Nano Materials
&
its Applications

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What is Nano Technology and who gave the concept?

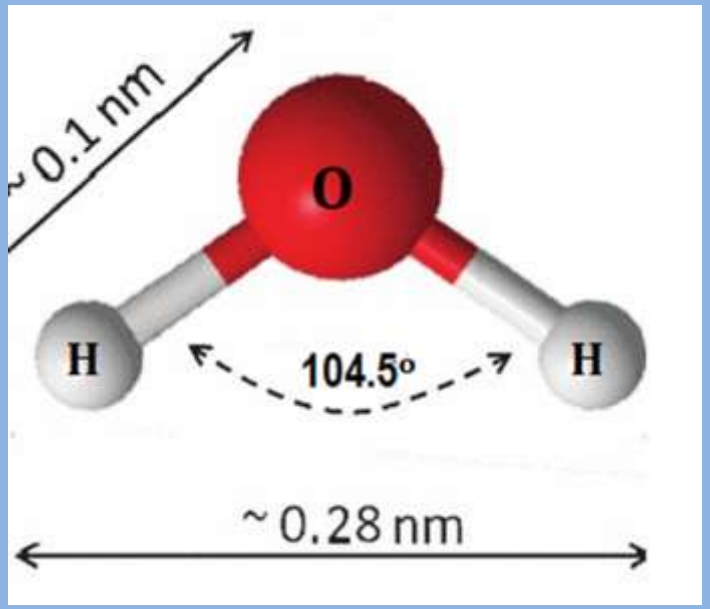
"There's Plenty of Room at the Bottom."

Noble Laureate Richard Philips Feynman,
American Physicist
Annual American Physical Society meeting, 1959

The origin of the term 'nano' comes from Greek word for 'dwarf means very small.

But the term nano means extremely small that is of the order 10^{-9}
1nm=10^{-9} m

Nano Technology is the Science, Engineering and technology conducted at nano size of the material i.e. 10^{-9}.



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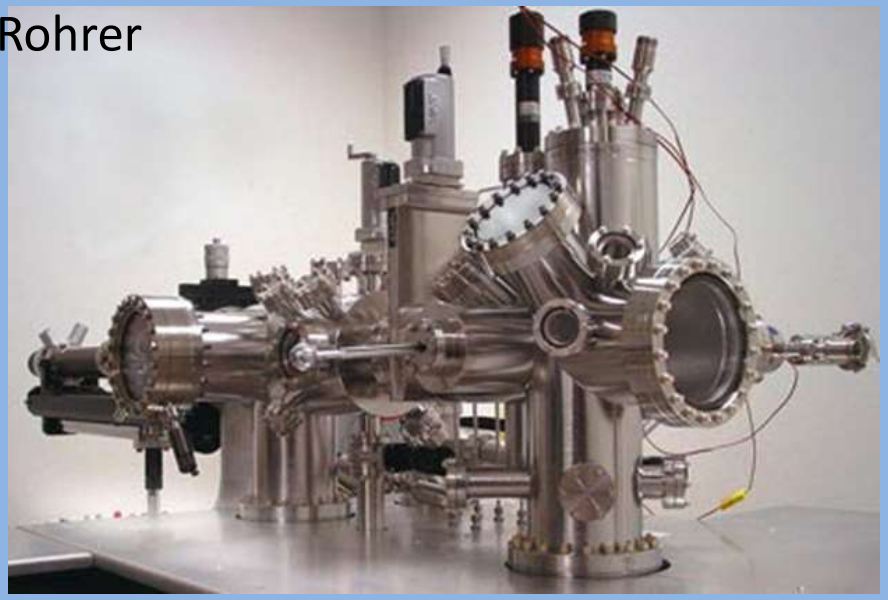


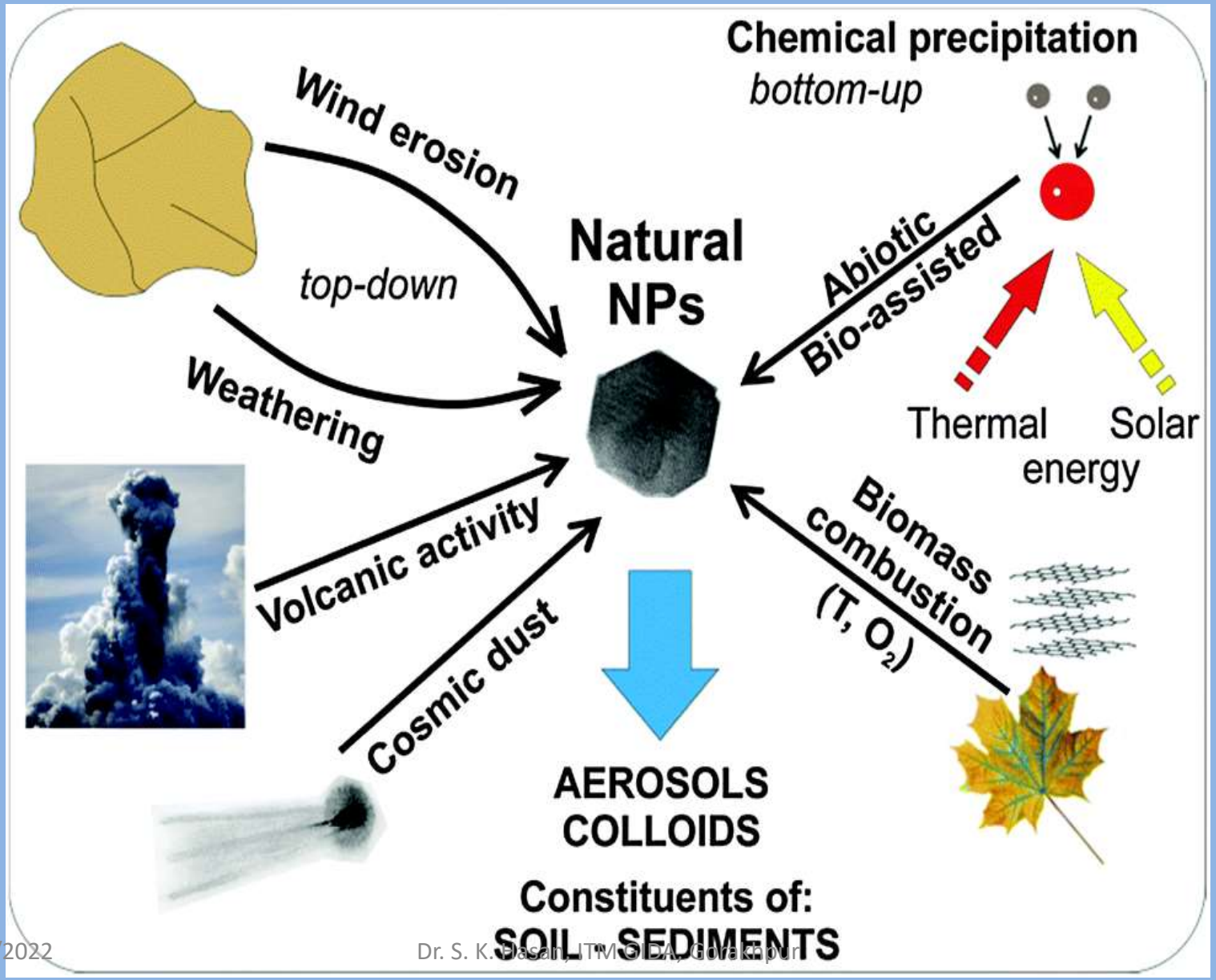
Scanning Tunneling Microscope (STM)

Atomic Force Microscope (AFM)

Effect of smaller size on macroscopic properties

- Larger Surface Area
- Higher Strength,
- Lighter Weight,
- Controlled Light Spectrum and
- Enhanced Chemical Reactivity

Types of Nano Particles



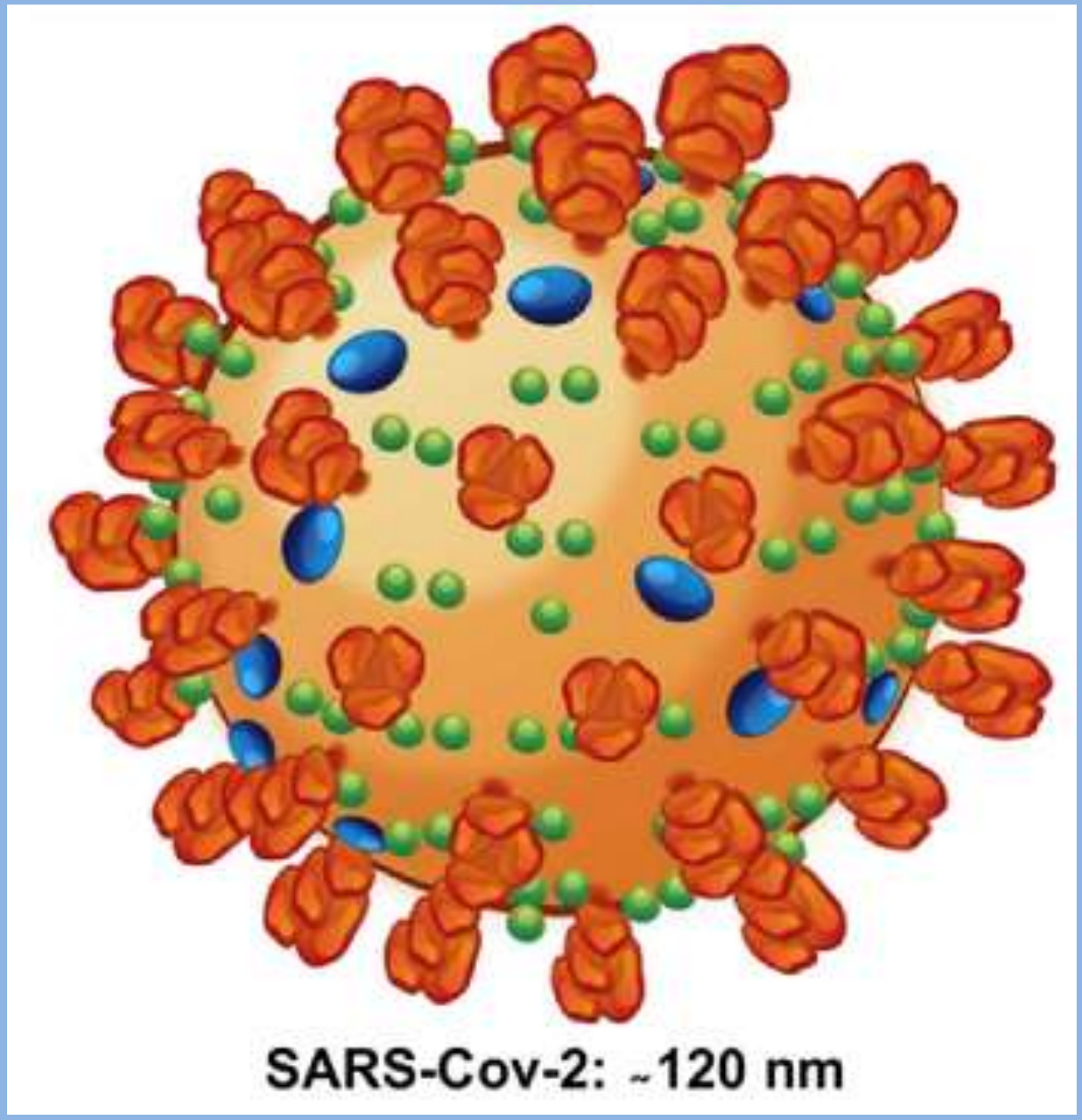
Naturally occurring nano-particles can be found in

volcanic ash

Embers and Smoke.

Ocean Spray

Fine Sand and Dust

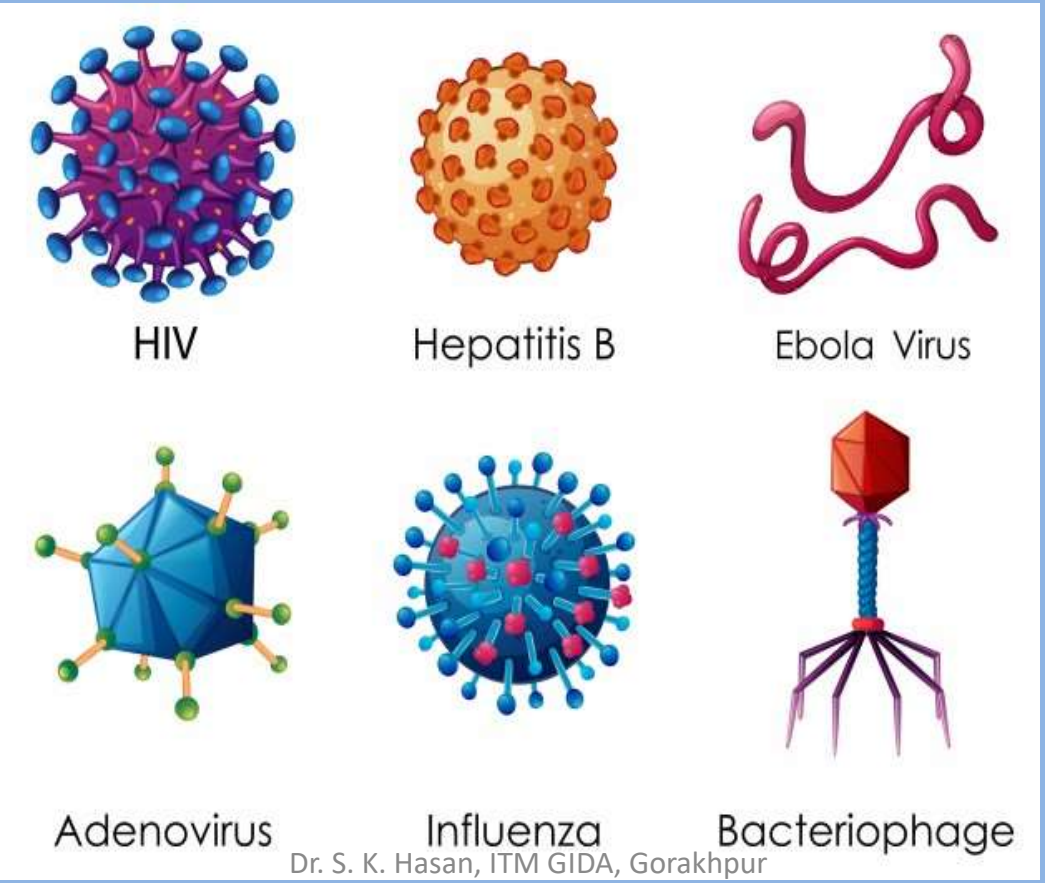


Average size 60 to 140 nm

Biological Matters (*e.g.* viruses).

Virus capsids measure between 20-500 nm in diameter.

A **capsid** is the protein shell of a virus.



- **Starting a Fire.**

Engineered nano particles

Specifically designed and deliberately synthesized by human beings.

They have very precisely controlled

- **Sizes,**
- **Shapes, and**
- **Compositions.**

Effects of Particle Size on Properties

Particle size plays an important role in various properties of materials such as

- **Geometrical Structure,**
- **Chemical Bonds,**
- **Ionization Potential,**
- **Electronic & Optical Properties,**
- **Mechanical Strength,**
- **Melting Point,**
- **Magnetic Properties etc.**

Mechanical properties:

- Nanocrystalline materials have reduced elastic modulus and density.
- Hardness or strength increases with decreasing size.
- Diffusivity of nano-materials also increases up to double of the initial.

Thermal properties:

Melting point is lowered with decreasing particle size.

Optical properties:

The color and transparency of materials change by changing the size of nano-particles.

Nano Materials:

Carbon Nanotubes (CNTs):

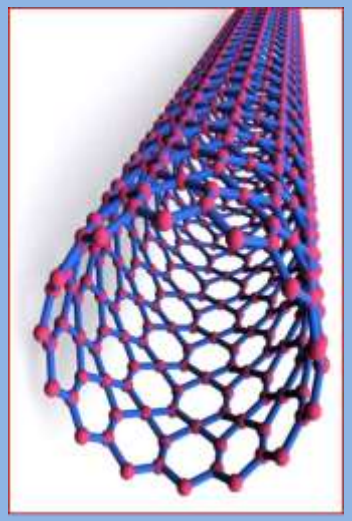
These can be considered as cylinders made of graphene sheets. The thickness of sheet is just the atomic size of carbon atom (diameter 0.22nm).

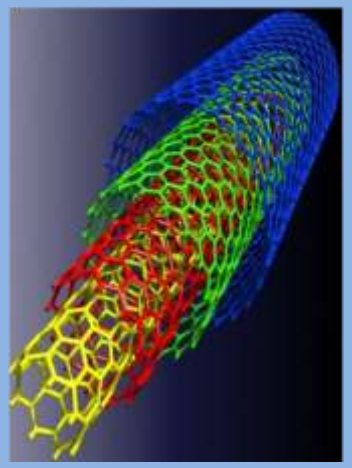
Two types of nanotube:

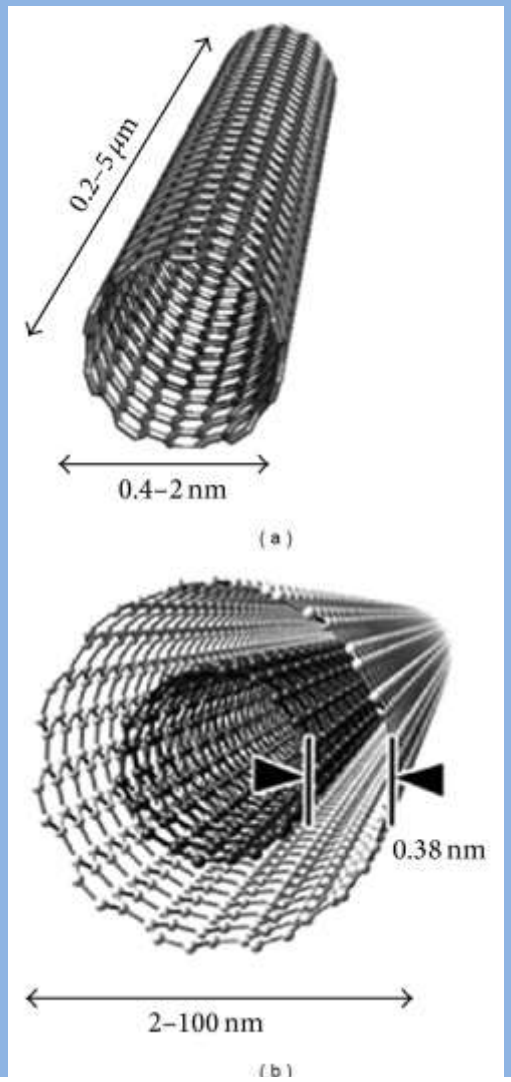
1. **Single-Walled Carbon Nanotube (SWCNT).**
2. **Multi-Walled Carbon Nanotube (MWCNT),**
   the distance between their walls is ~0.334nm.

Applications in

- **Electronics,**
- **Optoelectonics,**
- **Drug Delivery Etc.**





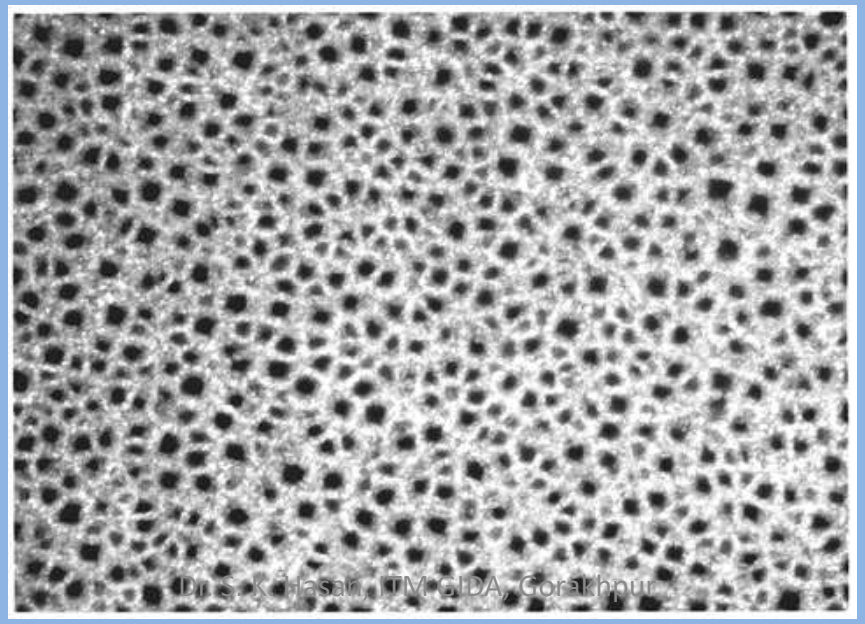

0.2–5 μm
0.4–2 nm
(a)
0.38 nm
2–100 nm
(b)


Graphite
Graphene
Carbon nanotube
Fullerene
Diamond

Porous silicon is a form of the chemical element silicon that has has nanopores in its microstructure, rendering a large surface to volume ratio in the order of 500 m2/cm3.

The properties of porous materials are quite different.

1. Silicon is very widely used in electronics.
2. Porous silicon with nano-size pores becomes direct band material and light emission is obtained from this in visible range.
3. This is useful for optical and electrical devices.



Aerogels

These materials are synthetic having nano sized pores. Aerogel are formed by various materials such as

Silica, Alumina, Gelatin, Cellulose etc.

Highly porous materials.

- Ultra low density materials
- Nano pores with sizes from ~10 to 100 nm.
- Lightest Materials Synthesized.
- Low Speed of Sound Through Them, (~20 M/S)
- Very Low Thermal Conductivity (.003 W/M.K).
- High Surface Area,
- Low Refractive Index,

Applications

- Thermal insulators in jackets,
- Blankets etc.,
- Sound proof rooms,
- Filters for gaseous pollutants etc.

Fig.: Aspen Aerogel's innovative insulation material works well under very cold and very hot temperatures. Here, the insulation is held over a flame.

Applications

1. Due to their enhanced chemical activity, nanomaterials can be used as catalysts.
2. **Pollution Control:** Used as catalytic converters to control toxic gases such as carbon monoxide and nitrogen oxide in automobile and power generation equipment to prevent environmental pollution.
3. **High-power Magnets**: magnets made of nanocrystalline yttrium-samarium-cobalt grains possess very unusual magnetic properties due to their extremely large surface area.

4. **Quantum dots** (**QDs**):
   QDs are tiny semiconductor particles having optical and electronic properties that differ from larger LED particles.
5. **Nanocomposites**
6. In drug delivery system.

Manufacturing Methods

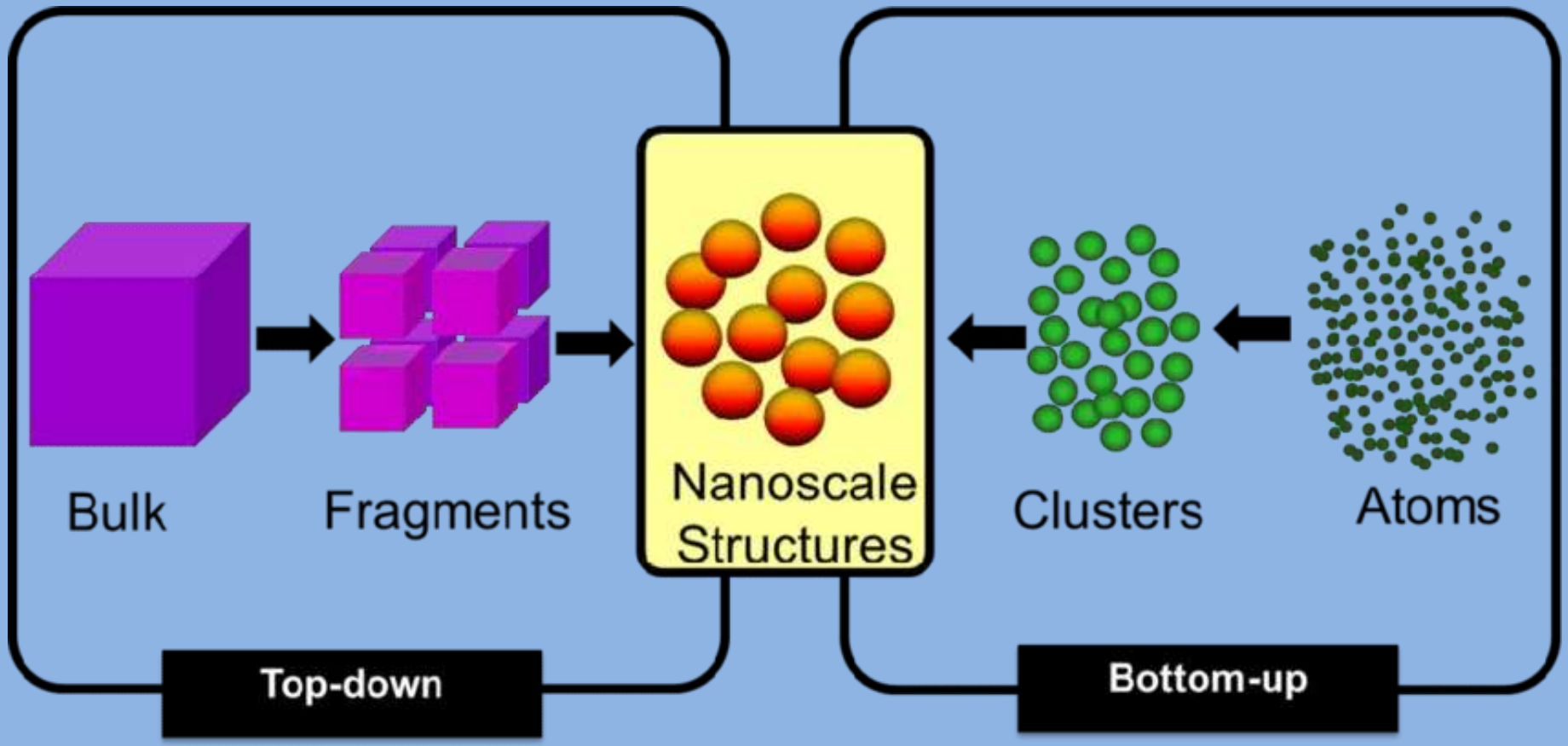
Two basic methods are used to produce nanoparticles:

1. **Top-Down Method**

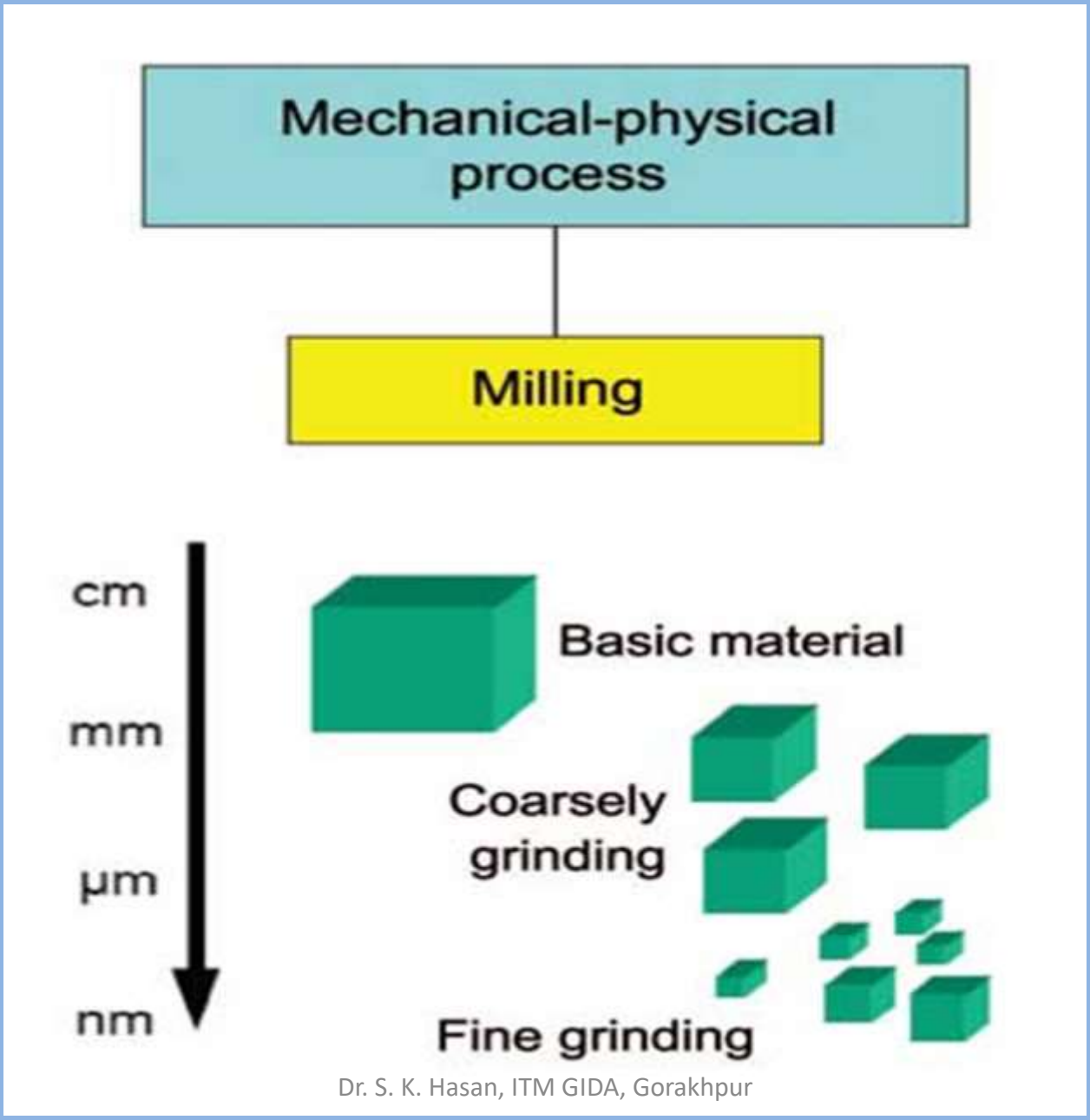
The term 'top-down' means the mechanical crushing of source material using a milling process.

2. **Bottom-Up Method**

Nano structures are built up by chemical processes or by increasing particle size to nano size


Bulk
Fragments
Nanoscale Structures
Clusters
Atoms
Top-down
Bottom-up

Top-Down Method



Methods for large-Scale Synthesis of Nanomaterials

- **Vapour phase techniques**

i. **Atomic or Molecular Condensation** (Gas Condensation) - The Metal to be Vaporized.

ii. **Arc discharge generation -** Metals can also be vaporized by an **electric arc** as a source of energy.

- **Laser Ablation Process-** the high-power laser beam is used
- **Chemical Vapor Deposition**

i. Thermal Chemical Vapor Deposition (CVD):

ii. Plasma Enhanced Chemical Vapour Deposition (PECVD)

- **Liquid phase techniques (Sol-gel)-** Colloidal nanoparticles from liquid phase
- **Solvo-thermal Method-** Temperature higher than boiling point of solvent and high pressure
- **Solvo-thermal Method:** High intensity ultrasound is used.

Applications in

1. Medicines –Cancer, Controlled Drug Delivery, medical equipment
2. Electronics- nanosensors, nanoradio, computer and mobile devices,
3. Environment- energy efficient desalination, nano solar cells, nano fabrics Filters
4. Sporting goods – more precised tennis balls and racquets, fishing rods, bicycle parts etc
5. Consumer Products- Sun Screen Lotions, Batteries, nano fabrics etc.

Thank You

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