Nanotechnology

A New Direction towards Progressive World

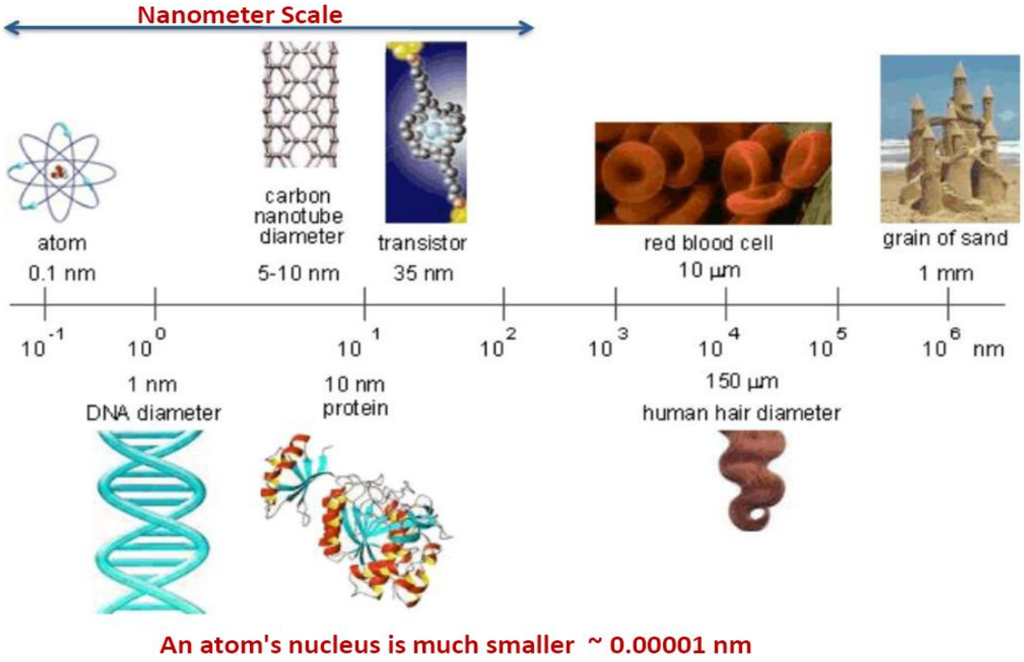
"*There's Plenty of Room at Bottom*", Dr. Richard Feynman has given the vision for new generation scientists/technocrats in his lecture on the occasion of an American Physical Society meeting at the California in Dec 1959. He said " *is the problem of manipulating and controlling things on a small scale……*" The breadths of Feynman provide the industrial revolution in 21st century through evolution of nanotechnology. Afterwards many researchers have contributed significantly in the development of Nanotechnology.

The first experimental breakthrough was done by IBM Company to write letters I, B, and M on a nickel crystal surface using individual Xenon atoms and gave wonderful evidence that individual atoms could be manipulated by human hands.

IBM Letter (Xenon atoms)

What is Nano?

The word "Nano" has derived from Greek and its means "Dwarf" i.e. small. Nano is an abbreviation of nanometer (nm) which is a unit of length. Nano is billionth part of meter i.e. 1 Nanometer = 10^{-9} Meter. If you measure the real objects at nanoscale then you can say that the diameter of human's hair is about sixty thousand to hundred thousand nanometers. If we could put hydrogen atoms together, one nanometer would approximately equal to the length of ten hydrogen atoms that put together in a line. A material is called the nano-material if one of the dimensions of the material is below 100 nm.

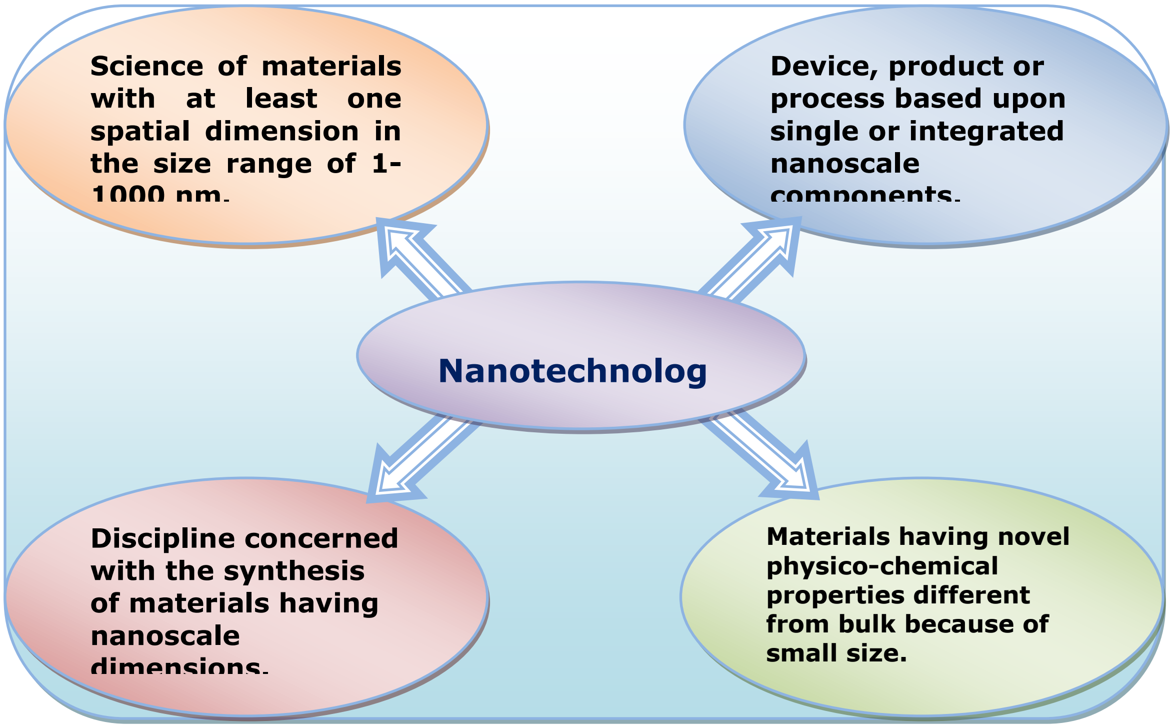


What is Nanotechnology?

According to the definition ***Nanotechnology is the creation of materials, devices and systems through control/manipulation of matters on the nanometer length scale and exploitation of novel phenomena and properties which arise because of the nanometer length scale.*** Nanotechnology is dealing with structures, devices and materials, which has at least one dimension below 100nm.

You may wonder why 100 nm but not 1000 nm or 10 nm? This is because many physical and chemical properties of the material change significantly when its size is below 100 nm.

When materials attain size below 100 nanometer, the physical (brittleness, ductility, magnetic properties, optical properties, mechanical strength etc) and chemical (reactivity of the molecules, molecule orientation, bond strength, force of attraction and repulsion between molecules etc) properties of the materials change significantly whereas at bulk state. For example, melting point of gold is around 1064 ^{o}C at bulk state whereas at nanoscale of 2 nm size gold particles have melting point 300 ^{o}C.



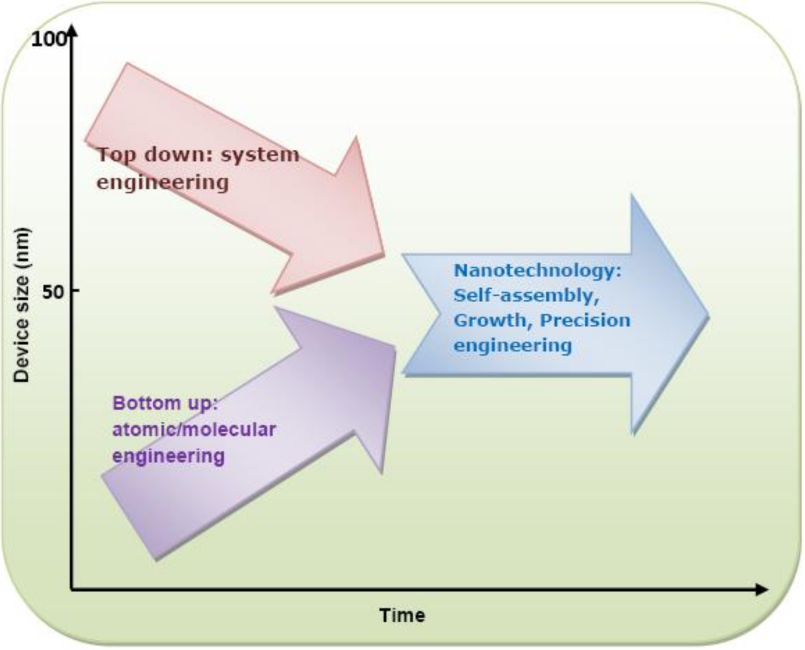
Domain of Nanotechnology

How to reach at Nanoscale: Approaches

There are two approaches to reach at nanoscale "*Bottom-up*" and *"Top-down"*. Nanotechnology is the integration of top-down system engineering and bottom-up atom-by- atom engineering approaches and it provides a complex, multi-functional, intelligent and robust system.

Bottom-up or *self-assembly* approach is the assembly of basic units into large structure because of chemical or physical forces existing at nanoscale to assemble basic units into larger structures. The materials/devices are built from molecular components which assemble themselves chemically by principles of molecular recognition; this is called self-assembly of the molecules.

Top down approach is the assembly of larger entities without the atomic-level control. These seek to create smaller devices by using larger ones to direct their assembly.



Nanotechnology: Integration of both the approaches (Top down engineering systems and Bottom up-atom-by atom engineering).

Applications of Nanotechnology

Nanotechnology is an emerging field of science and has great potential to create smart devices through intelligent materials and phenomena. Nanotechnology holds great promises for improving the performances, quality and durability at cost effective ways. It has opened a door to bring the revolution in Industries with sustainable development. There are various applications of nanotechnology and still scientists/researchers are exploring more applications:

(1) Nano-Engineering: Developing a novel function, high performance, durable devices, systems and products

(2) Nano-Materials: Exploring the New Materials, smart functional materials (utilize the native properties and functions of their own to achieve an intelligent action) with novel properties like Carbon Nanotubes (CNTs), nano- clay, Carbon fibers, Graphene etc

(3) Nano-Biology: Mapping the genetic information in DNA and RNA molecules, blood vessels cells etc

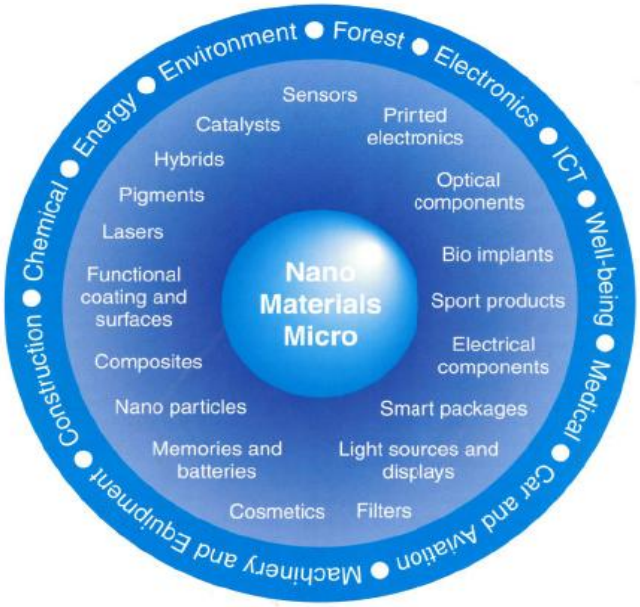
(4) Nano-Medicine: Discover, design, and deliver new drugs and nano-robots for surgery etc.

Industrial Applications of Nanotechnology

- **Energy (Conventional & Renewable Energy)**: Application of nanotechnology in energy sector has shown a great potential to fulfill the deficiency of world energy demand. Nanoparticles, nano-composite, nanorods, coating can be used to enhanced the production and storage of energy. Nanocrystalline Si, CdTe, CuInSe2, polymer/organic semiconducting materials at nanoscale are used in Photovoltaic (PV) solar cell technology and other suitable materials at nanoscale will provide the high performance and stable PV modules. Uses of Carbon Nanotubes (CNTs) for high voltage transmission cables will reduce the heat losses effectively. A number of nanostructured material systems like CNTs, nano-Mg based hydrides, complex hydride/carbon nanocomposites, BN nanotubes, TiS_2/MoS_2 nanotubes and polymer nanocomposites are promising candidates for storage of large quantities of hydrogen. It also has the potential to enhance the energy, life-times and power density, shorten the recharge time, as well as decrease the size and weight while improving safety and stability of the batteries such as Li-Ion, Ni-H_2 etc.

- **Fuel Additives:** Nanoparticulate ceria (cerium oxide), $CaCO_3$ nanoparticles as an additive in lubricant to neutralize the acid during combustion and increase the life and mileage of vehicles.
- **Electronic Industries:** Nanomaterials are used in flat-panel displays, screens with high brightness for TV, Computers, cameras and mobile phones etc. Carbon nanotubes (CNTs) are one of the most promising materials for low voltage filed-emission displays, which provide the strength, sharpness, conductivity and long-lasting emitters.
- **Water Treatment & Purification:** Nanofilters, Nanomembranes to removing water contaminants including bacteria, viruses, arsenic, mercury, pesticides and salt pose. TiO_2 nanomaterials can be used in water treatment to degrade organic pollutants.
- **Cosmetic Industries:** Nanosized titanium dioxide (TiO_2), SiO_2 and zinc oxide (ZnO) are currently used in sunscreens Sun-block lotion or Sun-screen make-ups. Iron oxide (FeO_2) is used in lipsticks as a colour pigments.
- Micro-Electro-Mechanical Systems, MEMS, miniaturized structures, sensors, actuators and microelectronics
- Giant Magnetoresistance In Nanocrystalline Materials
- Molecular Sieves, nano-membrane, nanofilters for water purification
- Tungsten carbide, tantalum carbide and titanium carbide for Tougher and Harder Cutting Tools
- Light-weighted, high strength war weapon, Bullet proof Military suits, high resolution cameras
- Nanofluids, smart fluids, sophisticated sensors for enhancing oil recovery
- Advanced Drug Delivery Systems through nano-robots
- Nanoparticle Reinforced Materials: CNTs, Polymers, fibers. Carbon black to reinforce vehicle tyres
- New Generation of Lasers for medical surgery and Holography
- Nanostructured Catalysts for Process Industries to increase high yield

- Chemical-Mechanical finest Polishing
- Ink Jet Systems, for fine quality printing
- Information Recording Layers
- Chemical, Bio-Detectors and sensor
- Nanolayers for Optical Barriers, Hard Coatings
- Packaging, insulation of materials and products
- Water and Fire resistant materials coating on textile and breathable, stain resistant fabrics
- Antifouling, Sunlight absorbing and Anti- graffiti paints
- Self-cleaning, Water repellent and Anti-bacterial coating on glass
- Biomedical Industry for imaging and sensing
- Micro stamps, Lithography, Regular and Irregular Patterns Formation for embossing fine objects etc.,



Adverse effect of Nanotechnology:

There are some adverse effects of nanotechnology came into limelight on the human life as well as ecology. Emerging studies indicate that properties of nanomaterials are expected to change and become toxic with their receiving favorable environmental media. Recent study shows the influence of physicochemical changes occurring to nanoparticles in freshwaters on their bioavailability and hazards to algae. Regular use of nano-materials might enter into cells though different pathways and become the part of food chain. The production, use and disposal of nanoparticles will lead to discharge to air; soil and water systems and increase hazardous effect on human-life and environment. For example silver nanoparticles could be toxic because of shape and size and surface charges, Silver nanoparticles release silver ions (Ag^+) and these silver ions are known to be highly toxic to algae as well as other aquatic organism.

Concluding Remarks: The significant contribution of nanotechnology in numerous industries already proved that nanotechnology has immense potential and can bring Industrial revolution in 21st century. It can be contributed more efficiently, cost effectively than those technologies that are readily available. Like other technologies, nanotechnology also has some negative effects. True knowledge of concentration and physicochemical properties of produced nanoparticles under realistic conditions is important to predict the fate of application of nanotechnology in various industries.

Dr. Narendra Kumar Agnihotra

Email Id: nkagnihotra@tce.co.in

TCE QSTP-LLC, Doha, Qatar

(A subsidiary of TATA Consulting Engineers Ltd, India)