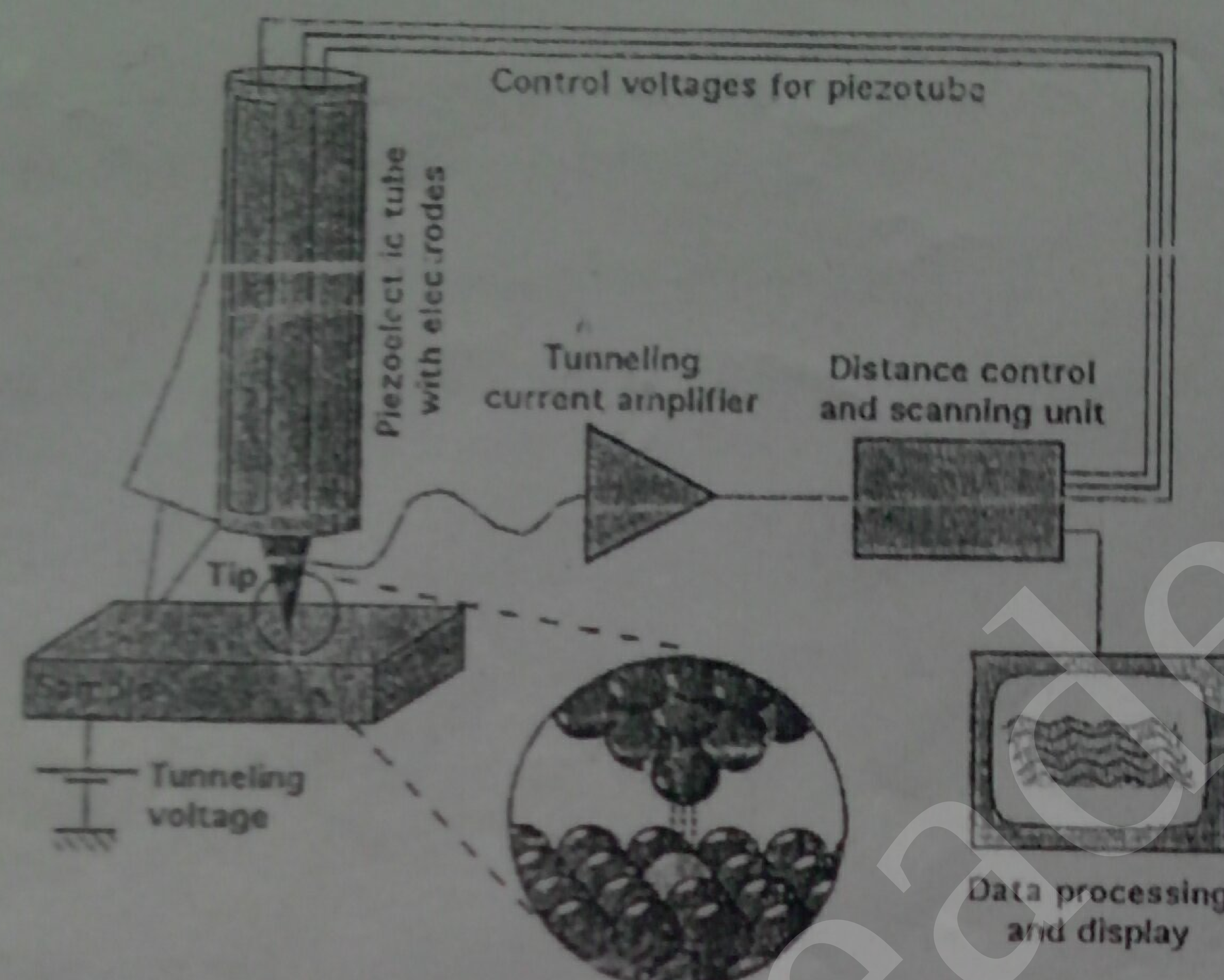
A2 Nano (Hand-writie

Terms:- **A raster scanning**, is the rectangular pattern of image capture and reconstruction in television.

Piezoelectricity is the **electric charge** that accumulates in certain solid materials in response to applied mechanical stress.

Scanning tunneling microscope



A STM is an instrument that is used for imaging surfaces (metal) at the atomic level. Discovered in 1981 by Gerd Binnig and Heinrich Rohrer and got Nobel Prize in Physics in 1986.

For an STM, good resolution is considered to be **0.1 nm lateral** resolution and **0.01 nm** depth resolution. With this resolution, individual atoms within materials can be routinely imaged.

The STM can work in :- Ultra-high vacuum

- air,
- water,
- various other liquid
- gas ambients,
- and at temperatures ranging from near 0K to a few hundred degrees Celsius.

Requirement:- Requires a conducting surface to be scanned.

Principle :- The STM is based on the principle of **quantum tunneling**.

Quantum tunnelling refers to the quantum mechanical phenomenon where a particle tunnels through a **barrier** that it classically could not surmount (get through).

An STM has a sharp tip, which can be moved very accurately over the surface. When a conducting tip is brought very near to the surface to be examined, a voltage difference applied between the two (tip and metal surface) can allow electrons to tunnel through the vacuum between them.

The resulting ***tunneling current*** is a function of a). tip position, b) applied voltage, and c) the local density of states of the sample.

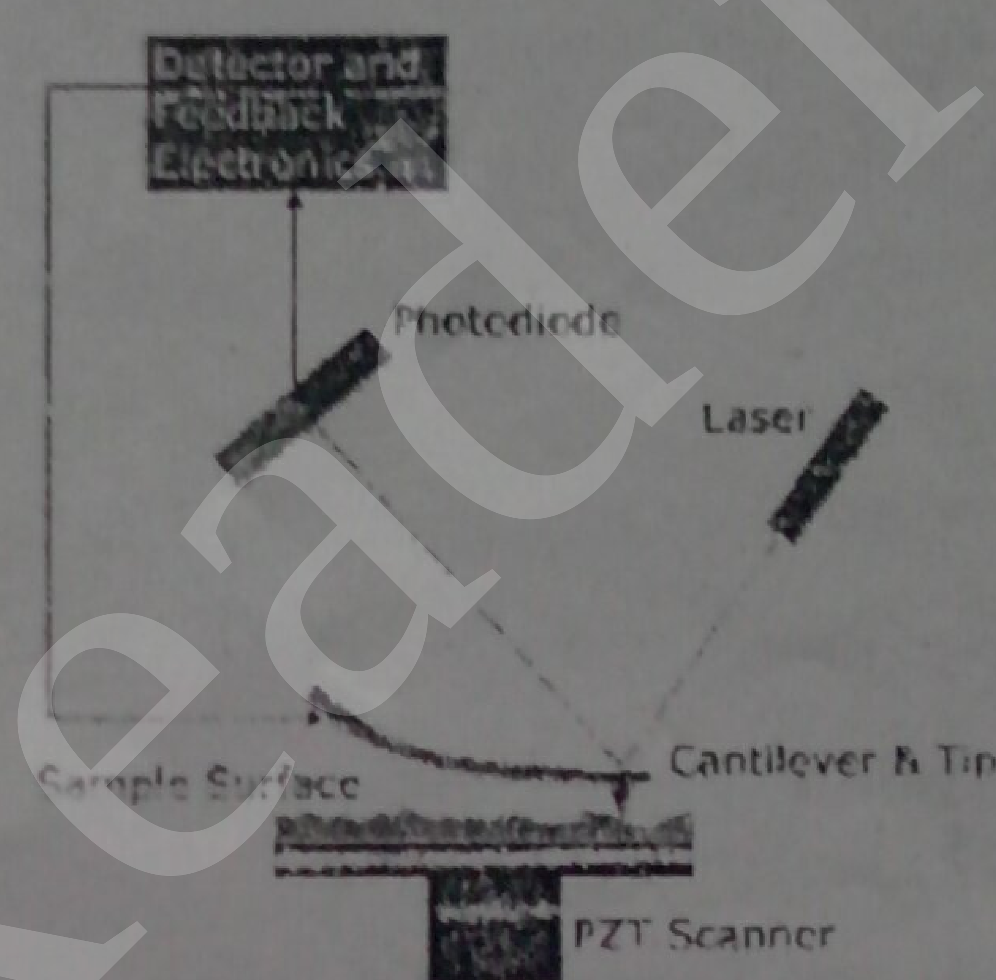
The height of tip above the surface is controlled by a piezoelectric element. By applying a voltage to the piezoelectric tube, the tip can be moved over surface. The movement of tip is recorded and displayed on computer screen. Always keeping the tunnelling current constant the tip gives the surface profile.

Information is acquired by monitoring the current as the tip's position scans across the surface, and is usually displayed in image form.

STM can be a challenging technique, as it requires extremely clean and stable surfaces, sharp tips, excellent vibration control, and sophisticated electronics.

Atomic force microscope

Atomic force microscope (AFM) is a modification of the tunnelling microscope. The first commercially available atomic force microscope was introduced in 1989.



- In AFM instead of keeping the needle tip at a distance from the sample the needle is pushed right against the surface of the sample.
- The force present in the tip is kept constant and the tip is scanned over the surface like a phonograph needle running in the grove of a record.
- A record of the vertical position of tip is made by reflecting a laser beam from a mirror which is fixed on the top of needle.
- An Interferometer is used to accurately measure the distance travelled by the laser beam and hence the position of tip.
- The record can be converted and displayed as an image of surface.
- Since AFM does not depend upon current, it can be used to visualize conducting as well as non-conducting materials.

The AFM is one of the foremost tools for imaging, measuring, and manipulating matter at the nanoscale. The information is gathered by "feeling" the surface with a mechanical probe. Piezoelectric elements that facilitate tiny but accurate and precise movements on (electronic) command enable the very precise scanning.

Difference between STM and AFM	
STM	AFM
In STM we monitor the electrical tunnelling current between the surface and the probe tip.	In AFM, We monitor the force exerted between the surface and the probe tip.

Disadvantages of AFM:-

A disadvantage of AFM compared with the scanning electron microscope (SEM) is the single scan image size.

In one pass, the SEM can image an area on the order of square millimetres (mm^2) with a depth of field on the order of millimetres (mm), whereas the AFM can only image a maximum height on the order of 10-20 micrometers and a maximum scanning area of about 150×150 micrometers.

Scanning Electron Microscope

A **scanning electron microscope** (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons.

SEM give information about:- a) External Morphology b) Chemical Composition c) Crystalline Structure d) Orientation of materials

The electrons that are used in the SEM are generated by thermally heating the tungsten filament. The electrons are then accelerated by an electric potential and focused by the electrostatic and electromagnetic lenses onto the sample.

SEM does not actually view a true image of the specimen, but actually view an **electronic map of the specimen** that is displayed on the Cathode Ray Tube (CRT).

In SEM an electron beam is emitted from an electron gun fitted with a tungsten filament. The e beam has the energy in 100ev -40 Kev. The electrons interact with electrons in the sample. The e lose their energy by repeated random scattering and absorption of the **interaction volume** of the sample and produce various signals that can be detected and that provide information about the sample's surface topography and composition.

The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer.

Specimens can be observed in high vacuum, low vacuum and in environmental SEM specimens can be observed in wet conditions.

Principle

The types of signals produced by a SEM include secondary electrons (SE), back-scattered electrons (BSE), characteristic X-rays, light (cathodoluminescence) (CL), specimen current and transmitted electrons.

SEM has a Secondary electron detectors. The signals result from interactions of the electron beam with atoms at or near the surface of the sample.

The signal produced by the secondary electron is detected and sent to CRT image. By changing the width (w) of of the electron beam, the magnification (M) can be changed as : M= W/w that width of CRT/width of electron beam.

In the most common mode, secondary electron imaging, the SEM can produce very high-resolution images of a sample surface, revealing details less than 1 nm in size. Due to the very narrow electron beam, SEM micrographs have a large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample.

Transmission Electron Microscope

Transmission electron microscopy is a microscopy technique in which a beam of electrons is transmitted through an ultra-thin specimen (200nm), interacting with the specimen as it passes through. The electrons are detected that passes through the sample. An image is formed from the interaction of the electrons transmitted through the specimen; the image is magnified and focused onto an imaging device, such as a **fluorescent screen**, on a layer of photographic film, or to be detected by a sensor such as a CCD camera.

The electrons that are used in the TEM are generated by thermal emission from the tungsten filament. The electrons are then accelerated by an electric potential and focused by the electrostatic and electromagnetic lenses onto the sample.

TEM is made up of:-

1. **Illumination System:-** It takes the e- from the gun and transfer them to the specimen giving either a broad beam or a focused beam.

2. **The Objective Lens and Stage:-** This combination is the heart of TEM.

3. **The TEM imaging System:-** Physically it includes the intermediate Lens and projector Lens.

Carbon Nanotubes

Carbon Nanotubes (CNTs) are allotropes of carbon with a **cylindrical nanostructure**. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than for any other material.

These cylindrical carbon molecules have unusual properties, which are valuable for **nanotechnology, electronics, optics** and other fields of materials science and technology.

In particular, because to their extraordinary thermal conductivity and mechanical and electrical properties, carbon nanotubes find applications as additives to various structural materials.

For example, nanotubes form a tiny portion of the materials in some (primarily carbon fiber) baseball bats, golf clubs, or car parts.

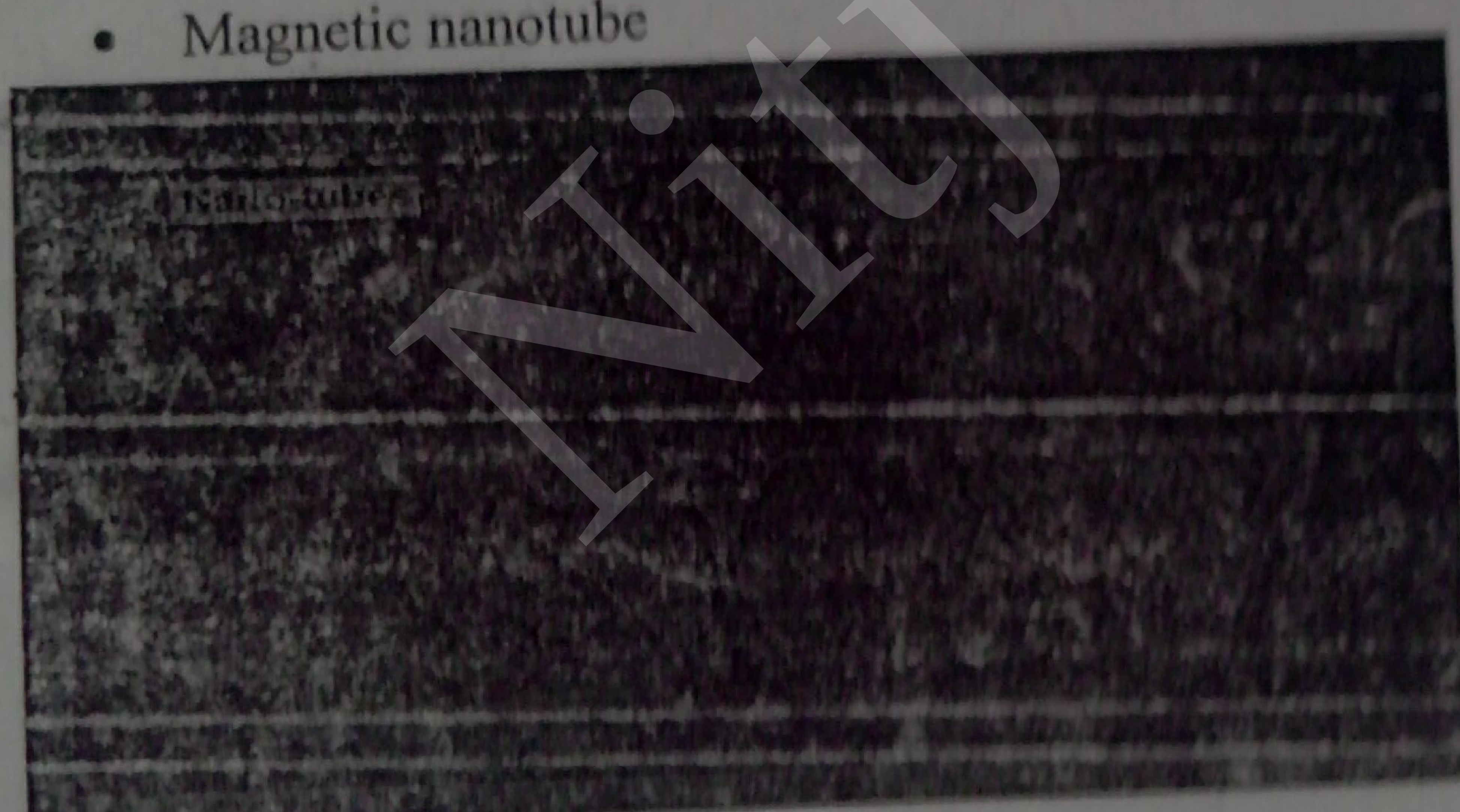
Nanotubes are members of the fullerene structural family. Their name is derived from their long, hollow structure with the walls formed by one-atom-thick sheets of carbon, called graphene. These sheets are rolled at specific and discrete angles, and the combination of the rolling angle and radius decides the nanotube properties; for example, whether the individual nanotube shell is a metal or semiconductor.

Nanotubes are categorized as single-walled nanotubes and multi-walled nanotubes. Individual nanotubes naturally align themselves into "ropes" held together by van der Waals forces, more specifically, pi-stacking.

The chemical bonding of nanotubes is composed entirely of sp^2 bonds, similar to those of graphite. These bonds, which are stronger than the sp^3 bonds found in alkanes and diamond, provide nanotubes with their unique strength.

Some applications of Carbon Nanotubes include the following:-

- Micro-electronics / semiconductors
- Conducting Composites
- Controlled Drug Delivery/release
- Artificial muscles
- Supercapacitors
- Batteries
- Nano lithography
- Nano electronics
- Doping
- Nano balance
- Nano tweezers
- Data storage
- Magnetic nanotube



Nanomaterial Synthesis Approach:-

Bottom-up approaches

These seek to arrange smaller components into more complex assemblies.

- DNA nanotechnology utilizes the specificity of Watson–Crick base pairing to construct well-defined structures out of DNA and other nucleic acids.

- Approaches from the field of "classical" chemical synthesis (inorganic and organic synthesis) also aim at designing molecules with well-defined shape (e.g. bis-peptides[30]).

- Atomic force microscope tips can be used as a nanoscale "write head" to deposit a chemical upon a surface in a desired pattern in a process called dip pen nanolithography.

Top-down approaches

Breaking of the Bulk Material:- These seek to create smaller devices by using larger ones.

- Many technologies that descended from conventional solid-state silicon methods for fabricating microprocessors are now capable of creating features smaller than 100 nm, falling under the definition of nanotechnology. Giant magnetoresistance-based hard drives already on the market fit this description,[31] as do atomic layer deposition (ALD) techniques. Peter Grünberg and Albert Fert received the Nobel Prize in Physics in 2007 for their discovery of Giant magnetoresistance and contributions to the field of spintronics.[32]

- Solid-state techniques can also be used to create devices known as nanoelectro mechanical systems or NEMS, which are related to microelectromechanical systems or MEMS.

- Focused ion beams can directly remove material, or even deposit material when suitable pre-cursor gasses are applied at the same time. For example, this technique is used routinely to create sub-100 nm sections of material for analysis in Transmission electron microscopy.

- Atomic force microscope tips can be used as a nanoscale "write head" to deposit a resist, which is then followed by an etching process to remove material in a top-down method.

Nano-Lithography:

- Lithography is the technique used to transfer a computer-generated pattern on a substance.
- This pattern is subsequently used to etch the underlying tin film.(Oxide, nitride).
- It is used for micro, nano electronic fabrication (MEMS, NEMS).
- Nanolithography is the art and science of etching (drawing, impression, design), writing, or printing at the microscopic level, where the dimensions of characters are on the order of nanometers. This includes various methods of modifying semiconductor chips at the atomic level for the purpose of fabricating integrated circuits (IC s).
- Instruments used in nanolithography include the scanning probe microscope (SPM) and the atomic force microscope (ATM). The SPM allows surface viewing in fine

detail without necessarily modifying it. Either the SPM or the ATM can be used to etch, write, or print on a surface in single-atom dimensions

Applications of Nanotechnology

Physicists all over the world are concentrating on application-oriented Physics rather than Fundamental Physics. The Physics of the Nanoworld is the latest field of active research in this century. The last few years have seen a gold rush to claim patents at the nanoscale. Over 800 nano-related patents were granted in 2003, and the numbers are increasing year to year.

Corporations are already taking out broad-ranging patents on nanoscale discoveries and inventions. Corporations like NEC and IBM, hold the basic patents on carbon nanotubes, one of the current cornerstones of Nanotechnology.

Carbon NanoTubes (CNT) have a wide range of uses, and look set to become crucial to several industries from electronics and computers, to strengthened materials to drug delivery and diagnostics. Hewlett-Packard has proposed the use of a Nanomaterial called "Memristor" as a future replacement of Flash memory.

What is Nanotechnology?

Nanotechnology, shortened to "nanotech", is the study of controlling of matter on an atomic and molecular scale. Generally, nanotechnology deals with developing materials or devices sized between 1 to 100 nanometer in at least one dimension. One nanometer (nm) is one billionth, or 10^{-9} of a meter.

By comparison, typical Carbon-Carbon Bond-Lengths, or the spacing between the atoms in a molecule, are in the range 0.12–0.15 nm, and a

DNA double-helix has a diameter of around 2 nm.

On the other hand, the smallest cellular life-forms, the bacteria of the genus Mycoplasma, are around 200 nm in length.

A number of physical phenomena become pronounced as the size of the system decreases. The electronic properties of solids are altered with great reductions in particle size. Quantum mechanical effects and Statistical mechanical effects become dominant when the nanometer size range is reached. A number of physical (mechanical, electrical, optical, etc.) properties change at such dimensions when compared to macroscopic systems. One example is the increase in surface area to volume ratio, which alters the mechanical, thermal and catalytic properties of materials. Diffusion reactions at nanoscale, nanostructure materials and nanodevices with fast ion transport are generally referred to as Nanoionics.

Mechanical properties of Nanosystems are of interest in the Nanomechanics research. Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macro scale, enabling unique applications. For instance

1) Opaque substances become transparent (copper);

2) Stable materials turn combustible (aluminum);

3) Insoluble materials become soluble (gold).

4) A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nano scales.

Much of the fascination with nanotechnology stems from these quantum and surface phenomena that matter exhibits at the nanoscale.

Nanotechnology and Nanoscience got a boost in the early 1980s with two major developments: the birth of Cluster Science and the invention of the Scanning Tunneling Microscope (STM). This development led to the discovery of "Fullerenes" in 1985 and the structural assignment of "Carbon Nanotubes", a few years later. in another development, the synthesis and properties of semiconductor Nanocrystals were studied. This led to a fast increasing number of semiconductor nanoparticles and Quantum dots.

Quantum dots are nanoscale objects, which can be used, among many other things, for the construction of lasers. The advantage of a quantum dot laser over the traditional semiconductor laser is that their emitted wavelength depends on the diameter of the dot. Quantum dot lasers are cheaper and offer a higher beam quality than conventional laser diodes.

APPLICATIONS OF NANOTECHNOLOGY:

Nanomedicine is the application of Nanotechnology in Medicine. The approaches to Nanomedicine range from the medical use of Nanomaterials to Nanoelectronic biosensors, and even possible future applications of Molecular Nanotechnology. Nanomedicine predicts to deliver a valuable set of research tools and clinically helpful devices in the near future.

The National Nanotechnology Initiative (NIN) expects new commercial applications in the pharmaceutical industry that may include advanced drug delivery systems, new therapies, and InVivo imaging. Neuro-electronic interfaces and other Nanoelectronic-based sensors are other active goals of research. Further down the line, the speculative field of Molecular Nanotechnology believes that cell repair machines could revolutionize medicine and the medical field.

Nanotechnology has been used in the medical field in delivering drugs to specific cells using nanoparticles. The overall drug consumption and side-effects can be lowered significantly by depositing the active agent in the morbid region only and in no higher dose than needed. This highly selective approach reduces costs and human suffering.

Use of Dendrimers (Dendrimers are repeatedly branched, roughly spherical large molecules) and nanoparticles in targeted and controlled drug delivery, is an emerging field of research called Nanobiopharmacuetics. The basic point to use drug delivery is based upon three facts: a) efficient encapsulation of the drugs, b) successful delivery of said drugs to the targeted region of the body, and c) successful release of that drug there.

NEMS (Nano Electro-Mechanical Systems) are being investigated for the active release of drugs in patients. Some potentially important applications include cancer treatment with iron nanoparticles or gold shells. A targeted or personalized medicine reduces the drug consumption and treatment expenses resulting in an overall social benefit by reducing the costs to the public health system.

Nanotechnology is also opening up new opportunities in implantable delivery systems, which are often preferable to the use of injectable drugs, because the latter frequently display first-order kinetics (the blood concentration goes up rapidly, but drops exponentially over time). This rapid rise may cause difficulties with toxicity, and drug efficacy can diminish as the drug concentration falls below the targeted range.

In 1965, Gordon Moore, one of the founders of Intel Corporation, made the outstanding prediction that the number of transistors that could be fit in a given area would double every 18 months for the next ten years. This it did and the phenomenon became known as "Moore's Law" This trend has continued far past the predicted 10 years until this day, going from just over 2000 transistors in the original 4004 processors of 1971 to over 700,000,000 transistors in the Core2 Processor. There has, of course, been a corresponding decrease in the size of individual electronic elements, going from millimeters in the 60's to hundreds of nanometers in the modern circuitry of this millennium.

In 1999, the ultimate CMOS transistor developed at the Laboratory for Electronics and Information Technology in Grenoble, France, tested the limits of the principles of the MOSFET transistor with a diameter of 18 nm (approximately 70 atoms placed side by side). This was almost one tenth the size of the smallest industrial transistor in 2003 (130 nm in 2003, 90 nm in 2004, 65 nm in 2005 and 45 nm in 2007). It enabled the theoretical integration of seven billion junctions on a €1 coin. However, the CMOS transistor, which was created in 1999, was not a simple research experiment to study how CMOS technology functions, but rather a demonstration of how this technology functions on a molecular scale.

Manufacturers like NANTERO have developed a Carbon Nano Tube (CNT) based crossbar memory called Nano-RAM. Carbon nanotubes are electrically conductive and due to their small diameter of several nanometers, they can be used as field emitters with extremely high efficiency for field emission display (FED). The principle of operation resembles that of the Cathode Ray Tube (CRT) but on a much smaller length scale. The production of displays with low-energy consumption could be accomplished using CNT.

In the modern communication technology, traditional analog electrical devices are increasingly replaced by optical or Optoelectronic devices due to their enormous bandwidth and capacity, respectively. Two promising examples are Photonic Crystals and Quantum Dots. Photonic crystals are materials with a periodic variation in the refractive index with a lattice constant that is half the wavelength of the light used. They offer a selectable energy band gap for the propagation of a certain wavelength. Thus, they resemble a semiconductor, not for electrons but for photons.

Nanolithography is that branch of nanotechnology, which deals with the study and application of fabrication of nanoscale structures like semiconductor circuits. As of 2007, Nanolithography has been is a very active area of research in academia and in industry.

Quantum Computers use the Laws of Quantum Mechanics for computing fast quantum Algorithms. The Quantum computer has quantum bit memory space termed "Qubit" for several computations at the same time. This facility may improve the performance of the older systems.

An inevitable use of nanotechnology will be in heavy industry. Lighter and stronger materials will be of immense use to aircraft manufacturers, leading to increased performance. Spacecraft will also benefit, where weight is a major factor. Nanotechnology would help to reduce the size of equipment and thereby decrease fuel-consumption required to get it airborne.

Another useful application is Nanobatteries. Because of the relatively low energy density of batteries the operating time is limited and a replacement or recharging is needed. The huge number of spent batteries and accumulators represent a disposal problem. The use of batteries with higher energy content or the use of rechargeable batteries or Super- capacitors with higher rate of recharging using Nanomaterials could be helpful for the battery disposal problem.

The most prominent application of nanotechnology in the household is self-cleaning or "easy-to-clean" surfaces on ceramics or glasses. Nanoceramic particles have improved the smoothness and heat resistance of common household equipment such as the flat iron. 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.

New foods are among the nanotechnology-created consumer products coming onto the market at the rate of 3 to 4 per week, according to the 'Project on Emerging Technologies' (PEN), based on an inventory it has drawn up of 609 known or claimed nano-products. On PEN's list are three foods— a brand of canola cooking oil called Canola Active Oil, a tea called Nanotea and a chocolate diet shake called Nanoceuticals Slim Shake Chocolate. According to company information posted on PEN's Web site, the canola oil, by Shemen Industries of Israel, contains an additive called "nanodrops" designed to carry vitamins, minerals and phytochemicals through the digestive system and urea. The shake, according to U.S. manufacturer RBC Life Sciences Inc., uses cocoa infused "NanoClusters" to enhance the taste and health benefits of cocoa without the need for extra sugar.

The joint use of Nanoelectronics, Photolithography and new biomaterials provides a possible approach to manufacturing Nanorobots for common medical applications, such as for surgical instrumentation, diagnosis and drug delivery. Nanorobotics is the technology of creating machines or Robots at or close to the microscopic scale of a Nanometer (10-9 meter). Another definition is a robot that allows precision interactions with nanoscale objects, or can manipulate with nanoscale resolution. Following this definition, even a large apparatus such as an Atomic Force Microscope (AFM) can be considered as a Nanorobotic instrument when configured to perform Nanomanipulation. Also, macro-scale robots or microrobots that can move with nanoscale precision can also be considered Nanorobots.

Nanomachines are largely in the research-and-development phase, but some primitive molecular machines have been tested. An example is a sensor having a switch approximately 1.5 nanometers across, capable of counting specific molecules in a chemical sample.

There has been much debate on the future implications of Nanotechnology. Nanotechnology has the potential to create many new materials and devices with a vast range of applications. On the other hand, nanotechnology raises many issues as with the introduction of any new technology, including concerns about toxicity and environmental impact of Nanomaterials and their potential effects on global economics. These concerns have led to a debate among advocacy groups and governments on whether special regulations on Nanotechnology are warranted. Calls for tighter regulation of nanotechnology have occurred alongside a growing debate related to the human health and safety risks associated with nanotechnology.

Reflecting the challenges for ensuring responsible life cycle regulation, the "Institute for Food and Agriculture Standards" has proposed that the standards for nanotechnology research and development be integrated across consumer, worker and environmental standards. They also propose that NGOs and other citizen groups play a meaningful role in the development of these standards.

So, what does this mean? Right now, it means that scientists are experimenting with substances at the nanoscale to learn about their properties and that we might be able to take advantage of them in various applications. Engineers are trying to use nano-size wires to create smaller, more powerful microprocessors. Doctors are searching for ways to use nanoparticles in medical applications. Still, we've got a long way to go before nanotechnology dominates the technology and medical markets.

Everyday Applications of Nanotechnology

Here are a few examples:

Medicine

One application of nanotechnology in medicine currently being developed involves employing nanoparticles to deliver drugs, heat, light or other substances to specific types of cells, such as cancer cells. Particles are engineered so that they are attracted to diseased cells, which allowdirect treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease. For example, nanoparticles that deliver chemotherapy drugs directly to cancer cells are under development.

Electronics

Nanoelectronics holds some answers on expanding the capabilities of electronics devices can be expanded while reducing their weight and power consumption. These include improving display screens on electronics devices and increasing the density of memory chips. Nanotechnology can also reduce the size of transistors used in integrated circuits. One researcher believes it may be possible to put the power of all of today's present computers in the palm of your hand.

Environment

Nanotechnology is being used in several applications to improve the environment. This includes cleaning up existing pollution, improving manufacturing methods to reduce the generation of new pollution, and making alternative energy sources more cost effective. Potential applications include:

- Cleaning up organic chemicals polluting groundwater. Researchers have shown that iron nanoparticles can be effective in cleaning up organic solvents that are polluting groundwater. The iron nanoparticles disperse throughout the body of water and decompose the organic solvent in place. This method can be more effective and cost significantly less than treatment methods that require the water to be pumped out of the ground.

- Generating less pollution during the manufacture of materials. Researchers have demonstrated that the use of silver nanoclusters as catalysys can significantly reduce the polluting byproducts generated in the process used to manufacture propylene oxide. Propylene oxide is used to produce common materials such as plastics, paint, detergents and brake fluid.

- Increasing the electricity generated by windmills. Epoxy containing carbon nanotubes is being used to make windmill blades. The resulting blades are stronger and lower weight and therefore the amount of electricity generated by each windmill is greater.

- Producing solar cells that generate electricity at a competitive cost. Researchers have demonstrated that an array silicon nanowires embedded in a polymer results in low-