Introduction to Nanotechnology

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Topics

Introduction

Nanomaterials are not new

Nanomaterials have been produced and used by humans for hundreds of years. However, the understanding of certain materials as nanostructured materials is relatively recent, made possible by the advent of advanced tools that are capable of resolving information at nanoscale.

- We now know that the beautiful ruby red colour of some ancient glass paintings is due to gold and silver nanoparticles trapped in the glass matrix.

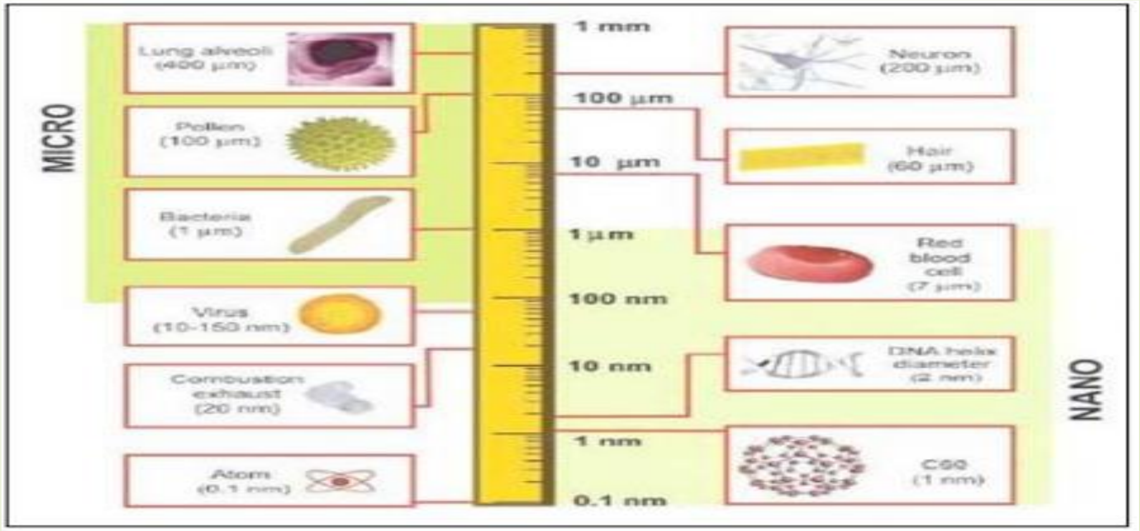
Introduction

- The <u>decorative glaze </u>or metallic film known as 'luster', found on some medieval pottery, contains metallic spherical nanoparticles dispersed in a complex way in the glaze, which gives rise to special optical properties.

- Carbon black is a nanostructured material that is used in car tyres to increase the life of the tyre and impart black colour. This material was discovered in the 1900s.

Introduction

In 1959, the physicist *Professor Richard Feynman* gave the first illuminating talk on *nano technology*, which was entitles as: **(There's Plenty of Room at the Bottom).** He explored the possibility of "**direct manipulation**" of the individual atoms to be effective as a more powerful form of '**synthetic chemistry**'. Feynman talked about a number of interesting results of a 'general ability' to manipulate matter on an atomic scale.

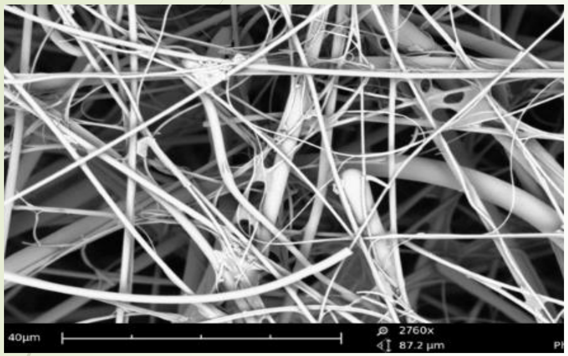


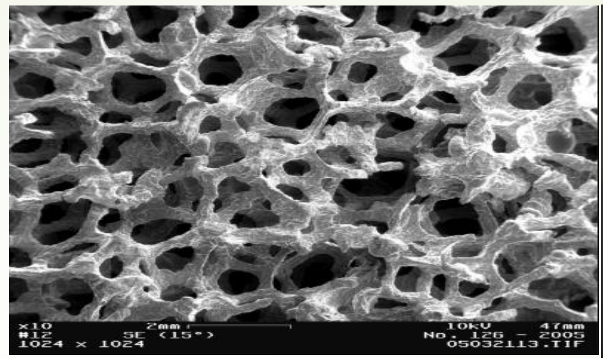
Introduction

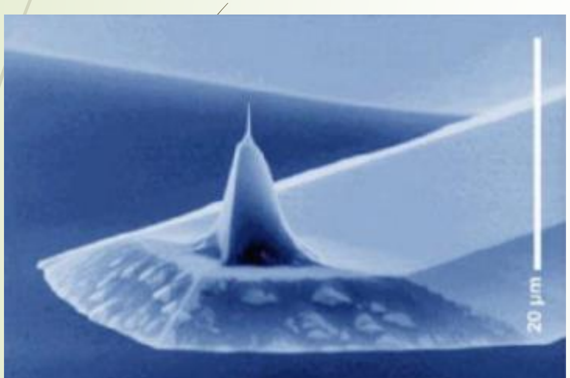
Scientists have been studying and working with nanoparticles for centuries, but the effectiveness of their work has been hampered by their inability to see the structure of nanoparticles. In recent decades the development of microscopes capable of displaying particles as small as atoms has allowed scientists to see what they are working with.

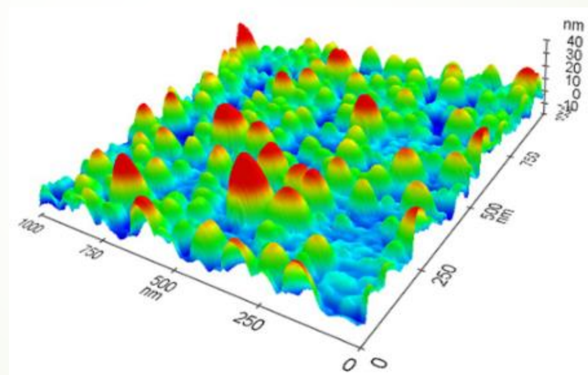
They was particularly interested in the possibility of denser computer circuitry and microscopes that could see things much smaller than is possible using (**Scanning Electron Microscope**). The IBM research scientists created today's **(atomic force microscope)** and **(Scanning Tunnelling Microscope)**, and there are other important examples. Feynman proposed that it could be possible to develop a **(general ability)** to manipulate things on an atomic scale with a **(top → down)** approach.

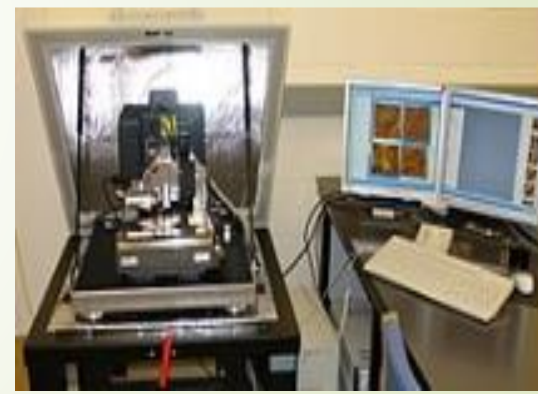
Introduction

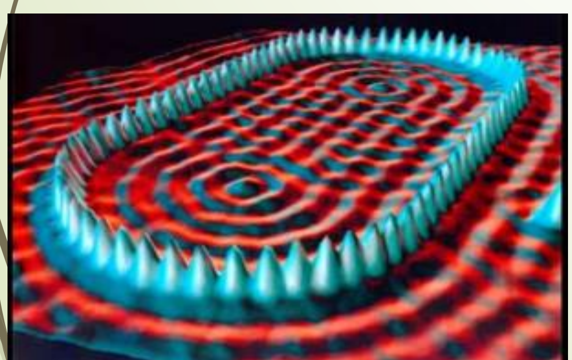


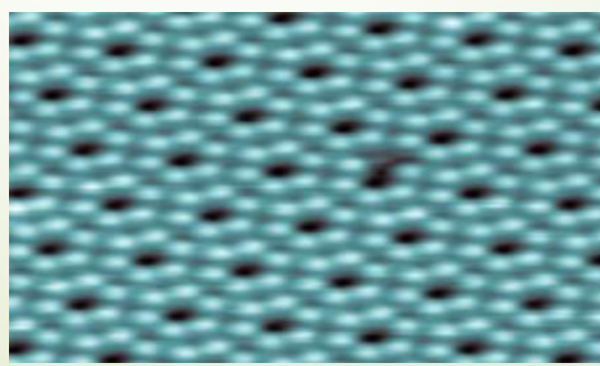






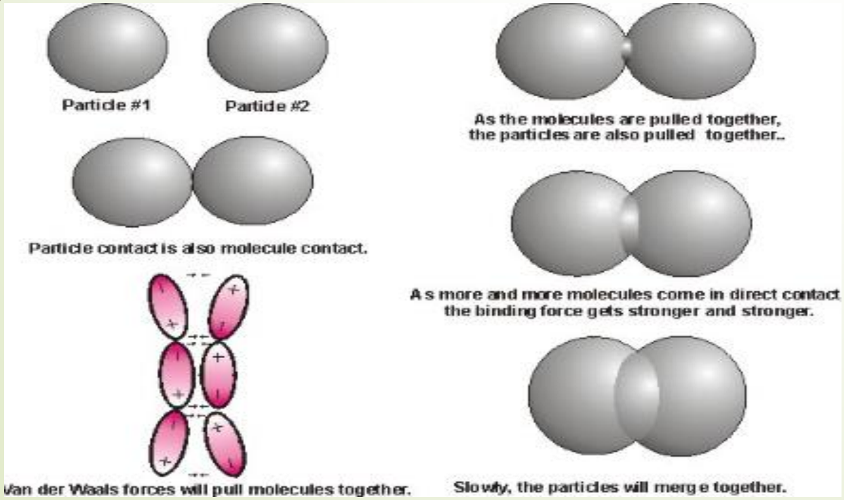


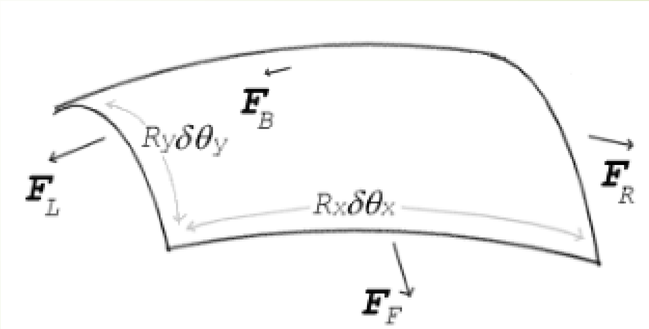




Introduction

We can continue with this particular trend of down-scaling until the tools are able to directly manipulate atoms, which will require redesign of the tools periodically, as different forces and effects come into play. Thus, *the effect of gravity will decrease, and the effects of surface tension and Van der Waals attraction will be enhanced*.





What is Nano

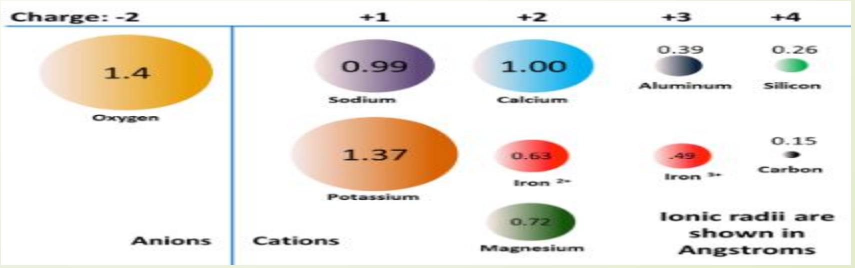
Nano-technology is an advanced technology, which deals with the synthesis of nano-particles, processing of the nano materials and their applications. Normally, if the particle sizes are in the **1-100 nm** ranges, they are generally called nano-particles or materials.

In order to give an idea on this sizerange, let us look at some dimensions :

- **1 nm** = 10 Å = 10^{-9} meter and 1 μm (*i.e.*, 1 micron) = 10^{-4} cm =

1000 nm.

For oxide materials, the diameter of one oxygen ion is about 1.4 Å. So, seven oxygen ions will make about 10 Å or **1 nm**, *i.e.*, the 'lower' side of the nano range. On the higher side, about 700 oxygen ions in a spatial dimension will make the so-called 'limit' of the nano range of materials.



Why Nano Technology

In the materials world, particularly in **ceramics**, the trend is always to prepare **finer powder** for the ultimate processing and better sintering to achieve dense materials with dense **fine-grained microstructure** of the particulates with better and useful properties for various applications. **The fineness** can reach up to a molecular level **(1 nm – 100 nm),** by special processing techniques. More is the fineness, more is the surface area, which increases the **'reactivity'** of the material. So, the densification or consolidation occurs very well at lower temperature than that of conventional ceramic systems, which is finally 'cost-effective' and also improves the properties of materials like abrasion resistance, corrosion resistance, mechanical properties, electrical properties, optical properties, magnetic properties, and a host of other properties for various useful applications in diverse fields.

Scope of Applications

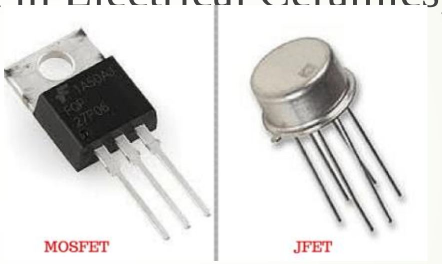
The deviations from the bulk phase diagram may be exploited to form certain compositions of alloys that are otherwise unstable in the bulk form. In addition, the thermal stability of interfacial regions is typically less than that of the bulk material : thus **the nano-phase materials are often sintered or undergo phase transformation at temperatures below those of the bulk material.** This is a characteristic which has numerous applications to material processing.

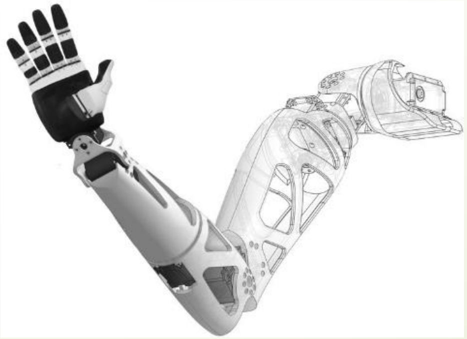
By improving material properties, we are able to find the **applications** as varied as *semiconductor electronics, sensors, special polymers, magnetics, advanced ceramics, and membranes.* We need to improve our current understanding of particle size control and methodologies for several classes of Nano phase materials and address the issues of their characterization. We should also explore the fields in which there are foreseeable application of nano-phase materials to long standing materials problems, since these ‘issues’ have to be tackled by us.

As said earlier, there is a scope of wider applications in different fields such as :

Scope of Applications

(a) Electronics in terms of Thin Films, Electronic Devices like MOSFET, JFET and in Electrical Ceramics,

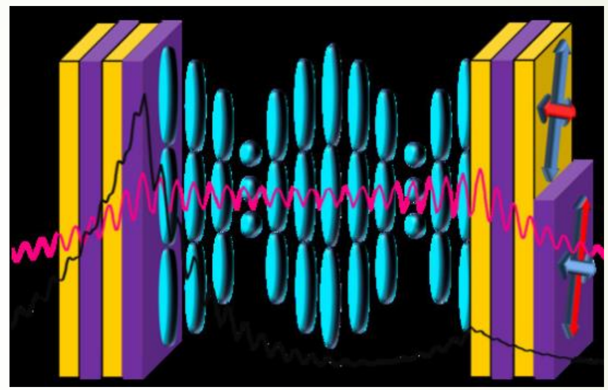




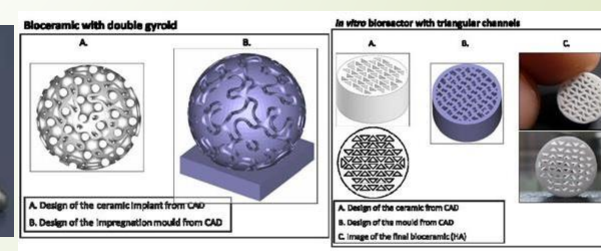
(b) Bionics,

Scope of Applications

(a) Photonics,



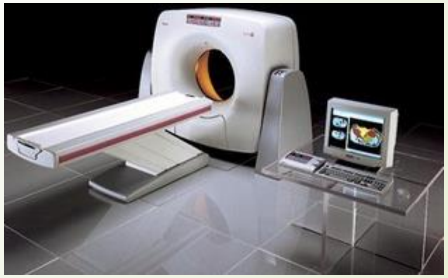
(b) Bio-Ceramics,



Scope of Applications

(a) Bio-Technology,

(b) Medical Instrumentation



Definition

"Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale."

How do properties change at the Nano scale?

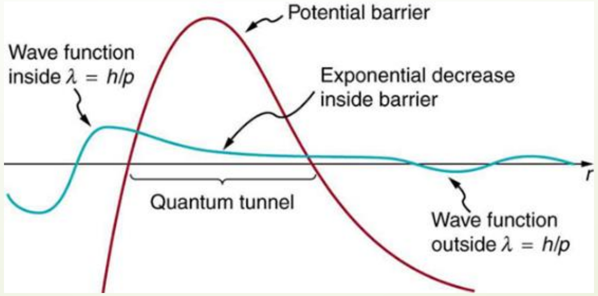
When particle sizes of solid matter in the visible scale are compared to what can be seen in a regular optical microscope, there is little difference in the properties of the particles. But **when particles are created with dimensions of about 1–100 nanometres the materials' properties change significantly from those at larger scales.** This is the size scale where so-called **quantum effects** rule the behaviour and properties of particles. Properties of materials are size-dependent in this scale range. Thus, when particle size is made to be Nano scale, properties such as melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity change as a function of the size of the particle.

How do properties change at the Nano scale?

Nanoscale gold illustrates the unique properties that occur at the nanoscale. Nanoscale gold particles are not the yellow color with which we are familiar; nanoscale gold can appear red or purple. At the nanoscale, the motion of the gold's electrons is confined. Because this movement is restricted, gold nanoparticles react differently with light compared to larger-scale gold particles. Their size and optical properties can be put to practical use: nanoscale gold particles selectively accumulate in tumors, where they can enable both precise imaging and targeted laser destruction of the tumor by means that avoid harming healthy cells.

How do properties change at the Nano scale?

An attractive and powerful result of the quantum effects of the nanoscale is the concept of **"tunability"** of properties. **That is, by changing the size of the particle, a scientist can literally fine-tune a material property of interest** (e.g., changing fluorescence color; in turn, the fluorescence color of a particle can be used to identify the particle, and various materials can be "labeled" with fluorescent markers for various purposes). **Another potent quantum effect of the nanoscale** is known as "tunneling" **which is a phenomenon that enables the scanning tunneling microscope and flash memory for computing**.



Current and Future Trends, Research and Applications

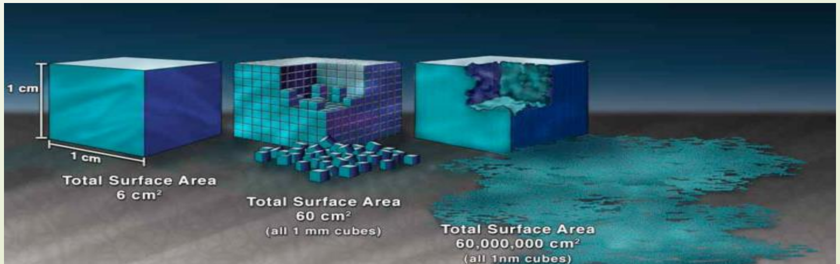
The ability to see Nano-sized materials has opened up a world of possibilities in a variety of industries and scientific endeavours. Because nanotechnology is essentially a set of techniques that allow manipulation of properties at a very small scale, it can have many applications, such as the ones listed below.

1.Drug delivery. Biocompatible nanomaterials having exceptional properties of high invasion rate, slow, controlled and targeted drug release, easily accessible to receptors overcome all these problems and are advantageous over traditional form of drug.. **Researchers at Harvard and MIT** **(Massachusetts Institute)** have been able to attach special RNA strands, measuring about 10 nm in diameter, to nanoparticles and fill the nanoparticles with a chemotherapy drug. These RNA strands are attracted to cancer cells. When the nanoparticle encounters a cancer cell it adheres to it and releases the drug into the cancer cell. This directed method of drug delivery has great potential for treating cancer patients while producing less side harmful effects than those produced by conventional chemotherapy.

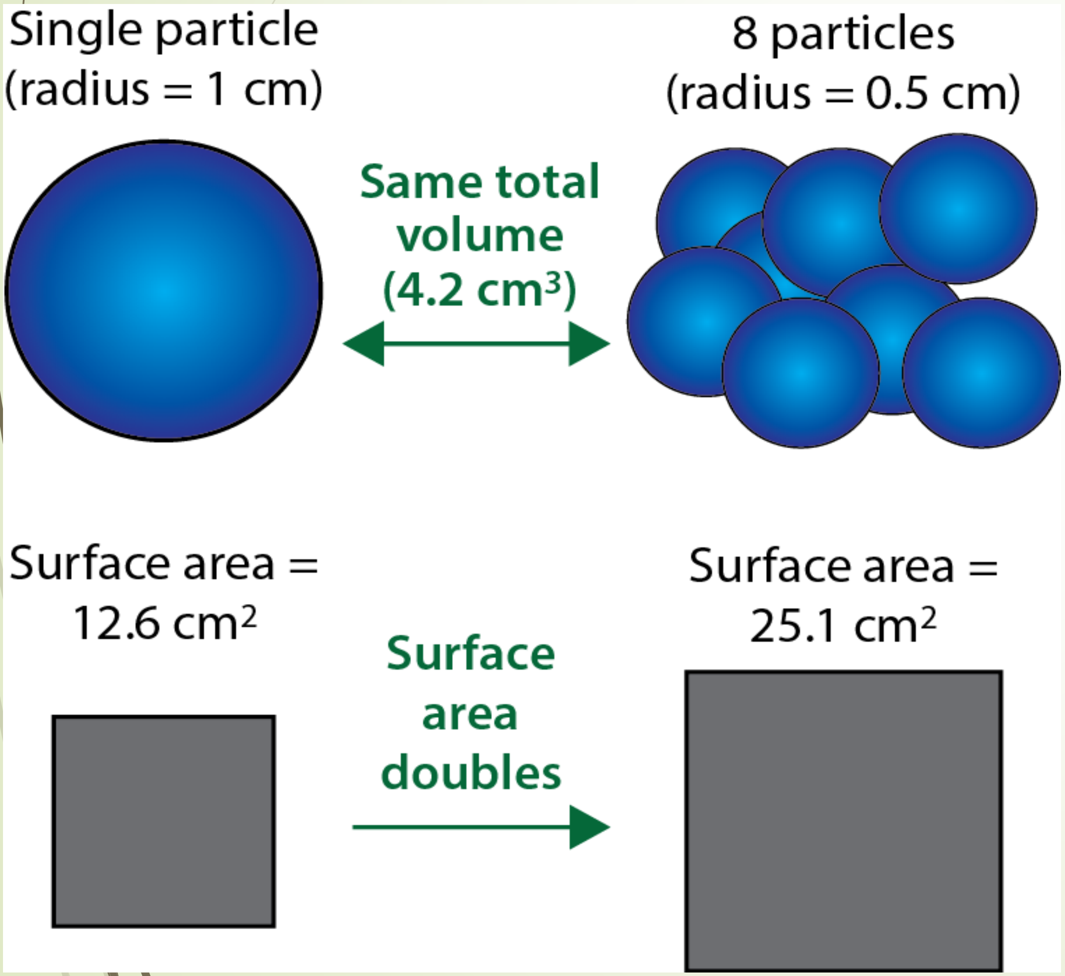
Current and Future Trends, Research and Applications

2.Fabrics. The properties of familiar materials are being changed by manufacturers who are adding Nano-sized components to conventional materials to improve performance. For example, some clothing manufacturers are making water and stain repellent clothing using Nano-sized whiskers in the fabric that cause water to bead up on the surface.

Reactivity of Materials. The properties of many conventional materials change when formed as nano-sized particles (nanoparticles). This is generally because nanoparticles have a greater surface area per weight than larger particles; they are therefore more reactive to some other molecules. For example studies have shown that nanoparticles of iron can be effective in the clean-up of chemicals in groundwater because they react more efficiently to those chemicals than larger iron particles.



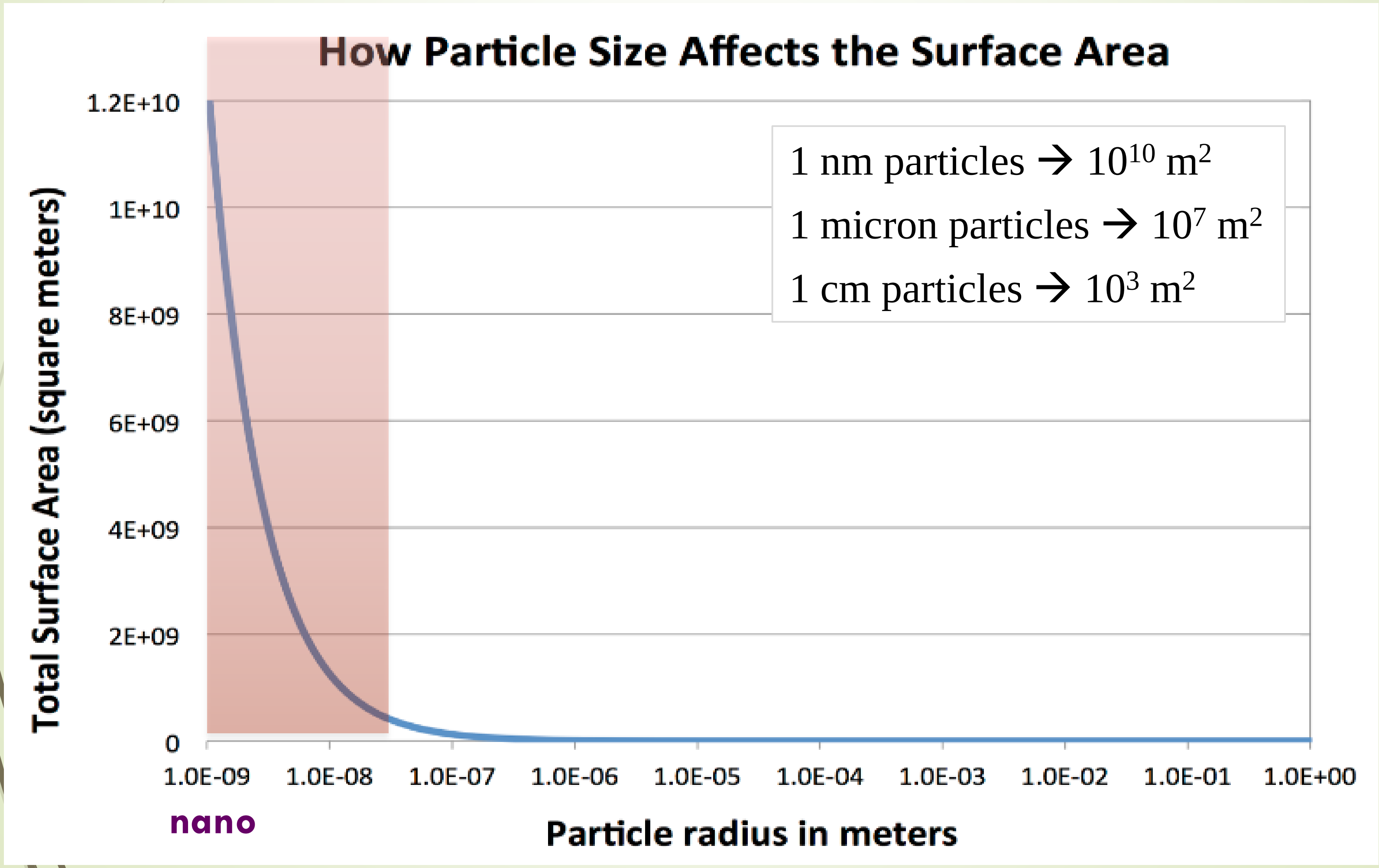
Current and Future Trends, Research and Applications



For a fixed total volume, decreasing the radius by a factor of two doubles the surface

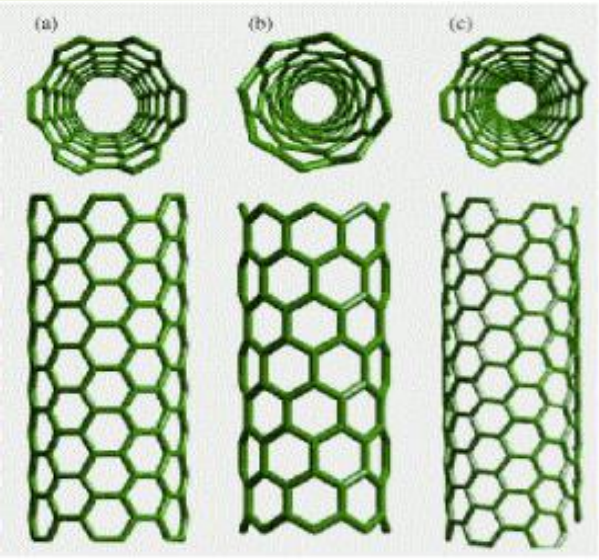
Crushing a 1cm particle into nano particles increases the surface area thousands of times!

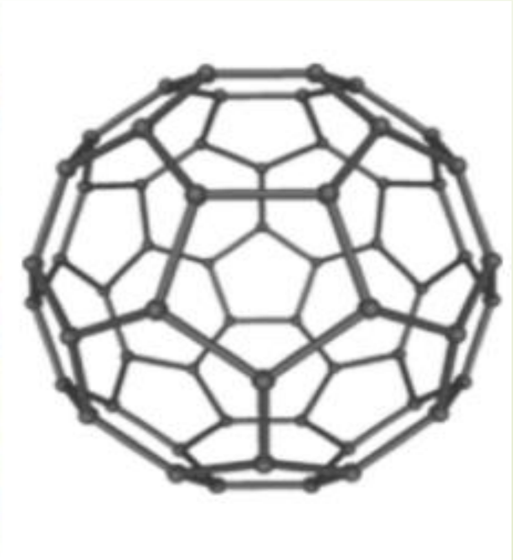
Current and Future Trends, Research and Applications



Current and Future Trends, Research and Applications

Strength of Materials. Nano-sized particles of carbon, (for example nanotubes and bucky balls) are extremely strong. Nanotubes and bucky balls are composed of only carbon and their strength comes from special characteristics of the bonds between carbon atoms. One proposed application that illustrates the strength of Nano sized particles of carbon is the manufacture of t-shirt weight bullet proof vests made out of carbon nanotubes.





Current and Future Trends, Research and Applications

3.Micro/Nano Electro-Mechanical Systems. The ability to create gears, mirrors, sensor elements, as well as electronic circuitry in silicon surfaces allows the manufacture of miniature sensors such as those used to activate the airbags in your car. This technique is called MEMS (Micro-Electro Mechanical Systems). The MEMS technique results in close integration of the mechanical mechanism with the necessary electronic circuit on a single silicon chip, similar to the method used to produce computer chips. Using MEMS to produce a device reduces both the cost and size of the product, compared to similar devices made with conventional methods. MEMS is a stepping stone to NEMS or Nano-ElectroMechanical Systems. NEMS products are being made by a few companies, and will take over as the standard once manufacturers make the investment in the equipment needed to produce nano-sized features.

Current and Future Trends, Research and Applications

4.Molecular Manufacturing **(MM)** means the ability to build devices, machines, and finally whole products with every atom in its specified place. Today the theories for using mechanical chemistry to directly fabricate Nano scale structures are well-developed and waiting progress in enabling technologies. Assuming all this theory works—and no one has established a problem with it yet—exponential general-purpose molecular manufacturing appears to be inevitable. MM can be built into a self-contained, personal factory (PN) that makes cheap products efficiently at molecular scale. The time from the first fabricator to a flood of powerful and complex products may be less than a year. The potential benefits of such a technology are huge. Unfortunately, the risks are also immense. Researchers believe that raw materials can be used to reproduce almost any non-living object using this method.

Current and Future Trends, Research and Applications

5. Nano-generators: It is a method uses proprietary 2D or 3D bio-hybrid printing and hybrid nanocomposite coating deposition technologies. Its autonomous nano-generators convert waste mechanical and chemical energy into electricity in real-time, thereby reducing dependence on fossil fuels. The technology finds use in autonomous devices for the Internet of Things (IoT), Internet of Body (IoB) networks, smart homes, and defence.

6. **ultra-thin nanosized graphene sensors for device temperature monitoring**: The technology directly spray-coats the graphene-sensing nanolayer on a thin flexible foil. This improves the measurement reliability of the sensor and enables large-area temperature monitoring, including on curved surfaces. This way, the startup offers a low-cost and reliable solution for temperature sensing in battery technology, electronics, aerospace, and process industries.

Nanotechnology Language

Home work

<u>Define</u>

- Nanoscale
- Nano bio
- Nanodots
- Nanowires
- Nanoelectronics
- Nanobots
- Nano materials

Scale of Things—Nanometers

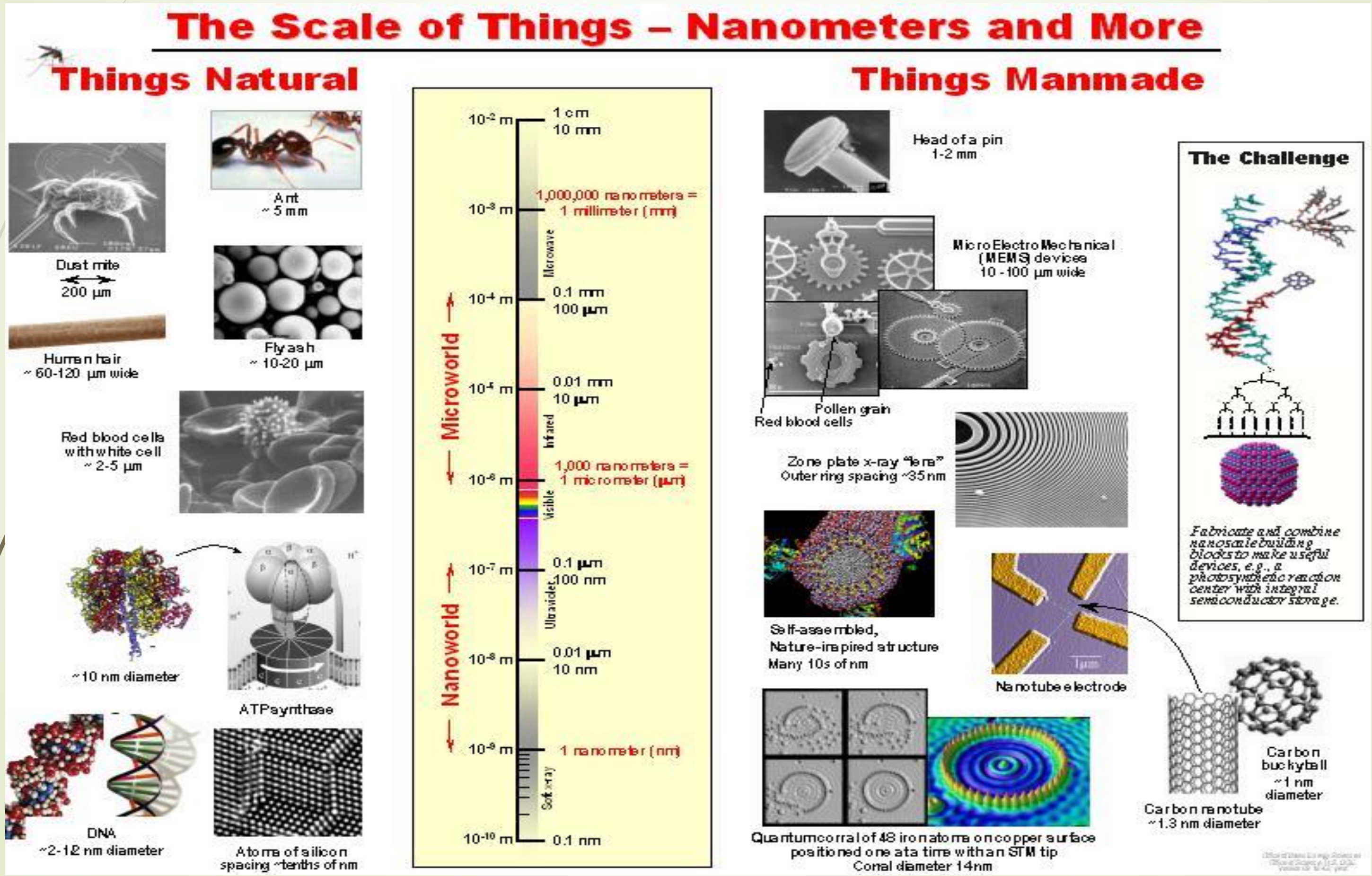


Figure 1.5: National Nanotechnology Initiative.