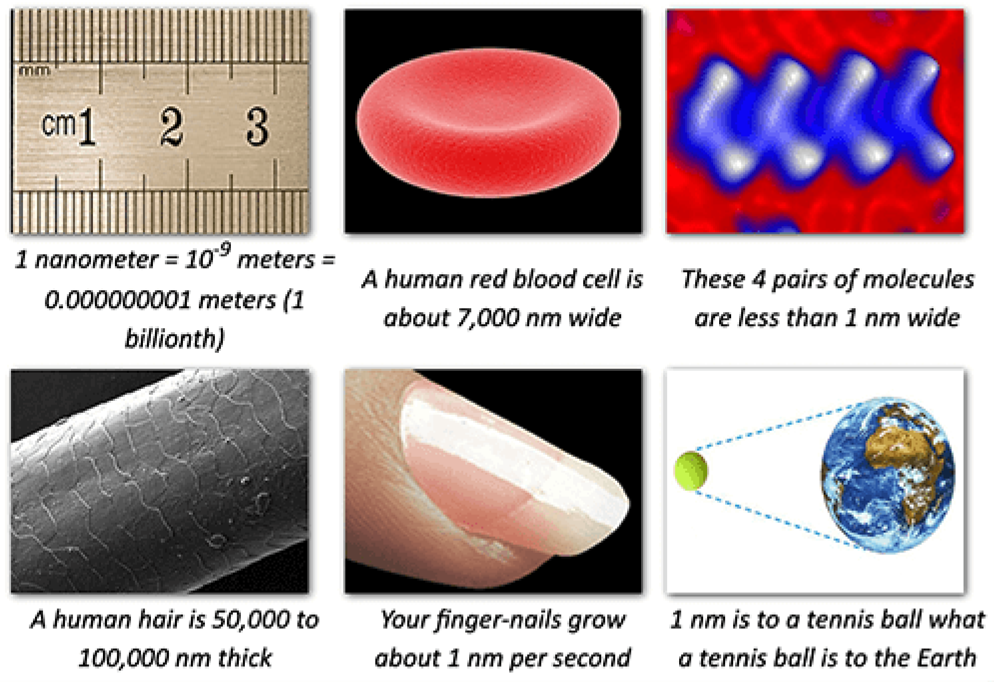
Nano

Physics

Contents

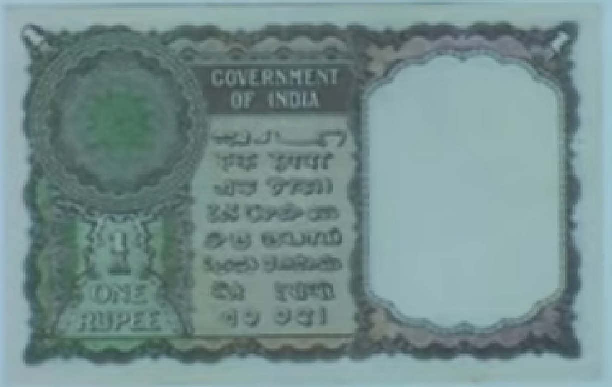
- What is a nanoparticle?
- Nanomaterials dimension
- Why small is good?
- Surface area-to-volume ratio
- Top-down and Bottom-up approach



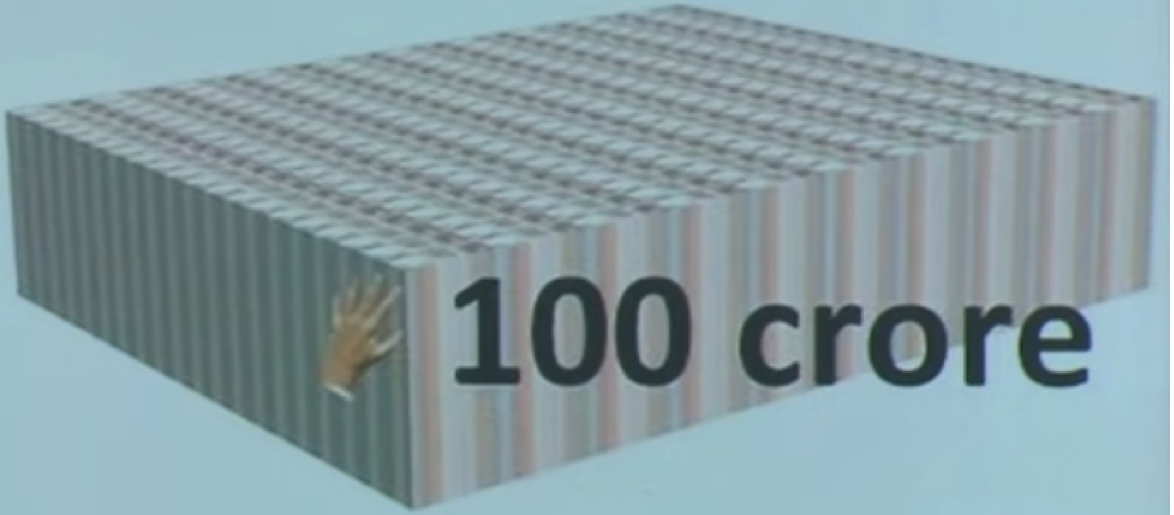
- The Greek word ***nano*** means ***dwarf-extremely small***
- A nanometer (nm) equals 10^{-9} meter
- One human hair is about 80,000 nm thick
- An atom is about 0.1 nm wide
- A DNA molecule is about 2.5 nm wide
- A red blood cell is about 5,000 nm in diameter
- A nanoelement can be compared to a basketball, like a basketball to the size of the earth.

Nano- Simple example

- One rupee in 100 crore rupees



One rupee



The concept of atomic precision was first suggested by Physics Nobel Laureate **Richard P. Feynman** (1959) in his speech entitled, “**There’s Plenty of Room at the Bottom**” on the occasion of the annual meeting of the American Physical Society

- *“A biological system can be exceedingly small. Many of the cells are very tiny, but they are very active; they manufacture various substances; they walk around; they wiggle; and they do all kinds of marvelous things – all on a very small scale. Also, they store information. Consider the possibility that we too can make a thing very small which does what we want – that we can manufacture an object that maneuvers at that level.”*

Richard P. Feynman, 1959

In1974, **Nario Taniguchi** used the term “N**anotechnology**” to describe materials with scales less than a micrometer

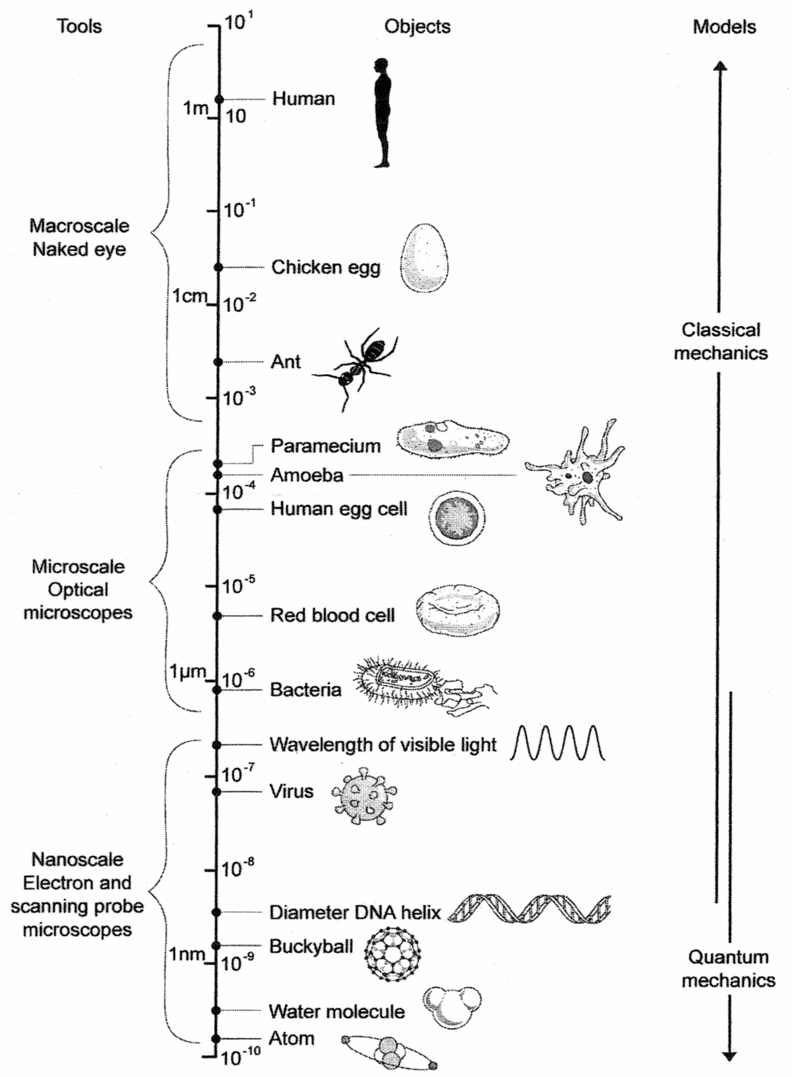
Definition…

- **The art and science of manipulating and rearranging atoms and molecules to create useful materials, devices, and systems**

- **At nanoscale regime, materials exhibit unique properties**

- **The properties of the materials are all size and shape dependent**

- Nano-science which deals with building up complex materials and machines using fine control on the matter at the nano meter scale.
- Study of materials and their properties at the length scale of few nano meters is called nano science.


Tools
Objects
Models
Human
1m
Macroscale
Naked eye
Chicken egg
1cm
Ant
Paramecium
Amoeba
Human egg cell
Microscale
Optical
microscopes
Red blood cell
1µm
Bacteria
Wavelength of visible light
Virus
Nanoscale
Electron and
scanning probe
microscopes
Diameter DNA helix
Buckyball
1nm
Water molecule
Atom
Classical
mechanics
Quantum
mechanics
10^1
10
10^{-1}
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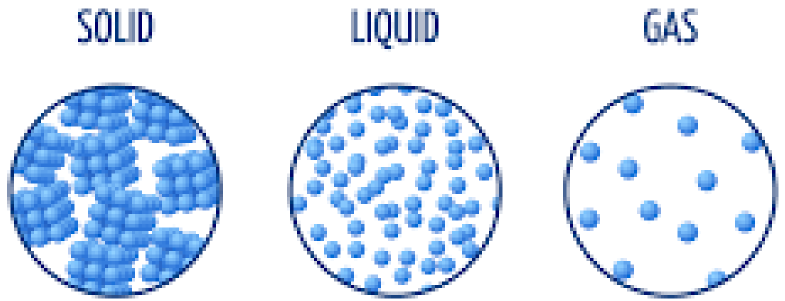
10^{-9}
10^{-10}


SOLID
LIQUID
GAS

Properties change at nanoscale

- At nano scale, optical, thermal, mechanical, electrical, magnetic, dynamic properties of the materials change.
- New properties can be used in variety of applications in different fields like –
  - food processing,
  - medicine,
  - automobiles,
  - paint technology,
  - computer technology,
  - robotics,
  - space technology etc.

Properties change at nanoscale

❑ Electrical Properties

- Electrical conductivity of material is altered when it is reduced to nano size.
- It is possible to invent nano materials having desired conductivity.

e.g. In ceramics, the electrical conductivity increases with decrease in nanoparticle size and

In metals, electrical conductivity decreases with decrease in nanoparticle size.

Properties change at nanoscale

❑Magnetic Properties

- Nanomaterials are more magnetic than bulk material.
- Even non-magnetic solids are found to show magnetic properties when reduced to nano level.
- Magnetic properties of the materials can change when reduced to nano level.

e.g. Sodium, Potassium which are paramagnetic at the bulk level become ferromagnetic at the nano level.

Iron, Cobalt, Nickel which are ferromagnetic at the bulk level become super-paramagnetic at the nano level.

Properties change at nanoscale

❑Structural Properties

- In nanoparticles surface area to volume ratio is very large.
- Atoms on the surface of a material are often more reactive than those in the centre, so a larger surface area means the material is more reactive.
- Forces of attraction between surfaces can appear to be weak on a larger scale, but on a nanoscale they are strong.
- This may lead to different surface morphology, changes in crystal structure etc.

Properties change at nanoscale

❑ Mechanical Properties

- The mechanical properties like hardness, elasticity, adhesion, friction improve as the material size is decreased to nano scale.
- Lubrication improves at the nanoscale.
- Ductility of nanomaterial may be high at high temperatures.

Properties change at nanoscale

❑Optical Properties

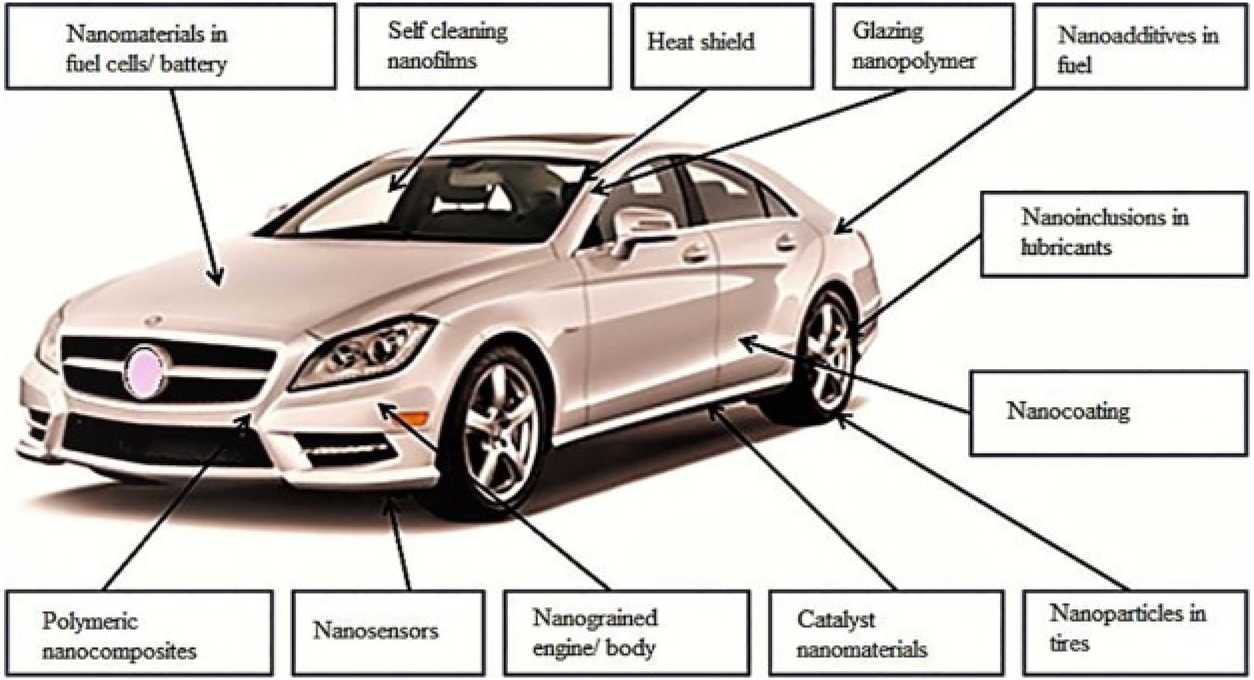
- When light is incident on the material, it can be absorbed or scattered.
- If the size of material is less than 20 nm, absorption is significant and if the size greater than 100 nm, scattering is significant.
- Thus by designing the nanoparticle of different sizes, optimal amount of absorption or scattering can be achieved.
- This may result different colour for the particles of different sizes of nanoparticles.

e.g. Opaque substances at the bulk level, become transparent at nano level (copper)

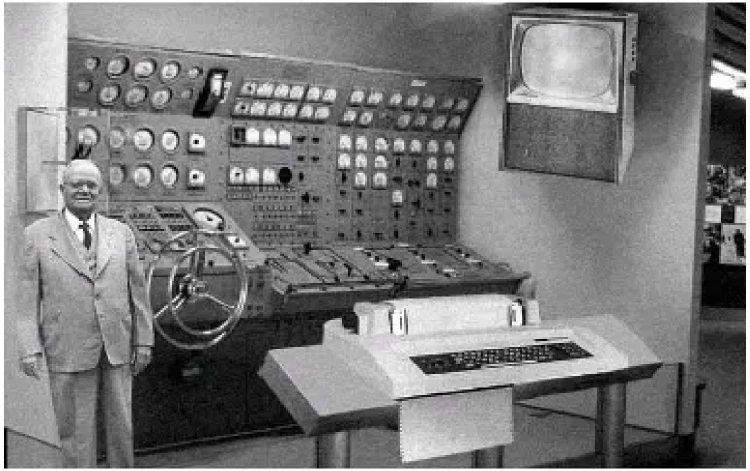
Gold nanospheres of 50 nm are green in colour and of 100 nm size appear orange in colour and at bulk level it is yellow.

NANO TECHNOLOGY IN TEXTILES

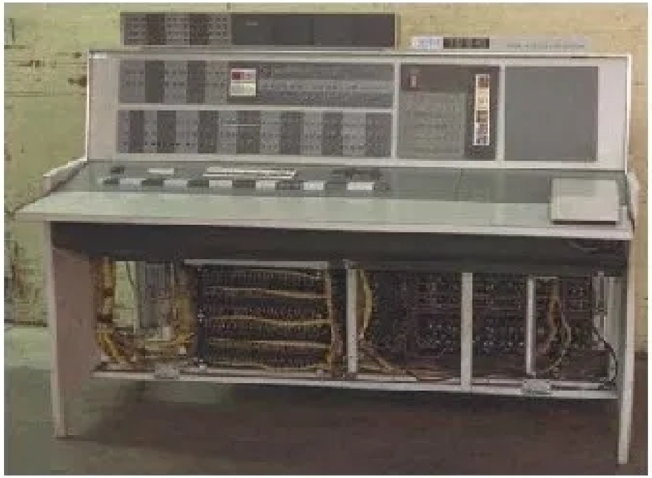
- Textiles:- The use of engineered nanofibers already makes clothes water- and stain-repellent or wrinkle-free. Textiles with a nanotechnological finish can be washed less frequently and at lower temperatures. Nanotechnology has been used to integrate tiny carbon particles membrane and guarantee full- surface protection from electrostatic charges for the wearer.



Nanomaterials in fuel cells/ battery
Self cleaning nanofilms
Heat shield
Glazing nanopolymer
Nanoadditives in fuel
Nanoinclusions in lubricants
Nanocoating
Polymeric nanocomposites
Nanosensors
Nanograined engine/ body
Catalyst nanomaterials
Nanoparticles in tires



First Generation



Second Generation

Third Generation

Fourth Generation

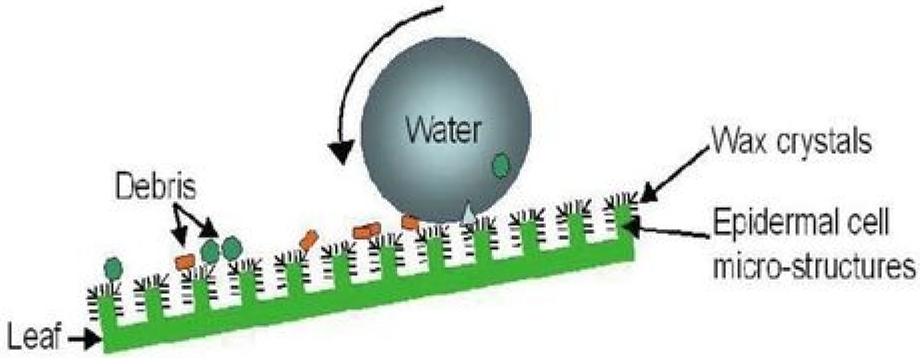
Fifth Generation

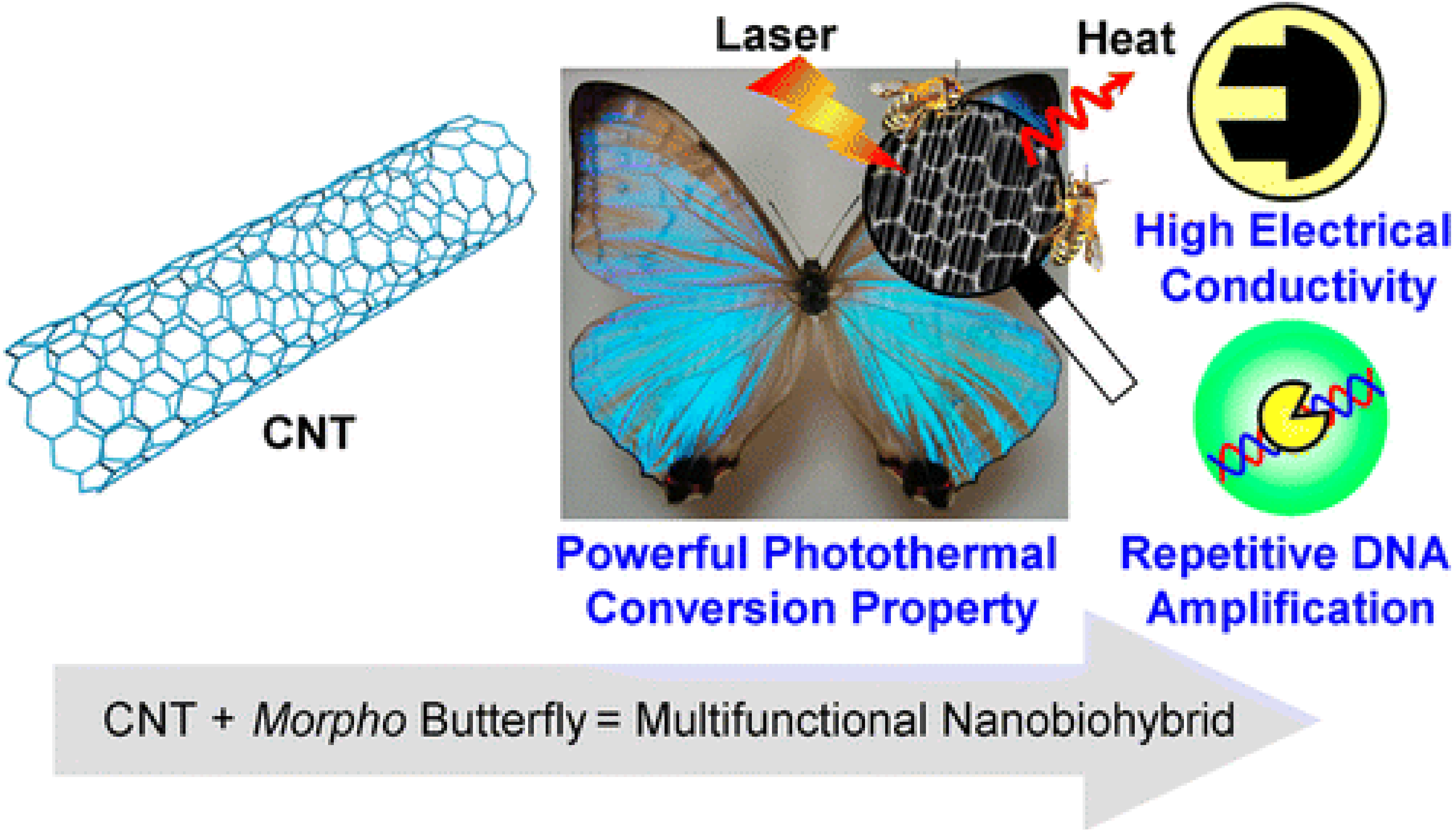
❖The Lotus Effect

The superhydrophobic power of self cleaning:
The leaves of the lotus flower exhibit extremely water-repellent properties due to micro and nano-structures on the leaf surface.

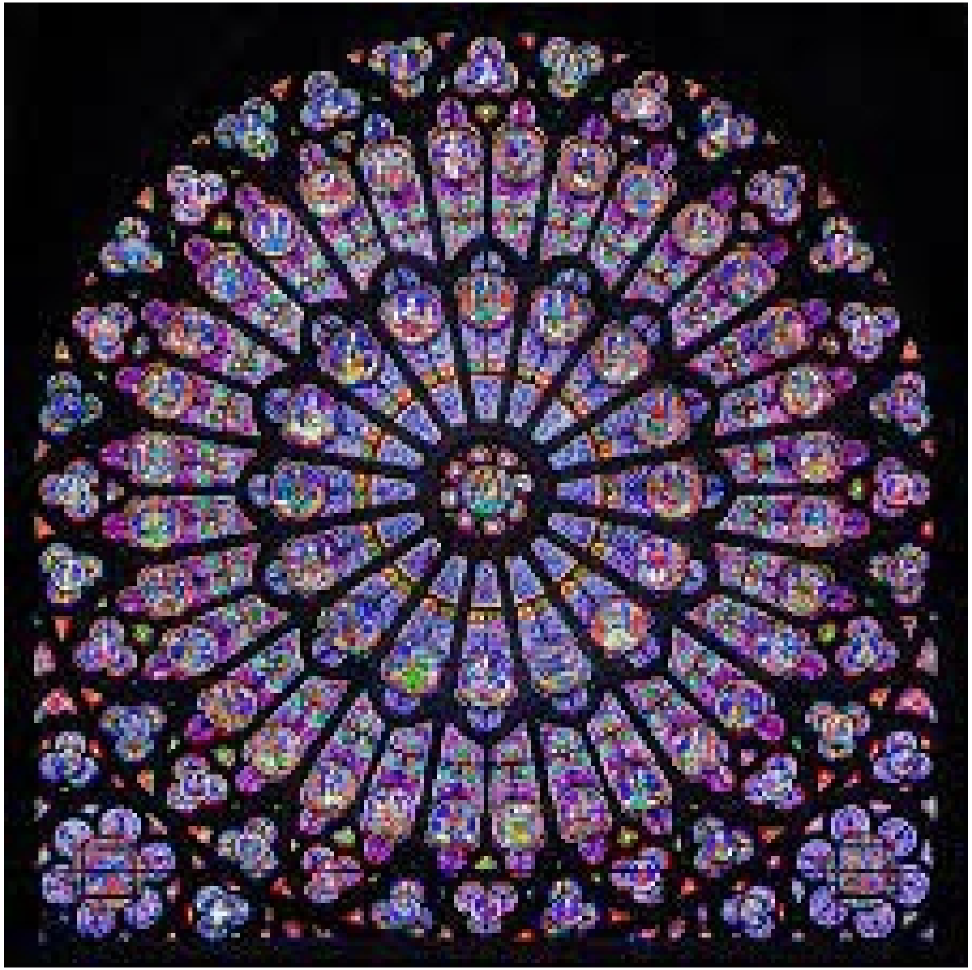
These structures allow the plant to have a magnificent self-cleaning function

This concept has been extrapolated and applied to sealing windshields, waterproofing phones, and protecting fabrics, wood, and other surfaces from dirt, dust, or car exhaust particle residue.

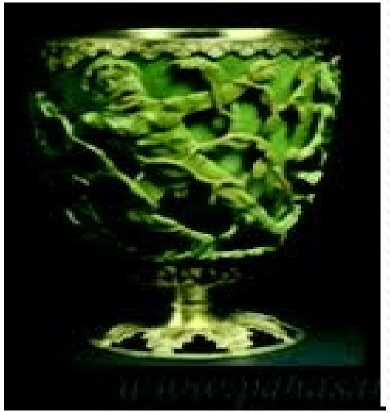




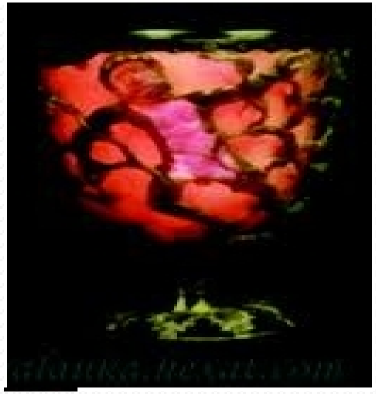
Laser
Heat
High Electrical Conductivity
CNT
Powerful Photothermal Conversion Property
Repetitive DNA Amplification
CNT + *Morpho* Butterfly = Multifunctional Nanobiohybrid



Lycurgus cup (IV Century)



The Lycurgus Cup
London, The British Museum



Lycurgus cup: British Museum, London

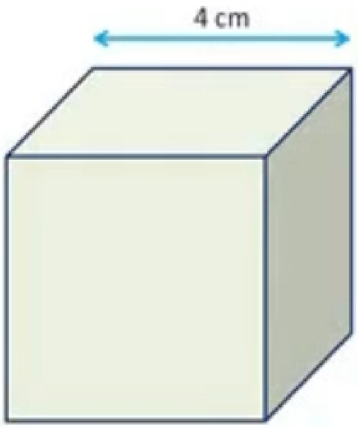
It is made from soda lime glass containing nanoparticles of silver and gold. Its colour changes from green to red when a source of light is placed inside the cup. The Cup shows the myth of King Lycurgus

Colour from nanostructures

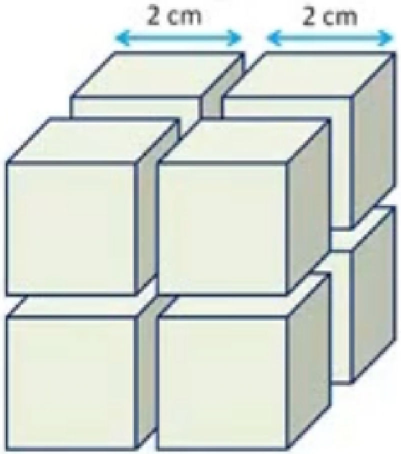
Light scattering from a regular array of nanostructures create interference, which results colours

Surface area to Volume Ratio

- Nanoparticles of a material show different properties compared to larger particles of the same material.
- Forces of attraction between surfaces can appear to be weak on a larger scale, but on a nanoscale they are strong.



Surface area = (4 cm x 4 cm x 6 faces) = 96 cm^2
Volume = (4 cm x 4 cm x 4 cm) = 64 cm^3



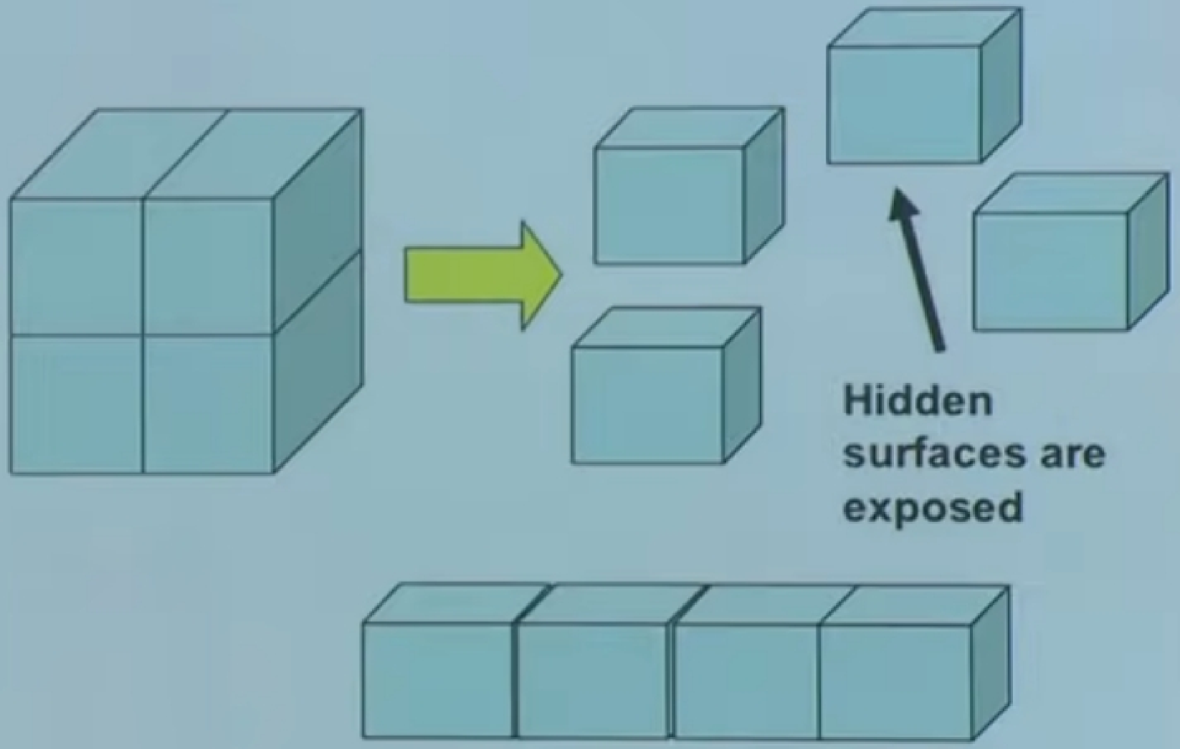
Surface area = (2 cm x 2 cm x 6 faces x 8 cubes) = 192 cm^2
Volume = (4 cm x 4 cm x 4 cm) = 64 cm^3

One reason for this is the **surface area to volume ratio**.

In nanoparticles this is very large. Atoms on the surface of a material are often more reactive than those in the centre, so a larger surface area means the material is more reactive.

Surface area-to-volume ratio

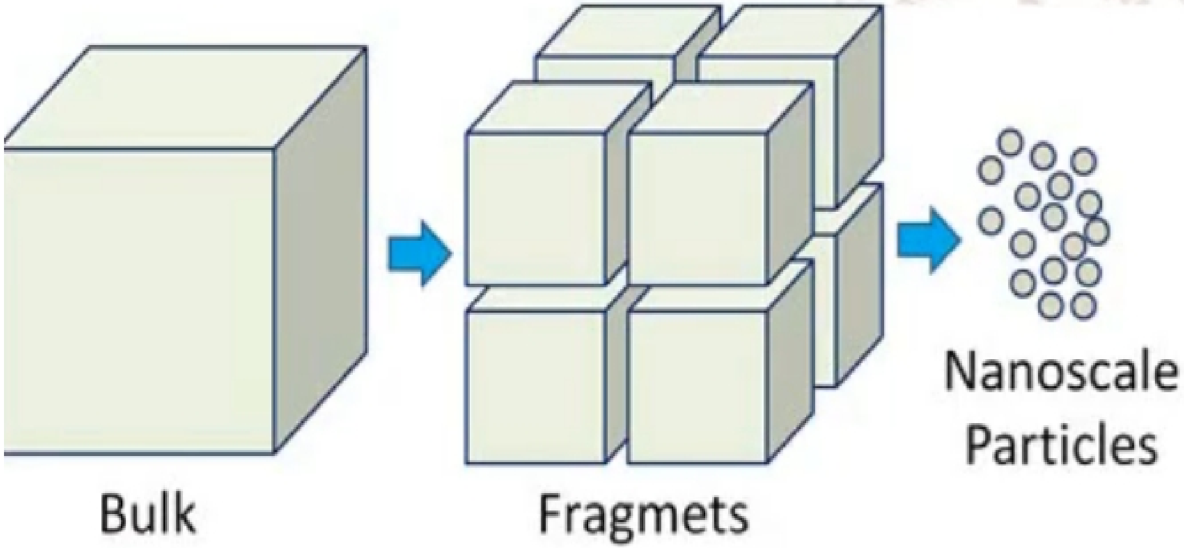
- As surface to volume ratio increases
- A greater amount of a substance comes in contact with surrounding material
- This results in better catalysts, since a greater proportion of the material is exposed for potential reaction



Properties change at nanoscale

	Macroscale	Nanoscale
Copper	Opaque	Transparent
Platinum	Inert	Catalytic
Aluminuim	Stable	Combustible
Gold	Solid at room temperature	Liquid at room temperature
Silicon	Insulator	Conductor

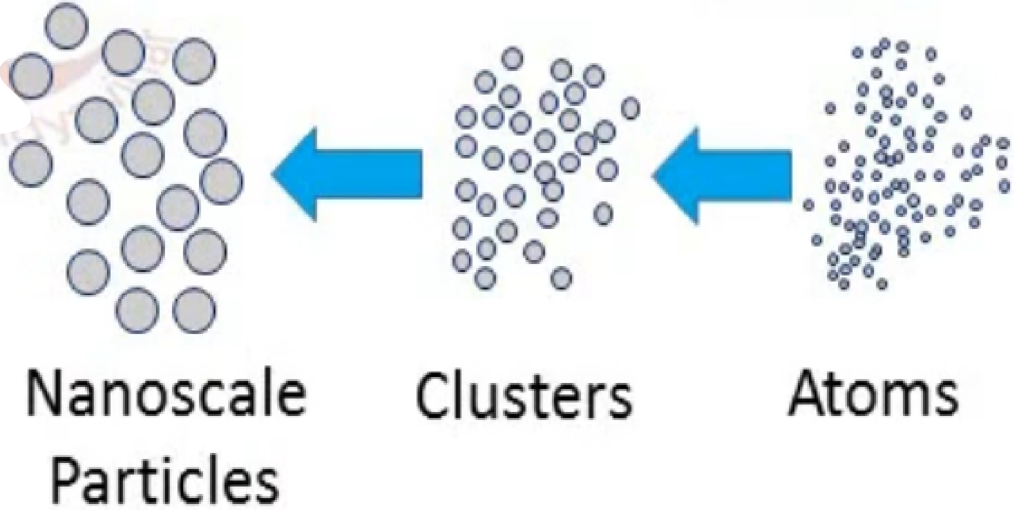
Top Down Approach

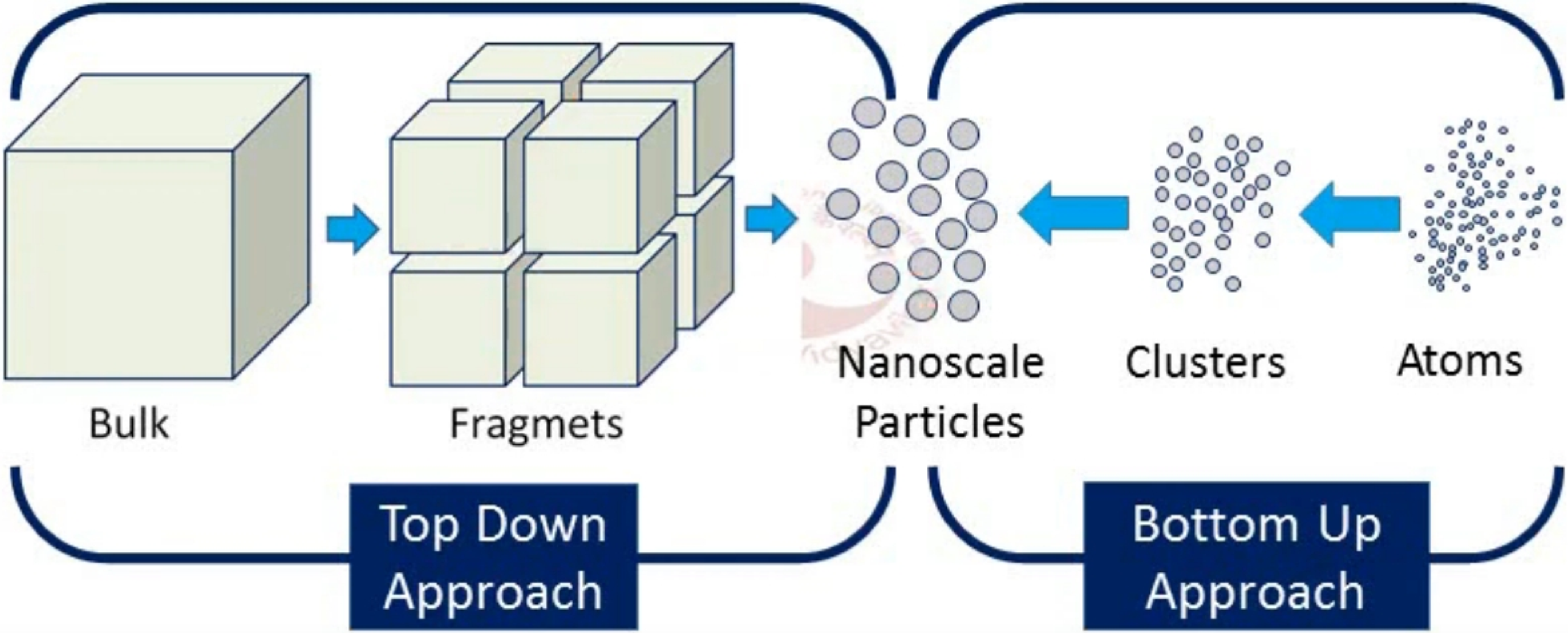


- It is a physical process.
- In top down approach, a large scale object is progressively reduced in dimensions.
- It consists of ultra fine micro machining of materials using lithography, epitaxy and etching.
- This method is time consuming and relatively costly.

- This is a chemical process.
- In bottom up approach, different materials and devices are constructed from molecular components on their own which do not require any external agent to assemble them.
- They chemically assemble themselves by recognising the molecules of their own type.
- This approach starts by collection and combination of atoms and molecules to build complex structures.

Bottom Up Approach




Bulk
Fragmets
Nanoscale
Particles
Clusters
Atoms
Top Down
Approach
Bottom Up
Approach

- The properties of materials can be different at the Nanoscale for two main reasons:

- **First,** Nanomaterials have a relatively **larger surface area** when compared to the same mass of material produced in a larger form.
- Nano particles can make materials more **chemically reactive** and affect their strength or electrical properties.

- **Second,** quantum effects can begin to dominate the behaviour of matter at the nanoscale.
- A bulk material should have constant physical properties regardless of its size but at the nanoscale this is often not the case.
- Size-dependent properties are observed such as quantum confinement in semiconductor particles, and superparamagnetism in magnetic materials, etc..