Nanotechnology

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What is Nanotechnology?

Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.

In general NANOTECHNOLOGY deals with Materials / devices having dimensions 1 – 100 nm.

Fundamental Concept of Nanoscience & Nanotechnology

How small is “nano?” In the International System of Units, the prefix "nano" means one-billionth, or $10^{-9}$; therefore one nanometer is one-billionth of a meter.

It’s difficult to imagine just how small that is, so here are some examples:

- 1 meter = $10^{-9}$ nanometers = 1 billionth of a meter
- 1 centimeter = 10 million nanometers
- 1 millimeter = 1 million nanometers
- A boy/girl of height 4 feet = 1.219 billion nanometers
- An ant of 5 mm length = 5 million nanometers
- Human hair = 100,000 nanometers
- A sheet of paper is about 100,000 nanometers thick
- A strand of human DNA is 2.5 nanometers in diameter
- A single gold atom is about a third of a nanometer in diameter
- On a comparative scale, if the diameter of a marble was one nanometer, then diameter of the Earth would be about one meter
- One nanometer is about as long as your fingernail grows in one second

NASA DEFINITION

Nanotechnology is the creation and utilization of materials, devices and systems through the control of matter on the nanometer-length scale, that is, at the level of atoms, molecules, and supramolecular structures……

The term “Nanotechnology” was invented by Taniguchi in 1974, and it was first popularized in the 1980 by scientist and visionary K. Eric Drexler in his book “Engines of Creation”.

At present scientists are interested in increasing device speed and lowering device size
Modern computer CPU: Transistor count = 2.6 crore transistor (with each transistor size ~ 20 nm)
This is possible only due to development of Nanotechnology
Seeing at Nanoscale

Limits of vision (Naked eye):

According to experts
— A person with healthy naked eye can see objects as small as about 0.1 millimeters = 100,000 nanometers
— Smallest object human being can usually see with the naked eye are things like human hair and lice etc.

We need microscope to see object size lower than 0.1 millimeter
We all know about optical microscope that we have used in schools / laboratories

Limits of optical microscope:

According to science of light
Using optical microscope one can see objects as small as about 0.0002 millimeters = 200 nm
Special arrangements are required to visualize smaller than 200 nm.
Using Atomic Force Microscope, Electron microscope one can see below 200 nm

Presently the words “NANO or NANOTECHNOLOGY” is a Buzz
Example: Tata Nano car

….The next generation technology….where SMALL is very BIG

“To understand the VERY LARGE, we must understand the VERY SMALL”
------- Democritus (400 BC)

How to achieve the nano-dimension?

Two approaches
Top – Down approach: Creation of nanodimensional objects by physically or chemically breaking larger objects.

Bottom – Up approach: Creation of nanodimensional objects by assembling atom by atom or molecule by molecule.

Confinement of dimension

Physical objects are three dimensional – length, breath & width
At least one or more of these dimensions has to be confined in Nano dimension
One dimensional confinement: 2-D structures:
Example: Thin films, Planar quantum wells, Superlattices

Two dimensional confinements: 1-D structures:
Example: Nanowires, Quantum wires, Nanorods, Nanotubes

Three dimensional confinements: 0-D structures:
Example: Nanoparticles, Quantum dots

Nanotechnology at the early age

LYCURGUS CUP: Made from glass impregnated with gold nanoparticle during 4th century A.D.
Use of Stained Glass (13 th, 14th Century)

Nanomaterials in Human body = Protein, DNA, Ribosomes, Antibody, Virus, RBC etc

If Nanotechnology was there during early days and in nature …..then
## Why people are interested in Nanotechnology?
## What is new in Nanotechnology?
Main thing is that –
- Previously we don’t have the technique of preparation and control of nanomaterials.
  Now, we can prepare with desirable size.
- Also we can see, manipulate the shape and use them in proper place.

Why Nanotechnology is so important?
Materials / devices of NANO dimension show interesting properties than that of LARGE dimension.

Properties of material changes at nanodimension
Conducting material become nonconducting
Magnetic material may become non magnetic
Ferro / Ferrimagnetic materials becomes Super-paramagnetic.
Paramagnetic materials can changes to ferromagnetic
Metal can behaves like a semiconductor.
Ductile materials can shows super-plasticity

Why properties changes at Nanoscale?

Delocalization of valence electrons - extent of delocalization vary with the size of the system.
Structure changes with size.
Large Surface Area (Aspect Ratio) (Aspect ratio = surface area/volume = 4πR / 4/3πR = 3/R)
The above changes can lead to different physical and chemical properties, depending on size:

**Optical properties**

**Band gap**

**Melting point**

**Specific heat**

**Surface reactivity**

**Example:**

**Change of optical properties:**

**Gold nanoparticle:**
- ~ 30 nm size = Red colour
- ~ 50 nm size = light green
- ~ 100 nm size = Yellow colour

**Silver nanoparticle:**
- ~ 100 nm size = Red colour
- ~ 80 nm size = light blue
- ~ 40 nm size = blue

**Conductivity:** Band gap increases with decreasing size

**Melting point** decreases with decrease in size
(Surface atoms require less energy to move because they are in contact with fewer atoms of the substance: Meting points get lower).

Now we can redefine Nanotechnology:

In Nanotechnology properties of the materials are governed by their SIZE!

**Applications:**

Let's through a ball and some dust to a wall. What will happen? …………..

This gives idea of using Nanotechnology in paints and cosmetics.

Cosmetics containing nanoparticle may protect from dust, harmful radiation etc
Cosmetics company like Uniliver, Avon, Nivea, The body Shop, Boots, Lo’real etc already using nanotechnology.

**Hydrophobic surface:** Using NANO lotion having particle size less than water molecules one can walk in rain without umbrella!

**Medicine:** 35000 million USD ($)
(I purchased a medicine from Siddhi Asram namely Cholecalciferol – Vitamin D3 drops: Nanotechechnolgy was used!)
Samsung silver care
A washing machine / A. C. that inhibits bacterial growth on the clothes it washes……on the market

Quantum Dot LED
Nano enhanced tennis ball, that bounce longer appeared at 2002 Davis cup.

Asian Paints & Behr Paints Offers Nano-guard
In 2007 Mercedes-Benz SL series cars sport a protective coating of nanoparticles that provides a three-fold improvement in the scratch resistance of the paintwork.

Self-cleaning car
Nissan recently developed a self-cleaning car that repels water, oil, dust, dirt, mud and grit and frees it’s owner from ever having to visit a car-wash again.

Nano skin cream and suntan lotions are already in market.
The zinc creams, including coloured ones are useful because one can make sure that ears, noses and cheeks are protected from direct exposure to the harmful UV rays.

Nano-food?
Preservation of food without refrigeration
Protection of food from bacteria and diseases
Lighter food for space-craft

Self healing Product:
In late 2013, LG unveiled its G Flex smartphone which utilizes advanced nanomaterial to imbue the phone’s casing with the ability to self-heal if scratched / curved.

Battery charger within 30 seconds
Graphene is already being successfully investigated for its potential to reduce the time it takes to charge an electric vehicle from 4 hours to less than 30 seconds.

Water purification system:

Some future applications of Nanotechnology

Targeted drug delivery: Nanoparticles can be used for drug delivery purposes, either as the drug itself or as the drug carrier

Nanotechnology Kevlar T-shirts (Bullet Proof)
Nanotechnology to repair the brain: Increase Cerebral Capacity (Artificial neuron)

Synthetic Blood/ Artificial Blood

Mind Control? Scientists Have Discovered How To Use Nanoparticles To Remotely Control Behavior!
(In the movie The Matrix (1999): 'jacking in' - a brain-machine neural interface that connects a human brain to a computer network)
**Cyberkinetics devices:** BrainGate™ Neural Interface System that has been used successfully by quadriplegic patients to control a computer with thoughts alone.

**Retinal implants:**

**Brain pacemakers:**
First brain pacemaker was implanted to Mr. Kim Rollins an Anorexia nervosa patient in 2013.

**3D Bio-Printing:**
3D printer that can produce organs, tissues, and bones that could theoretically be implanted into living humans.

**Flexible electronics** (LG OLED TV Display in market which can be folded)
**Stealth Technology** (Radar Absorbing Materials)

**Nano Bomb**
Fullerene based NANOBOMB that CREATES MASSIVE EXPLOSION ON TINY SCALE. Within 50 trillionths of a second the temperature goes from 1,300 degrees to 6,700 degrees Fahrenheit. That’s hot enough to melt most metals.

**Space elevator (60,000 miles) could be built by 2035:**
(Height of geostationary satellite = 22,236 miles)

**Using nanotube**
10 nanometers wide (weight equal to a human body)
140 ton load at a time
1/100th of the cost of today’s rocket launches

**Recognition of Nanoscience / nanostructure research**

Received **Nobel Prize in Chemistry (1996)**
Robert F. Curl, Jr, Richard E. Smalley, Sir Harold W. Kroto
For discovering Fullerene C_{60}

Received **Nobel Prize in Physics (2007)**
Albert Fert and Peter Grünberg
For their work on Nanotechnology

Received **Nobel Prize in Chemistry (2007)**
Gerhard Ertl
For his studies of chemical processes on solid surfaces (Thin Films).

Received **Nobel Prize in Physics (2010)**
Andre Geim and Konstantin Novosel
For their work on Graphene
**Graphene: Material of the millennium**

**Melting point:** 5000 K - 6000 K  
(The sun's surface having an effective temperature of 5,777 K)

Graphene is the strongest material ever tested with an intrinsic Tensile strength of **130.5 GPa** and a Young's modulus of **1 TPa** (Steel = 230 GPa)

In Tripura University also several researchers are working on different aspect of Nanotechnology:  
At Thinfilm and Nanoscience Lab, Dept. of Physics, Tripura University we have already developed  
- pH sensor  
- Ion sensor  
- Hard water sensor  
- Arsenic sensor  
- Mercury sensor  
- DNA sensor  
- Lipid / biomembrane conformation sensor  
- Cholesterol sensor  
- Organic RAM / ROM memory

**Negative impact of Nanotechnology:**

- Weapons of War  
- Health issue: Most of the nano materials are toxic  
- Nanoparticles can interact with living organisms since the size of nanoparticles are comparable with most of biomolecules and living cells  
- Robots Taking over the World  
- Fear of the Unknown and unseen