# MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)

Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

**LECTURE HANDOUTS**

**L 01**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Introduction- Biomaterials

**Introduction :**

- Biomaterials are used in surgical disciplines as ophthalmology, cardiology, neuromuscular surgery, orthopaedics and dentistry.
- All biomaterials must have intimate contact with patient's tissue or body fluid, providing a real physical interface.
- The biomaterial should have adequate mechanical strength, chemical and physical properties.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

Introduction- Biomaterials

- The ability to replace or augment damaged organs, or blood vessels or tissues, totally or in part, has improved both the quality and the length of life of many people.
- The decline in surgical risk duringrecent decades has encouraged the development of more complex procedures for prosthetic implantation.
- In addition, a variety of extracorporeal devices, such as the heart, lung and blood dialysis machines are used routinely
- The availability and suitability of traditional autogenous, or homogeneous prosthetic elements is severely limited; as a result, intense interest has been focused on the use of synthetic materials which would provide an asymptomatic, long term function within the body or in contact with body fluid.

- An alternate to artificial implants is transplantation of organs such as kidney, heart, etc., but this effort has been hindered due to social, ethical and immunological problems.

**Video Content / Details of website for further learning (if any):**

- https://study.com/academy/lesson/what-is-a-biomaterial-definition-examples.html
- https://www.nibib.nih.gov/science-education/science-topics/biomaterials
- https://blog.biolinscientific.com/what-is-a-biomaterial

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.1-6

**Course Faculty**

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**LECTURE HANDOUTS**

**L 02**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Definition, biocompatibility, Classification of biomaterials

**Introduction :**

- A biomaterial is defined as any systemically, pharmacologically inert substance utilized to replace functions of living tissues or organs.
- The success of these biomaterials is intimately associated with the chemical and mechanical properties of the materials used in device construction.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

**Definition of Biomaterial**

- A biomaterial can be defined as any material used to make devices to replace a part or a function of the body in a safe, reliable, economic and physiologically acceptable manner.
- A biomaterial is a synthetic material used to replace part of a living system or to function in intimate contact with living tissue.

**Biocompatibility**

- Biocompatibility is a general term describing the property of a material being compatible with living tissue.
- Biocompatible materials do not produce a toxic or immunological response when exposed to the body or bodily fluids.

**CLASSIFICATION OF BIOMATERIALS**

- Metallic implant materials
- Ceramic implant materials
- Polymeric implant materials
- Composite implant materials
-

| S.No. | Type | Examples | Application |
|---|---|---|---|
| 1 | Metallic implant materials | Ti and its alloys, Co–Cr alloys, stainless steels | Joint replacements,dental root implants,bone plates and screws |
| 2 | Ceramic implant materials | alumina zirconia, calcium phosphates including hydroxyapatite, carbon | Dental and orthopedic inplants |
| 3 | Polymeric implant materials | nylon, silicone rubber polyester | Sutures, blood vessels, soft tissues ,hip socket, ear, nose |
| 4 | Composite implant materials | carbon-carbon wire or fiber reinforced bone cement | Bone cement, Dental resin |

**Video Content / Details of website for further learning (if any):**

- https://www.nibib.nih.gov/science-education/science-topics/biomaterials
- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.8-11.

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**LECTURE HANDOUTS**

**L 03**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Shape memory alloys-properties and phases

**Introduction :**

- Shape memory alloys are SMART materials.
- SMA have memory of their shape even undergone change in shape
- Cu-Al-Ni alloy,Au-Cd alloy are the examples of SMA

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

Shape memory alloys-properties and phases

- The materials exhibiting the property of shape memory effect are called shape memory alloys.
- The SMA effect occurs in alloys due to the change in the crystalline structure of the materials with the change in temperature and stress
- Materials undergo change in shape only upon heating are called one-way shape memory alloys
- Materials undergo change in shape upon both heating and re cooling are called two way shape memory alloys.
- Martensite is relatively soft and easily deformed phase of SMA.
- When the martensite is deformed we can get a phase called austenite.
- Austenite is the stronger phase of SMA's.
- At high temperatures the SMA exhibits austenite structure and are hard.

Properties of Shape memory alloys

- The transformation of austenite phase into martensite phase occurs over wide range of lower temperature.
- Shape memory alloys exhibits a hysteresis curve.
- Austenite is the solid solution of carbon in gamma iron with FCC structure.
- Martensite is a super saturated solid solutions of carbon in alpha ions with BCC structure.
- The shape memory occurs by means of stress causing the material more elastic is called pseudo elasticity.

**Video Content / Details of website for further learning (if any):**

- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine
- https://www.slideshare.net/sathishsak/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.26-28.

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**LECTURE HANDOUTS**

**L 04**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Pseudo elasticity and applications of SMA

**Introduction :**

- Shape memory effect due to the Mechanical stress is Pseudo elasticity
- SMA are used in medical and Engineering field
- SMA have poor fatigue resistance and greater corrosion resistance

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

Applications of SMA

- SMA is used as a blood clot filter
- It is used for hydraulic coupling to join the ends of the tube.
- It acts as an actuator which shuts off the toxic or flammable gas flow when fire occurs
- SMA valves are used as thermostat to control the rate of fluid flow
- The pseudoelastic properties of SMA are used in the manufacture of eye glass frames.
- SMAs are used in surgical tools, space shuttle and also have some aeronautical applications
- Nitinol wires are used as the muscle fibres of robotic devices. Researchers have constructed robot hands of this type that are controllable enough to pick up paper cups of water.
- Antenna made with Ni-Ti wires offer superior durability and quickly recover their straight shape when bending stress is removed. This super elastic property helps to extending the life of antenna.

**Video Content / Details of website for further learning (if any):**

- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine

- https://www.slideshare.net/sathishsak/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.6-8.

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**LECTURE HANDOUTS**

**L 05**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Properties of NiTinol, Applications of NiTinol in medical field

**Introduction :**

- NiTinol is Nickel Titanium Alloy belongs to SMA group
- Orthodontic Application
- Orthopedic Implants

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

**Properties of NiTinol**

**Physical Properties**

- Appearance: this is a bright silvery metal.
- Melting Point: Its melting point is around 1310 °C.
- Resistivity: It has a resistivity of 82 ohm-cm in higher temperatures and 76 ohm-cm in lower temperatures.
- Thermal Conductivity: The thermal conductivity of this metal is 0.1 W/ cm-°C.

**Mechanical Properties**

- Ultimate Tensile Strength: The ultimate tensile strength of this material ranges between 754 and 960 MPa.
- Typical Elongation to Fracture: 15.5 percent
- Typical Yield Strength: 560 MPa in high temperature; 100 MPa in low temperature
- Approximate Elastic Modulus: 75 GPa in high temperature; 28 GPa in low temperature
- Approximate Poisson's Ratio: 0.3

- **Medical Applications of nitinol**

- This alloy is very useful in dentistry, especially in orthodontics for wires and brackets that connect the teeth. Sure Smile (a type of braces) is an example of its orthodontic application.
- It is also used in endodontic mainly during root canals for cleaning and shaping the root canals.
- In colorectal surgery, it is used in various devices for the purpose of reconnecting the intestine

after the pathology is removed.

- Nitinol stents are another significant application of this metal in medicines.
- Its biocompatible properties make useful in orthopedic implants.
- Nitinol wires can be used for marking and locating breast tumors.
- The use of Nitinol tubing for various medical purposes is increasing in popularity.

**Video Content / Details of website for further learning (if any):**

- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine
- https://www.slideshare.net/sathishsak/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.30-33

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**LECTURE HANDOUTS**

**L 06**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Properties and applications of Alumina

**Introduction :**

- Alumina have Mechanical and elastic properties
- Alumina is used in Orthopetic and dental applications
- Alumina finds applications in a reconstructive maxillofacial surgery

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

Properties and applications of Alumina

- Alumina has high corrosion and wear resistance.
- .α-alumina has hcp crystal structure.
- High density alumina has good biocompatibility and reasonable strength.
- Strength, fatigue resistance and fracture toughness of polycrystalline α-alumina are function of grain size and purity. An increase in grain size from 4 $\mu m$ to 7 $\mu m$ can decrease mechanical properties by 20%.
- Alumina is not cytotoxic and there is no activation of body's immune response. Alumina implants do not show inflammatory or progressive fibrotic reactions.

**Applications of Alumina**

- .Aluminas are mainly used in orthopedic surgery.
- High-density alumina is used in load-bearing hip prostheses and dental implants because of its combination of excellent corrosion resistance, good biocompatibility, high wear resistance and reasonable strength.

- Orthopedic uses of alumina consist of hip and knee joints, tibial plate, femur shaft, shoulders,

radius, vertebra, leg lengthening spacer and ankle joint prostheses.

- Alumina finds applications in dentistry as well as in a reconstructive maxillofacial surgery to cover bone defects. Porous alumina is also used in teeth roots.

**Video Content / Details of website for further learning (if any):**

- https://www.nibib.nih.gov/science-education/science-topics/biomaterials
- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine
- https://www.slideshare.net/sathishsak/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.39-41

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**LECTURE HANDOUTS**

**L 07**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Polymers in bio medical use

**Introduction :**

- Polymers are used in tissue replacement
- Polymers are used in ophthalmology
- Polymers are also used to manufacture surgical instruments

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

Polymers in bio medical use

| S.No. | Polymer | Biomedical uses |
|---|---|---|
| 1 | Polyethylene | Tubes for various catheters, hip joint, knee joint prostheses |
| 2 | Polypropylene | Yarn for surgery, sutures |
| 3 | Tetrafluoroethylene | Vascular and auditory prostheses, catheters, tubes |
| 4 | Polyvinylchloride | Components of dialysis installation and temporary blood storage devices. |
| 5 | Polyacetals | Hard tissue replacement |
| 6 | Polymethyl methacrylate | Bone cement, intraocular lenses, contact lenses, |
| 7 | Polyurethane | Adhesives, dental materials, blood pumps, artificial heart and skin |
| 8 | Silicone rubber | Encapsulant for pacemakers, burn treatment, shunt,Mammary prostheses, foam dressing,valve, catheter, contact lenses, membranes, maxillofacial implants |
| 9 | Polyamide | surgical suture, films for packages, dialysis devices components, |

**Video Content / Details of website for further learning (if any):**

- https://www.nibib.nih.gov/science-education/science-topics/biomaterials
- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine
- https://www.slideshare.net/sathishsak/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.56-59.

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**LECTURE HANDOUTS**

**L 08**

**Physics**

**I / II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Schematic diagram, Working of heart and lung machine

**Introduction :**

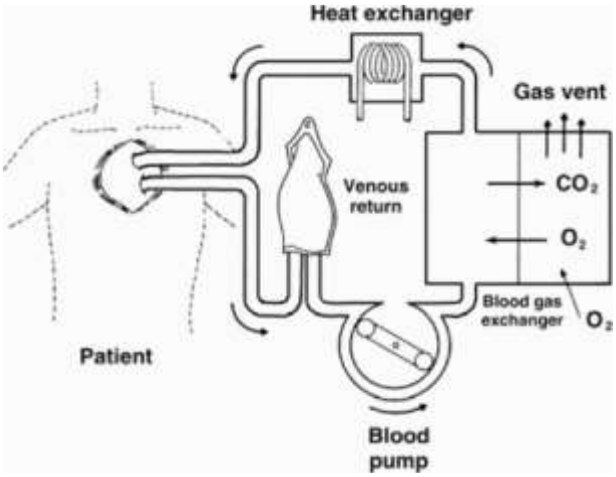
- Heart lung machine is a combination of blood pump and oxygenator
- It oxygenates up to 5 liters of blood per minute
- A heat exchanger of heart lung machine is used to cool or re-warm the blood.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

Working of heart and lung machine




- It is almost impossible to repair intra cardiac defects while the heart is still pumping.
- For this purpose different types of devices called the heart-lung machines have been developed to take the place of the heart for many hours during the course of the surgery.
- While the blood is circulated by pump, it can be oxygenated by patient's own lungs or through an artificial oxygenator.
- The combination of a blood pump and an oxygenator is known as the *heart-and-lung* machine.

- Every heart lung machine consists of a blood pump to replace the heart's function and gas

exchange device to substitute for the natural lungs.

- The machine oxygenates up to 5 liters/minute of venous blood to 95-100% hemoglobin saturation for the required period.
- It simultaneously removes enough carbon dioxide to avoid respiratory acidosis.
- It is simple, dependable, safe, easily cleaned and assembled, easily sterilizable and conveniently, quickly and smoothly connected to and disconnected from the patient.
- The natural lungs expose a very thin (5-10 Jim) blood layer to a gas containing 100 mm Hg oxygen partial pressure for only 0.1-0.3 sec.
- The artificial devices have much thicker blood films and are thus forced to rely on much longer exposure times and use of very oxygen rich gas with 700 mmHg oxygen partial pressure.

**Video Content / Details of website for further learning (if any):**

- https://www.nibib.nih.gov/science-education/science-topics/biomaterials
- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine
- https://www.slideshare.net/sathishsak/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.134-138

**Course Faculty**

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**LECTURE HANDOUTS**

**L 09**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **II- Biomaterials and its applications** **Date of Lecture:**

**Topic of Lecture:** Applications of contact lenses

**Introduction :**

- Eye implants are used to restore functionality of cornea, lens, vitreous humor.
- Optical biomaterials are an important component of the procedures that are used to improve and maintain vision.
- Contact lenses are also used for the therapeutic purpose such as nonhealing chronic corneal ulcers.mn

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on different types of materials
- Basic knowledge on human physiology
- A knowledge on chemical elements and compounds

**Detailed content of the Lecture:**

Applications of contact lenses

| Device | Medical application |
|---|---|
| Contact lens | Correct vision |
| Intraocular lens | Replace lens containing cataracts |
| Epikeratoplasty | Change corneal curvature and correct vision |
| Scleral buckling materials | Indent detached retina |
| Viscous polymer solutions | Insertion in intraocular lenses, cataract removal and maintain retinal position |

**Uses of Contact lenses**

- Contact lenses are used most often for the correction of ametropias,
- They are also used cosmetically to improve the appearance of damaged eyes and to change or enhance eye color.
- Contact lenses are also used for the therapeutic purpose such as nonhealing chronic corneal ulcers, recurrent erosions, pain in bulbous keratopathy,entropion etc.
- Therapeutic contact lenses may be considered a bandage on the cornea and thus they have also been called bandage lenses.

**Properties of contact Lenses**

- High oxygen permeability, to minimize lens interference with corneal respiration.

- Good wetability by tears.
- Resistance to deposition of protein, mucus, lipid, microorganisms and other foreign substances

**Video Content / Details of website for further learning (if any):**

- https://www.nibib.nih.gov/science-education/science-topics/biomaterials
- https://blog.biolinscientific.com/what-is-a-biomaterial
- https://www.sciencedirect.com/topics/nursing-and-health-professions/heart-lung-machine
- https://www.slideshare.net/sathishsak/heart-lung-machine

**Important Books/Journals for further learning including the page nos.:**

- Sujata V. Bhatt, Biomaterials, Second Edition,Narosa Publishing House,2005 Page No.165-167.

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**LECTURE HANDOUTS**

**L 10**

**PHYSICS**

**I / II**

**Course Name with Code** **:BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** **: II- Introduction to Nanotechnology** **Date of Lecture:**

**Topic of Lecture:-**Definition of Nanoscale system

**Introduction :**

- The nanostructure science and technology is a broad and interdisciplinary area of research and development activity that has been growing explosively worldwide in the past few years.
- The nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. The nanomaterials are of interest because at this scale they posses unique optical, magnetic, electrical, and other properties emerge.

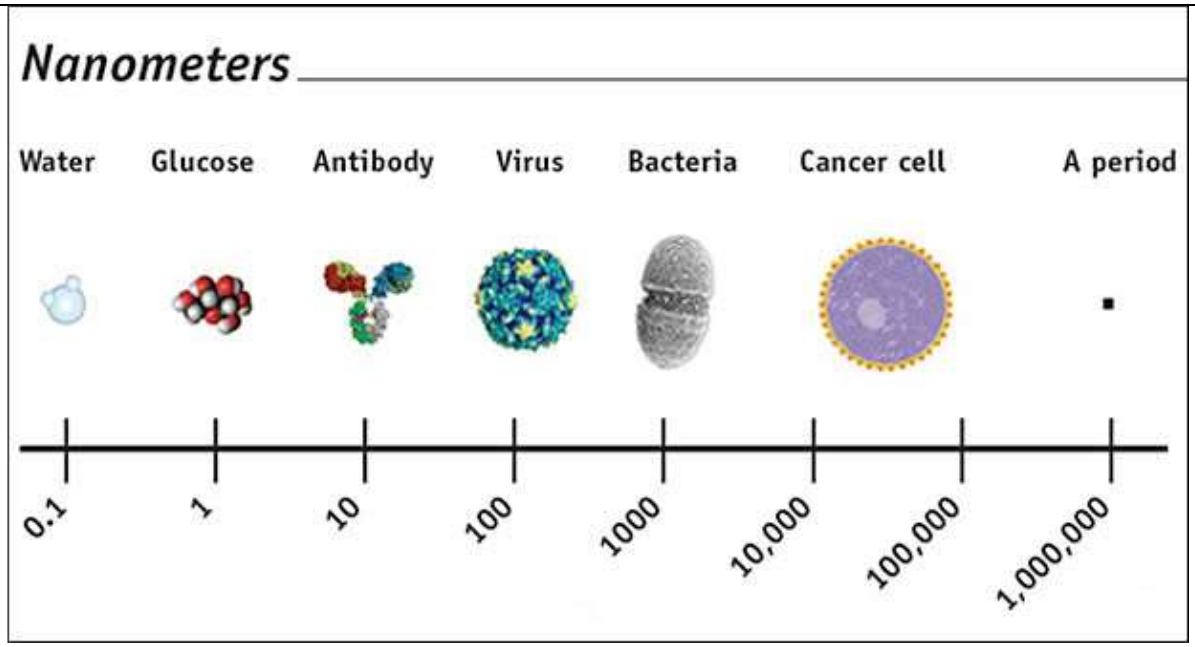
**Prerequisite knowledge for Complete understanding and learning of Topic:**

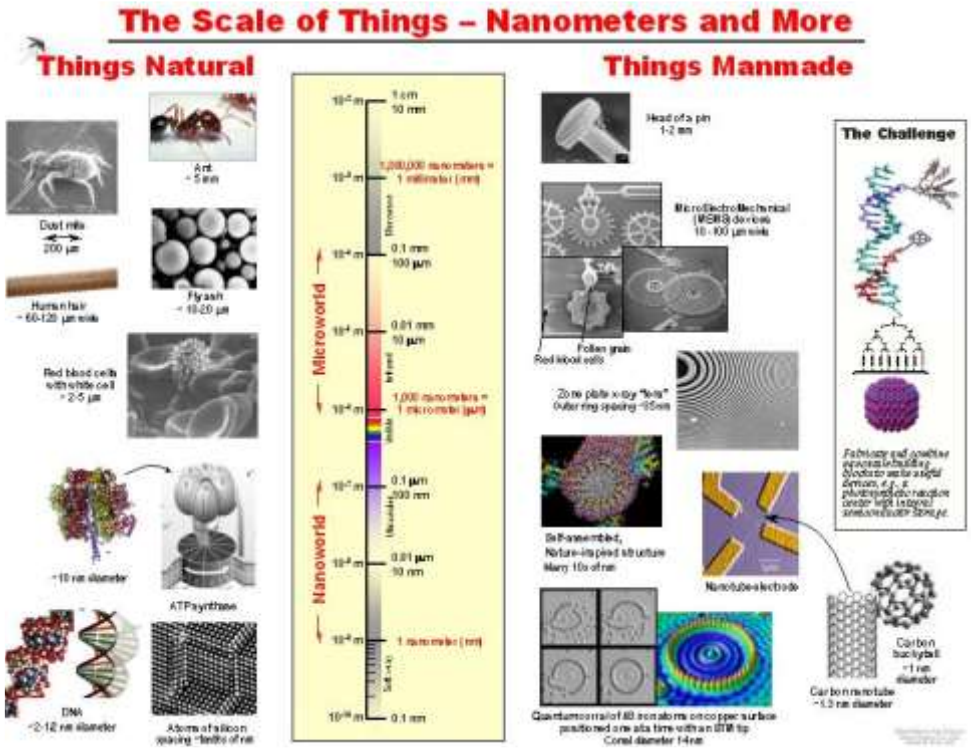
- Basic knowledge in the field of Nanotechnology
- Nanomaterials occur naturally but for particular interest those are Engineered Nanomaterials(EN), which are designed for and being used in many commercial products and processes.

Detailed content of the Lecture:

Thenanometrescaleisconventionallydefinedas1to100nm.Onenanometreisonebillionthofa metre(10-9 m).Thesizerangeissetnormallytobeminimum1nmtoavoidsingleatomsorverysmall groups of atoms being designated as nano-objects. Therefore nanoscience and nanotechnologies deal withatleastclustersofatomsof1nmsize.

Theupperlimitisnormally100nm,butthisisa“fluid”limit; often objects with greater dimensions (even 200nm) are defined asnanomaterials.




**Video Content / Details of website for further learning (if any):**

https://www.nap.edu/read/10395/chapter/3

**Important Books/Journals for further learning including the page nos.:**

**Nanotechnology, A Gentle Introduction to the Next Big idea- Mark Ratner,Daniel Ratner Page No.5-7**

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**LECTURE HANDOUTS**

**L 11**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE /21BSS03**

**Unit** : **II- Introduction to Nanotechnology** **Date of Lecture:**

**Topic of Lecture: Theory of Nanotechnology**

**Introduction :**

- Nanotechnology is the understanding and control of matter atdimensions of roughly 1 to 100 nanometers, where uniquephenomena enable novel applications."

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- In today's scientific, the word nano describes physical lengthscales that are on the order of a billionth of a meter long.
- Nanoscale materials therefore lie in a physical size regime between bulk, macroscale, materials (the realm of condensed matter physics) and molecular compounds (the realm of traditional chemistry).

**Detailed content of the Lecture:**

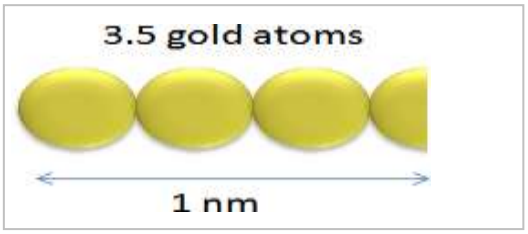
**THEORY OF NANOTECHNOLOGIES:**

"Encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale."

The most common working definition of nanoscience is the following:

"Nanoscience is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale" .

Bulk materials (the "big" pieces of materials we see around us) possess continuous (macroscopic) physical properties. The same applies to micron-sized material (e.g., a grain of sand). But when particles assume nano-scale dimension, the principles of classical physics are no longer capable of describing their behaviour (movement, energy, etc). At these dimensions, quantum mechanics principles apply. The same material (e.g., gold) at the nanoscale can have properties (e.g., optical, mechanical, electrical, etc.) which are very different from (even opposite to!) the properties the material has at the macro scale.




In today's scientific , the word nano describes physical lengthscales that are on the order of a billionth of a meter long. Nanoscale materials therefore lie in a physical size regime between bulk, macroscale, materials (the realm of condensed matter physics) and molecular compounds (the realm of traditional chemistry).

This mesoscopic size regime has previously been unexplored and beckons the researcher with images of a scientific wild west with opportunites abound for those willing to pack their wagons and head into the scientific and technological hinterland.

In this respect, nanoscale physics, chemistry, biology and engineering asks basic, yet unanswered, questions such as how the optical and electrical properties of a given material evolve from those of individual atoms or molecules to those of the parent bulk.

**Video Content / Details of website for further learning (if any):**

https://ntp.niehs.nih.gov/ntp/factsheets/nanocolor06srch.pdf

**Important Books/Journals for further learning including the page nos.:**

**Introduction to Nano science and Nanotechnology , Lusia Filippon and Duncan Page No.4-15**

**CourseFaculty**

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# MUTHAYAMMAL ENGINEERING COLLEGE

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

**LECTURE HANDOUTS**

**L 12**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **II- Introduction to Nanotechnology Date of Lecture:**

**Topic of Lecture: Surface to Volume Ratio**

**Introduction :**

- The surface area to volume ratio for a material or substance made of nanoparticles has a significant effect on the properties of the material.
- It means that the surface area to volume ratio increases as the radius of the sphere decreases and vice versa.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- To get the knowledge about the size of the material.
- Surface area to volume ratio in nanoparticles has a significant effect on the nanoparticles properties.

**Detailed content of the Lecture:**

The surface area to volume ratio for a material or substance made of nanoparticles has a significant effect on the properties of the material. It means that the surface area to volume ratio increases as the radius of the sphere decreases and vice versa.

Surface area to volume ratio in nanoparticles has a significant effect on the nanoparticles properties. Firstly, nanoparticles have a relative larger surface area when compared to the same volumeof the material.

**Surface to Volume Ratio for ICE cube:**

Surface-to-volume ratio is a very important characteristic of nanoparticles.

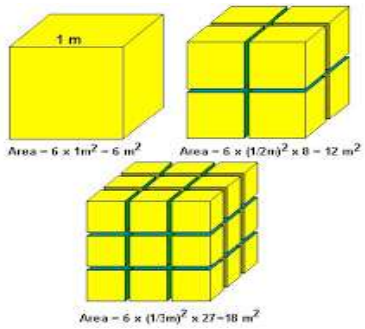
For example, imagine that you have a big block of ice with one-meter sides (Figure 1). This block has a surface area of 6 square meters (1 square meter on a side x 6 sides) and a volume of 1 cubic meter. In this case, the surface area to volume ratio for the ice block is 6/1 or 6.

Suppose that cut the ice into 8 pieces that are one-half of a meter per side. The surface area of each piece of ice would be 1.5 square meters (0.5 m x 0.5 m x 6 sides). So the total surface area of all the pieces would be 12 square meters. However, the total volume of ice would stay the same: we haven't

added or removed any ice. So in this case, the surface area to volume ratio is 12/1, or 12—twice the surface area to volume ratio of the block before it was cut. If you cut the ice into 27 pieces, the surface area increases to 18 square meters, and the surface area to volume ratio is 18/1 or three times that of the uncut block. If you keep going, and cut the ice into 1000 small pieces, the surface area to volume ratio is 60/1 or ten times that of the uncut block.

Imagine how big the surface area to volume ratio would be for something as small as a bunch of nanoscale particles.

The increased ratio of surface area to volume makes interactions between the surfaces of particles very important. If something has more surface area, there are more places for other chemicals to bind or react with it. For example, fine powders offer greater reaction speed because of the increased surface area. Think about how much faster you can cool a glass of water if you put crushed ice in it rather than ice cubes.




**Video Content / Details of website for further learning (if any):**

https://study.com/academy/lesson/surface-area-to-volume-ratio.html

**Important Books/Journals for further learning including the page nos.:**

Introduction to Nanoscience , student material Page no 1S3-S4

Ratio of surface to volume in nanotechnology and nanoscience, Peter I. Kattan Page No 3-5

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**LECTURE HANDOUTS**

**L 13**

**PHYSICS**

**I / II**

**Course Name with Code** **:BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** **: II-Introduction to Nanotechnology** **Date of Lecture:**

**Topic of Lecture:** Classification of nano structures based on dimension: 0D, 1D

**Introduction :**

- Classification is based on the number of dimensions, whichare not confined to the nanoscale range (<100nm).

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic Knowledge on Classification of nanomaterials which is based on the dimension.

**Detailed content of the Lecture:**

Classification is based on the number of dimensions, whichare not confined to the nanoscale range (<100nm).

- (1) zero-dimensional(0-D),
- (2) one-dimensional(1-D),
- (3) two-dimensional (2-D),and
- (4) three-dimensional(3-D).

**Zero-dimensional nanomaterials**

- Materials wherein all the dimensions are measured withinthe nanoscale (no dimensions, or 0-D, are larger than 100nm).
- The most common representation ofzero dimensional nanomaterials arenanoparticles.
- Be amorphous orcrystalline
- Be single crystalline orpolycrystalline
- Be composed of single or multi-chemicalelements
- Exhibit various shapes andforms
- Exist individually or incorporated in amatrix
- Be metallic, ceramic, orpolymeric

**One-dimensionalnanomaterials**

- One dimension that is outside thenanoscale.

- This leads to needle like-shapednanomaterials. 1-D materials include nanotubes, nanorods,and nanowires
- Amorphous orcrystalline
- Single crystalline orpolycrystalline
- Chemically pure orimpure
- Standalone materials or embedded in within anothermedium
- Metallic, ceramic, orpolymeric

**Video Content / Details of website for further learning (if any):**

**https://www.materialstoday.com/download/50948/**

**Important Books/Journals for further learning including the page nos.:**

Introduction To nanomaterials And nanotechnology-Vladimir Pokropivny Rynno Lohmus Irina HussainovaAlex Pokropivny, Page No: 14-16

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**LECTURE HANDOUTS**

**L 14**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE /21BSS03**

**Unit : II-Introduction to Nanotechnology Date of Lecture:**

**Topic of Lecture:**

Classification of nano structures based on dimension:2D, 3D

**Introduction :**

- Two of the dimensions are not confined to thenanoscale.
- Bulk nanomaterials are materials that are not confined to the nanoscale in any dimension.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic Knowledge on Classification of nanomaterials which is based on the dimension.

**Detailed content of the Lecture:**

**Two-dimensionalnanomaterials**

- Twoof the dimensions are not confined to thenanoscale.
- 2-D nanomaterials exhibit plate-likeshapes.
- Two-dimensionalnanomaterialsincludenanofilms, nanolayers, andnanocoatings.
- Amorphous orcrystalline
- Made up of various chemicalcompositions
- Used as a single layer or as multilayerstructures
- Deposited on asubstrate
- Integrated in a surrounding matrixmaterial
- Metallic, ceramic, orpolymeric

**Three-dimensionalnanomaterials**

- Bulk nanomaterials are materials that are not confined to the nanoscale in any dimension.These materials are thus characterized by having three arbitrarily dimensions above 100nm.
- Materials possess a nanocrystalline structure or involve the presence of features at thenanoscale.
- Intermsofnanocrystallinestructure,bulknanomaterialscanbe composed of a multiple arrangement of nanosize crystals, most typically in

differentorientations.

- With respect to the presence of features at the nanoscale, 3-D nanomaterials can contain dispersions of nanoparticles, bundles of nanowires, and nanotubes as well asmultinanolayers.

**Video Content / Details of website for further learning (if any):**

**https://www.materialstoday.com/download/50948/**

**Important Books/Journals for further learning including the page nos.:**

Introduction To nanomaterials And nanotechnology-Vladimir Pokropivny Rynno Lohmus Irina HussainovaAlex Pokropivny, Page No: 14-16

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**LECTURE HANDOUTS**

**L 15**

**PHYSICS**

**I / II**

**Course Name with Code** **:BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** **: II-Introduction to Nanotechnology** **Date of Lecture:**

**Topic of Lecture: Carbon and Diamond**

**Introduction :**

- The most known types of carbonmaterials: diamondgraphite; fullerenes; and carbon nanotubes

**Prerequisite knowledge for Complete understanding and learning of Topic:**

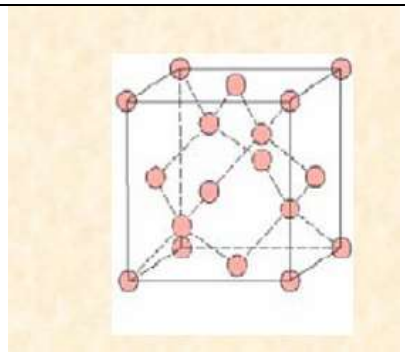
- Basic knowledge of nanomaterials of Carbon and Diamond

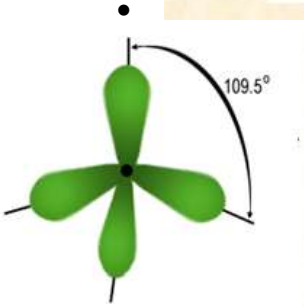
**Detailed content of the Lecture:**

- Carbon is a basic element oflife
- Carbon is special because of its ability tobond to many elements in many differentways
- It is the sixth most abundant element inthe universe
- The most known types of carbonmaterials: diamond; graphite; fullerenes; and carbon nanotubes

**Diamond**

- chemical bonding is purelycovalent
- highly symmetrical unitcell
- extremelyhard
- low electricalconductivity
- high thermal conductivity(superior)
- opticallytransparent
- used as gemstones and industrial grinding, machining andcutting






**Video Content / Details of website for further learning (if any):**

https://en.wikipedia.org/wiki/Allotropes_of_carbon

**Important Books/Journals for further learning including the page nos.:**

**Introduction Tonanomaterials Andnanotechnology**-Vladimir Pokropivny Rynno Lohmus Irina HussainovaAlex Pokropivny, Page No: 14-16

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**LECTURE HANDOUTS**

**L 16**

**PHYSICS**

**I / II**

**Course Name with Code** **:BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** **: II-Introduction to Nanotechnology** **Date of Lecture:**

**Topic of Lecture:**Graphite, Quantum Effect and Electron Confinement

**Introduction :**

- The overall behavior of bulk crystalline materials changes when the dimensions are reduced to thenanoscale.
- Easy interplanar cleavage, applications as a lubricant and for writing(pencils)
- Good electrical conductor

**Prerequisite knowledge for Complete understanding and learning of Topic:**

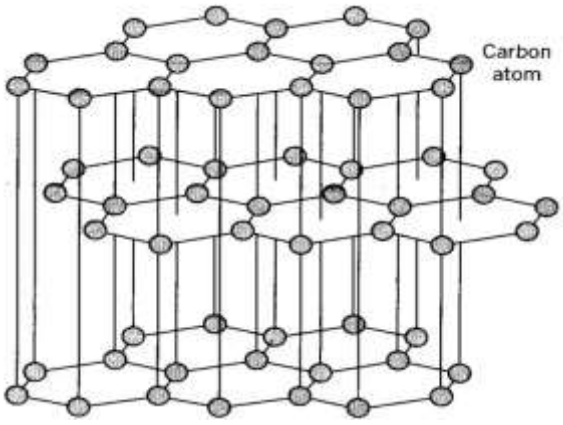
- .Basic knowledge about Graphite and Quantum effect and electron confinement

**Detailed content of the Lecture:**

**Graphite**

Layered structure with strong bonding within the planar layers and weak, van der Waals bonding betweenlayers

- Easy interplanar cleavage, applications as a lubricant and for writing(pencils)
- Good electricalconductor
- Chemically stable even at high temperatures
- Excellent thermal shock resistance




**Quantum Effect and Electron Confinement**

- The overall behavior of bulk crystalline materials changes when the dimensions are reduced to thenanoscale.
- For 0-D nanomaterials, where all the dimensions are at the nanoscale, an electron is confined in 3-D space. No electron delocalization (freedom to move)occurs.
- For 1-D nanomaterials, electron confinement occurs in 2-D, whereas delocalization takes place along the long axis of the nanowire/rod/tube.
- In the case of 2-D nanomaterials, the conduction electrons will be confined across the thickness but delocalized in the plane of thesheet.

- For 0-D nanomaterials the electrons are fullyconfined.
- For 3-D nanomaterials the electrons are fullydelocalized.
- In 1-D and 2-D nanomaterials, electron confinement and delocalizationcoexist.
- Theeffectofconfinementontheresultingenergystatescan be calculated by quantum mechanics, as the "particle in thebox"problem.Anelectronisconsideredtoexistinside of an infinitely deep potential well (region of negative energies),fromwhichitcannotescapeandisconfinedbythe dimensions of thenanostructure.

**Video Content / Details of website for further learning (if any):**

https://ec.europa.eu/health/scientific_committees/opinions_layman/en/nanotechnologies/l-3/1-introduction.html

**Important Books/Journals for further learning including the page nos.:**

Introduction nanotechnology ,Kazuo Igarashi Page No.10-12

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**LECTURE HANDOUTS**

**L 17**

**PHYSICS**

**I / II**

**Course Name with Code** **:BIO AND NANO MATERIALS SCIENCE /21BSS03**

**Unit** **: II-Introduction to Nanotechnology** **Date of Lecture:**

**Topic of Lecture:**

**Applications of Nanotechnology**-Medicine, Electronics, Agriculture, Fuel Cells

**Introduction :**

- Medicine
- Electronics
- Agriculture
- Fuel Cells
- Solar Cells
- Batteries

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Nanotechnology is being used in developing countries to help treat disease and prevent health issues.

**Detailed content of the Lecture:**

**Medicine:**

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). This technique reduces damage to healthy cells in the body and allows for earlier detection of disease.

**Electronics:**

- By reducing the size of transistors used in integrated circuits.
- Researchers are developing a type of memory chip with a projected density of one terabyte of memory per square inch and this increases the density of memory chips.

**Agriculture:**

Direct applications of nanotechnology in agriculture include delivery of agrochemicals and nutrition, pesticides,

**Fuel Cells:**

Nanotechnology is being used to reduce the cost of catalysts used in fuel cells to produce

hydrogen ions from fuel such as methanol and to improve the efficiency of membranes used in fuel cells to separate hydrogen ions from other gases such as oxygen.

**Solar Cells**

Nanotechnology might be able to increase the efficiency of solar cells, but the most promising application of nanotechnology is the reduction of manufacturing cost.

**Batteries**

Nanobatteries are fabricated batteries employing technology at the nanoscale, particles that measure less than 100 nanometers or $10^{-7}$ meters.

- These batteries may be nano in size or may use nanotechnology in a macro scale battery. Nanoscale batteries can be combined together to function as a macrobattery such as within a nanopore battery.
- Traditional lithium-ion battery technology uses active materials, such as cobalt-oxide or manganese oxide, with particles that range in size between 5 and 20 micrometers (5000 and 20000 nanometers – over 100 times nanoscale). It is hoped that nano-engineering will improve many of the shortcomings of present battery technology.

**Video Content / Details of website for further learning (if any):**

**https://www.understandingnano.com/nanotech-applications.html**

**https://www.intechopen.com/books/application-of-nanotechnology-in-drug-delivery/application-of-nanotechnology-in-drug-delivery**

**Important Books/Journals for further learning including the page nos.:**

Introduction Nanomaterials Engineering Stanko R. Brankovic Lecture notes

**Nanotechnology, A Gentle Introduction to the Next Big idea- Mark Ratner,Daniel Ratne Page no 64-78**

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**LECTURE HANDOUTS**

**L 18**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **II - Introduction to Nanotechnology** **Date of Lecture:**

**Topic of Lecture:** Applications of Nanotechnology-Space, Chemical Sensors, Sporting Goods, Fabric

**Introduction :**

- Space
- Chemical Sensors:
- Sporting Goods:
- Fabric

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Applications of nanotechnology in commercial products, although most applications are limited to the bulk use of passive nanomaterials.

**Detailed content of the Lecture:**

**Space**

Nanotechnology may hold the key to making space-flight more practical. Advancements in nanomaterials make lightweight spacecraft and a cable for the space elevator possible. By significantly reducing the amount of rocket fuel required, these advances could lower the cost of reaching orbit and traveling in space.

**Chemical Sensors:**

Nanotechnology can enable sensors to detect very small amounts of chemical vapors. Various types of detecting elements, such as carbon nanotubes, zinc oxide nanowires or palladium nanoparticles can be used in nanotechnology-based sensors. Because of the small size of nanotubes, nanowires, or nanoparticles, a few gas molecules are sufficient to change the electrical properties of the sensing elements. This allows the detection of a very low concentration of chemical vapors.

**Sporting Goods:**

Current nanotechnology applications in the sports arena include increasing the strength of tennis racquets, filling any imperfections in club shaft materials and reducing the rate at which air leaks from tennis balls.

**Fabric**

Making composite fabric with nano-sized particles or fibers allows improvement of fabric properties without a significant increase in weight, thickness, or stiffness as might have been the case with previously-used techniques.

**Video Content / Details of website for further learning (if any):**

**https://www.understandingnano.com/nanotech-applications.html**

**https://www.intechopen.com/books/application-of-nanotechnology-in-drug-delivery/application-of-nanotechnology-in-drug-delivery**

**Important Books/Journals for further learning including the page nos.:**

Introduction Nanomaterials Engineering Stanko R. Brankovic Lecture notes

**Nanotechnology, A Gentle Introduction to the Next Big idea- Mark Ratner,Daniel Ratne Page no 64-78**

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**LECTURE HANDOUTS**

**L 19**

**PHYSICS**

**I / II**

**Course Name with Code :BIO AND NANO MATERIALS SCIENCE /21BSS03**

**Unit : III–SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture:Introduction to Nanomaterials**

**Introduction :**

- Nanoparticles can be derived from larger molecules, or synthesized by "bottom–up" methods that, for example, nucleate and grow particles from fine molecular distributions in liquid or vapor phase.

  Synthesis can also include functionalization by conjugation to bioactive molecules. Synthesis of nanomaterials in high yield and low cost has been a great challenge since the very early development of nanoscience.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Application of the nanoparticles in medicine depends on the ability to synthesize particles with different shape, monodispersity, chemical composition, and size.

**Detailed content of the Lecture:**

- Methods to Synthesis of Nanomaterials In general, top-down and bottom-up are the two main approaches for nanomaterials synthesis.
- Top-down: size reduction from bulk materials.
- Bottom-up: material synthesis from atomic level.

Top-down:

- Producing very small structures from larger pieces of material. One way of acheving this is mechanical crushing of solid into fine nano powder e.g. ball milling

Bottom-up:

- The atoms or molecules array themselves into a structure due to their natural properties(In bottom-up stratergy, structures are built up by chemical process) e.g: crystal grown

## ➢ Top-down:

Producing very small structures from larger pieces of material. One way of acheving this is mechanical crushing of solid into fine nano powder e.g. ball milling

In this process, the bulk materials are broken into nano sized particle . Top-down routes are included in the typical solid –state processing of the materials. This route is based with the bulk material and makes it smaller, thus breaking up larger particles by the use of physical processes like crushing,

milling or grinding. Usually this route is not suitable for preparing uniformly shaped materials, and it is very difficult to realize very small particles even with high energy consumption. The biggest problem with top-down approach is the imperfection of the surface structure. Such imperfection would have a significant impact on physical properties and surface chemistry of nanostructures and nanomaterials. It is well known that the conventional top-down technique can cause significant crystallographic damage to the processed patterns.

## ➢ Bottom-up:

The atoms or molecules array themselves into a structure due to their natural properties(In bottom-up stratergy, structures are built up by chemical process) e.g: crystal grown

In this procsess, nano materials are produced by building of atom by an atom . Bottom –up approach refers to the build-up of a material from the bottom: atom-by-atom, molecule-by-molecule or cluster-by-cluster. This route is more often used for preparing most of the nano-scale materials with the ability to generate a uniform size, shape and distribution. It effectively covers chemical synthesis and precisely controlled the reaction to inhibit further particle growth. Although the bottom-up approach is nothing new, it plays an important role in the fabrication and processing of nanostructures and nano materials.There are many methods of synthesizing materials, Chemical vapour depositin , electrodeposition method ,Ball Milling technique , pulsed laser deposition method.

**Video Content / Details of website for further learning (if any):**

https://www.investopedia.com/articles/investing/030116/topdown-vs-bottomup.asp

https://en.wikipedia.org/wiki/Top-down_and_bottom-up_design

**Important Books/Journals for further learning including the page nos.:**

Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.5.

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**LECTURE HANDOUTS**

**L 20**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III – SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture:Difference between Top down and Bottom up process**

**Introduction :**

- Breaks the massive problem into smaller subproblems.
- Solves the fundamental low-level problem and integrates them into a larger one.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Producing very small structures from larger pieces of material. One way of acheving this is mechanical crushing of solid into fine nano powder e.g. ball milling
- The atoms or molecules array themselves into a structure due to their natural properties(In bottom-up stratergy, structures are built up by chemical process) e.g: crystal grown

**Detailed content of the Lecture:**

## Difference between Top-down and Bottom-up approach in nanotechnology

1. Manufacturing process starts from larger structures in top-down approach where starting building blocks are smaller than the final design in bottom-up approach

2. Bottom-up manufacturing can produce structures with perfect surfaces and edges (not wrinkly and does not contain cavities etc.) though surfaces and edges resulted by top-down manufacturing are not perfect as they are wrinkly or containing cavities.

3. Bottom-up approach manufacturing technologies are newer than top-down manufacturing and expected to be an alternative for it in some applications (example: transistors).

4. Bottom-up approach products have a higher precision accuracy (more control over the material dimensions) and therefore can manufacture smaller structures compared to top-down approach.

5. In top-down approach there is a certain amount of wasted material as some parts are removed from the original structure contrast to bottom-up approach where no material part is removed.

| |
|---|
| **Video Content / Details of website for further learning (if any):**<br>https://www.thecrazyprogrammer.com/2018/10/difference-between-top-down-and-bottom-up-approach.html |
| **Important Books/Journals for further learning including the page nos.:**<br>Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.5 |

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**LECTURE HANDOUTS**

**L 21**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III – SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture: ELECTRO DEPOSITION METHOD**

**Introduction :**

This principle is used for the deposition of nanosized particles.

- Nanostructured films of copper , platinum , nickel, gold, etc.. can be produced by this electro deposition method.
- These nano films have very wide range of applications such as batteries, fuel cells, solar cells, magnetic read heads.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

For example pure silver (Ag) is taken as anode and another metal or conducting material is taken as cathode. These two electrodes are placed in $AgNo_3$ solution. When the current is passed through the solution, the following reaction takes place.

$AgNo_3$ ----------> $Ag+ + NO_3-$

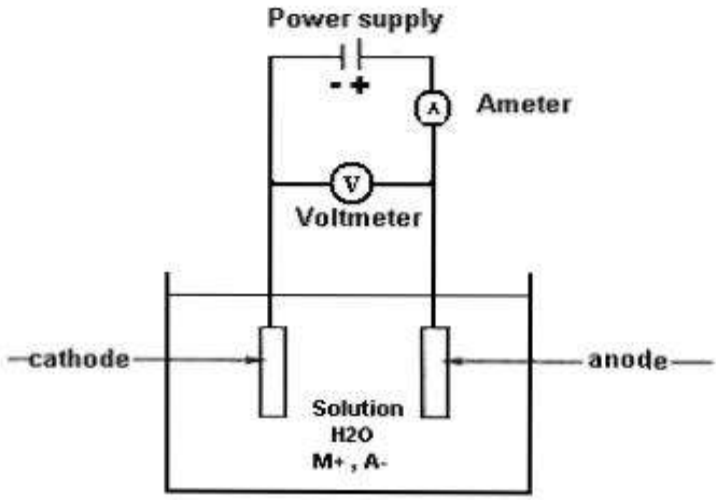
**Detailed content of the Lecture:**

This technique is used generally in electroplating and in the production of nano- films.

The electrode position process is also known as electroplating and is restricted to electrically conductive materials. ELECTRO deposition is made either by electroplating or electroless plating. When current is passed through the electrodes immersed in the electrolyte, certain mass of the substance liberated at one electrode and gets deposited on the surface of the other.

DESCRIPTION AND WORKING

In the electroplating process the substrate is placed in the electrolyte solution and is connected with external potential. For the supply of external potential one additional electrode is also connected. An electric potential is applied between a conducting areas on the substrate. The chemical process takes place results a formation of thin layer on the thin films deposited over the substrate can be controlled by adjusting the applied potential.




The electro deposition process is more suitable to make the films of metals such as copper or gold with a thickness ranging from 1 um to 100 um. The deposition is controlled by an external electric potential. Nanostructured film of copper, platinum,nickel,etc can be produced by this method.

Also in The electro less plating process, the chemical solution only is used. The deposition of thin layer forms spontaneously on any surface which forms a high electrochemical potential with the solution. This process is more desirable since it does not require any external electric potential and contact to the substrate during processing. The main disadvantage of this technique is it difficult to control the film thickness and uniformity.

**Video Content / Details of website for further learning (if any):**

https://nanoyou.eu/attachments/188_Module-1-chapter-7-proofread.pdf

**Important Books/Journals for further learning including the page nos.:**

Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.14

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**LECTURE HANDOUTS**

**L 22**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III – SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture:PLASMA ARCING METHOD**

**Introduction :**

- This technique is used for the production of nanoparticles by generating plasma using heating coils at radio frequency.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- This method is widely used to produce fullerens and carbon nano tubes.
- To produce the plasma (ionized gas) inside the chamber a potential difference is applied the electrodes.

**Detailed content of the Lecture:**

Description:

The experimental setup consists of chamber which is highly evacuated. The chamber is surrounded by means of high voltage RF coil. The starting metal from which the nanoparticles to be produced is taken in a container and then placed inside the chamber. Above the starting material a cold collector rod is provided for the collection of nano particles.the starting materials and the collecting rod are acts as electrodes. To produce the plasma (ionized gas) inside the chamber a potential difference is applied the electrodes.

**Working:**

The chamber is initially vacuumized and filled with helium gas for ionization. When the potential difference is applied across the electrodes, an arc is produced from one electrode (starting metal-anode) and reaching the other electrode (collector rod-cathode). Now the helium gas is allowed to pass through the molten metal.

The electrons emitted from the anode plate by means of potential are passes through the ionized gas (plasma). While the electrons are passed through the ionized gas , the process of nucleation starts and it diffuses towards the cold collector rod.

Quenching can be done using inert gases such as Ar or $N_2$ depending on the type of nano powder to be synthesized. This technique is used to produce carbon nanotubes.

| |
|---|
| **Video Content / Details of website for further learning (if any):**<br>https://www.google.com/search?q=plasma+arcing+method&oq=plasma+arcing+meth |
| **Important Books/Journals for further learning including the page nos.:**<br>Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.8 |

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**LECTURE HANDOUTS**

**L 23**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III – SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture: BALL MILLING** Method

**Introduction :**

In ball milling, small hard balls are allowed to rotate inside a container (drum)and then it is made to fall on a solid with high force to crush the solid into nano crystal

**Prerequisite knowledge for Complete understanding and learning of Topic:**

A variety of intermetallic compounds of nickel and aluminium can be formed.

The ball mill is key equipment for regrinding, it is widely used for the preparation of cement the silicate product, new type building materials , fire – proof materials, chemical fertilizer, black and non ferrous metal, glass ceramics, etc.

**Detailed content of the Lecture:**

Construction and Working:

The hardened steel or tungsten carbide balls are put in a container as shown in fig.(a) along with powder of particles(<50µm)of a desired material. The container is closed with tight lids.

When the container is rotating around the central azis, the material is forced to press against the walls. The milling balls impart energy on collision and produce smaller grain size of nano particle.

Ball milling is also known as mechanical alloying or crushing.

Advantages:

Few milligram to several kilograms of nanoparticles can be synthesized in a short time.

This technique can be operated at large scale.

Applications:

This method is preferred mainly in the preparation of elemental and metal oxide nano crystals like co, cr, Al-Fe and iron.

**Video Content / Details of website for further learning (if any):**

https://scholar.google.co.in/scholar?q=ball+milling+method&hl=en&as_sdt=0&as_vis=1&oi=scholart

**Important Books/Journals for further learning including the page nos.:**

Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.6

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**LECTURE HANDOUTS**

**L 24**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III – SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture: CHEMICAL VAPOUR DEPOSITION (CVD) METHOD**

**Introduction :**

In this technique, initially the materials is heated to gaseous state and then it is deposited on a solid surface under vavuum condition to form nano powder after chemical reaction with the substrate.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

The deposition of nano films from gaseous phase by chemical reaction on high temperature is know as **chemical vapour deposition**. The fundamental principle of the process is that a chemical reaction takes place between the source gases at high temperature and the nano films are deposited. The CVD process produce layers with excellent uniformity of thickness and material characteristics.This method is used to prepare nano powder.

**Detailed content of the Lecture:**

Description:

The chemical vapour deposition technique consists of a reactor made of quartz within which the nanoparticles are deposited. The substrate (wafer) is placed inside the reactor of which a number of gases are supplied.

The product of the reaction is a solid material with condenses on all surfaces inside the reactor. Thermal decomposition of gas phase is takes place at higher temperature between 500°C-1000°C and the subsequent deposition onto a substrate is made possible at a slow deposition rate. The reactor consists of a wafers arranged parallel to one another for deposit the thin films. In this technique the films are deposited on both sides of at least 25 wafers at a time .

WORKING

The reactor is initially evacuated by using the pump and thus the required gases (sources) are allowed inside the reactor through the inlet. Suitable environment is produced for the deposition process by adjusting the temperature with the help of furnace. The gas passes through the inlet of reactor contains diffused reactants (substance to be deposited in the vapour).

When the gas flows over the hot solid surface, the heat energy increases the reaction of the reactants. The process of deposition of nanoparticles started at the faces of the wafers. Large variety of materials can be deposited with this technology however some of them are less popular

because of hazardous byproducts formed during processing. The quality of the material varies from process to process whereas higher process temperature yields high quality materials with fewer defects. In several CVD processes, catalysts are employed to enhance the rate of certain chemical reaction.

Advantages of CVD:

- ✓ Deposition is not limited to line of sight
- ✓ The CVD method is used to produce defect free nanoparticles.
- ✓ Due to the simplicity of the experiment, the scaling up of the unit for mass production in industry is achieved without any major difficulties.
- ✓ Coatings of up to several centimeters can be realized
- ✓ Ultra high vacuums are not necessary
- ✓ Codeposition of elements or compounds is achievable Disadvantages.
- ✓ Use of high temperatures (>600$^{O}$C)
- ✓ Requirements of chemical precursors with high vapour pressure and toxicity.

**Video Content / Details of website for further learning (if any):**

https://en.wikipedia.org/wiki/Chemical_vapor_deposition

**Important Books/Journals for further learning including the page nos.:**

Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.10

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**LECTURE HANDOUTS**

**L 25**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III – SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture:PULSED LASER DEPOSITION Method**

**Introduction :**

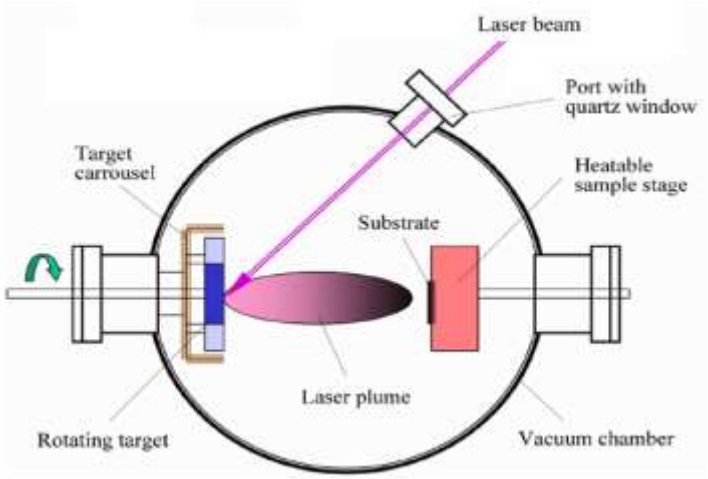
Pulsed laser Deposition (**PLD)** is a thin film deposition technique, where a high power pulsed laser beam is focused inside a vacuum chamber to strike a target material. The high power laser pulse is used to melt, evaporate and ionize the material from the surface of a target

**Prerequisite knowledge for Complete understanding and learning of Topic:**

The ablated material is collected by the substrate (such as a silicon wafer facing the target) upon which it condenses and the thin grows. This process can occur in ultra high vacuum or in the presence of a background gas, such as oxygen.

**Detailed content of the Lecture:**

Generally, **PLD** is an extremely simple technique**,** which uses pulses of laser energy to remove material from the surface of a target. The vaporized material, containing ions, electrons etc., Is known as laser-produced plasma plume expands rapidly away from the target surface.




**Pulse laser deposition**

- When the laser pulse is absorbed by the target, energy is first converted to electronic excitation and then into thermal, chemical and mechanical energy resulting evaporation.

- The ablation of the target material due to incident laser beam and the creation of plasma are very complex processes. The removal of atoms from the bulk material is done by vaporization of the bulk at the surface region.
- The free electrons oscillate within the electromagnetic field of the laser light and can collide with the atoms of the bulk material thus transferring some of their energy to the lattice of the target material within the surface region. The surface of the target is then heated up and the material is vaporized.
- The material expands in a plasma move towards the substrate. The distribution of the plume is dependent on the background pressure inside the vacuum chamber.
- The high energy particles ablated from the target are bombarding the substrate surface and may cause damage to the surface by sputtering off atoms from the surface. The sputtered particles from the substrate and the particles emitted from the target from a collision region, which serves as a source for condensation of particles.
- When the condensation rate is high enough, the film grows on the substrate surface at the expense of the direct flow of ablation particles.
- The plasma plume created during the laser ablation process is forward directed, therefore the thickness of material collected on a substrate is highly non-uniform and the composition can vary across the film. The area of deposited material is also quite small.

**Video Content / Details of website for further learning (if any):**

https://andor.oxinst.com/learning/view/article/pulsed-laser-deposition

**Important Books/Journals for further learning including the page nos.:**

Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.13

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**LECTURE HANDOUTS**

**L 26**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III – SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture: PLASMA ARCING METHOD**

**Introduction :**

- This technique is used for the production of nanoparticles by generating plasma using heating coils at radio frequency.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- This method is widely used to produce fullerens and carbon nano tubes.
- To produce the plasma (ionized gas) inside the chamber a potential difference is applied the electrodes.

**Detailed content of the Lecture:**

Description:

The experimental setup consists of chamber which is highly evacuated. The chamber is surrounded by means of high voltage RF coil. The starting metal from which the nanoparticles to be produced is taken in a container and then placed inside the chamber. Above the starting material a cold collector rod is provided for the collection of nano particles.the starting materials and the collecting rod are acts as electrodes. To produce the plasma (ionized gas) inside the chamber a potential difference is applied the electrodes.

**Working:**

The chamber is initially vacuumized and filled with helium gas for ionization. When the potential difference is applied across the electrodes, an arc is produced from one electrode (starting metal-anode) and reaching the other electrode (collector rod-cathode). Now the helium gas is allowed to pass through the molten metal.

The electrons emitted from the anode plate by means of potential are passes through the ionized gas (plasma). While the electrons are passed through the ionized gas , the process of nucleation starts and it diffuses towards the cold collector rod.

Quenching can be done using inert gases such as Ar or $N_2$ depending on the type of nano

| |
|---|
| powder to be synthesized. This technique is used to produce carbon nanotubes. |
| **Video Content / Details of website for further learning (if any):**<br>https://www.thecrazyprogrammer.com/2018/10/difference-between-top-down-and-bottom-up-approach.html |
| **Important Books/Journals for further learning including the page nos.:**<br>Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.10 |

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**LECTURE HANDOUTS**

**L 27**

**PHYSICS**

**I / II**

**Course Name with Code : BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit : III– SYNTHESIS OF NANOMATERIALS Date of Lecture:**

**Topic of Lecture: PROPERTIES AND APPLICATIONS OF NANOPARTICLES**

**Introduction :**

The properties on nanomaterials depend on the size of the nanoparticles that constitute the material. There is a possibility of a producing new material with unique properties by controlled the size of nanoparticles.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- ✓ When the crystalline grains are made very smaller to the nanoscale size, the interface area within the increases and it enhances its strength.

**Detailed content of the Lecture:**

- ✓ The cutting tools made of non crystalline materials are much harder and last longer.
- ✓ For the miniaturization of micro electronic circuits, micro drills ( diameter less than 100um) are required in industries. The strong and hard nanocrystallinecarbidesare used for these micro drills.
- ✓ Foam like structures of nanocrystalline material called aerogel is being used for insulation in offices and homes. Since they are porous and air is trapped inside, it had more after advantage as than the polyurethane foams.
- ✓ Nanocrystalline ceramics such as silicon nitride and silicon carbide are used in automotive applications as high strength springs and ball bearings.
- ✓ Nanocrystallinematerials are used in electrochromic display devices. This display device is similar to liquid crystal display used in calculators and watches.
- ✓ NanocrystallineYittrium-Samarium-Cobalt grains possess some special properties and are used in power generators, motors for ships and magnetic resonance imaging (MRI).
- ✓ Since the nanomaterials are stronger it can be operated at higher temperature and reduction in grains size of the nanomaterials provides higher fatigue life. This property leads the application in aircrafts.
- ✓ The nanophasemagnetic material are used in the in the devices like nantransistors, memory

devices such as recording heads, magnetic storages etc.,

- ✓ Nanophase materials are used for manufacturing small sized miniaturized antennas having large band width, tenability and mechanical flexibility

**Video Content / Details of website for further learning (if any):**

http://ocw.uc3m.es/ciencia-e-oin/materials-science-and-engineering/lecture-notes-_1/Chapter_1_2.pdf

**Important Books/Journals for further learning including the page nos.:**

Engineering Physics II by Dr.P.MANI, R.N.JAYAPRAKASH Page No.7.16

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**LECTURE HANDOUTS**

**L 28**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV- Introduction to Materials** **Date of Lecture:**

**Topic of Lecture :** Postulates of Rutherford atom model

**Introduction :**

- Rutherford performed a number of experiments on the scarierity of a particles passed through the gold foil.
- It was found that more of a particle passed through the gold foil without being deflected, but source of them were deflected through large angle.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Electron revolve in orbit
- Force of attraction between electron and nucleus
- Central petal force and centre fugal force

**Detailed content of the Lecture:**

**Postulates of Rutherford atom model**

- The atom has a small, positively charged nucleus. All positive charges of on atom and most of the mass of an atom are concentrated in the nucleus.
- The electrons round the nucleus at some distance away just planer round. The electron resolving in a closed orbit of radius 'r' with constant valuation 'v'. The system in subjected to two different forces.
- The centrifugal force area is balances by the force of electrostatic as reaction between the nucleus and electrons.
- The electrostatic force acting inwards in give by Coulomb's Law:

$$f_e = \frac{(Z_e)e}{4\pi\varepsilon_\circ r^2}$$

Here $\varepsilon_0$ is permittivity of force space

- The other force acting outwards called centrifugal force as given as :

- $f_c = \frac{mv^2}{r}$

Where m is the mass of an electron. $r^2/r$ is radical acceleration. Hence the

Condition foe orbit Stability is $f_e = f_c$.

$$\frac{mr^2}{r} = \frac{(Z_e)^2}{4\pi\varepsilon_\circ r^2}$$

**Video Content / Details of website for further learning (if any):**

https://www.toppr.com/guides/chemistry/structure-of-atom/rutherfords-model-of-an-atom/https://study.com/academy/lesson/rutherford-model-of-the-atom-definition-diagram-quiz.html

**Important Books/Journals for further learning including the page nos.:**

Solid state physics by S.O.Pillai Page No. 3

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**LECTURE HANDOUTS**

**L 29**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:** Postulates of Bohr's atom model

**Introduction :**

- Bohr assumed basically Rutherford nuclear model of the atom and tried to overcome the defers of the model.
- Electron motion in an atom

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Condition for electron revolve in the same orbit
- Emission of radiation

**Detailed content of the Lecture:**

**Bohr's atom model**

An electron in an atom move in a Circular orbit about the nucleus under the influence of Coulomb's force of attraction between electron and nucleus. The centrifugal force. Thus we have

$$\frac{mr^2}{r} = \frac{{Z_e}^2}{4\pi\varepsilon_\circ r^2}$$

An electron cannot revolve round the nucleus in all possible orbits as suggested by classical theory. It can revolve only in some permitted orbits. While moving round the nucleus the electrons does not radiate energy, that the orbits are called stationary orbits.

The electrons can revolve round the nucleus only ion those permitted orbits for which the angular momentums of the electron in an integral multiple of h/20.

Where ʎ is Planck's constant.

An atom radiates energy only when an electron jumps from a stationary orbit of higher energy to a lower energy. The energy is given by the relation,

$$h\gamma = E_i - E_f$$

Where $\gamma$ is frequency of radiation $E_i$ is the energy of initial orbit,

$E_f$ is the energy of final orbit.

**Video Content / Details of website for further learning (if any):**

https://www.toppr.com/guides/chemistry/structure-of-atom/bohrs-model-of-atom/http://abyss.uoregon.edu/~js/glossary/bohr_atom.html

**Important Books/Journals for further learning including the page nos.:**

Solid state physics by S.O.Pillai Page No.4

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**LECTURE HANDOUTS**

**L 30**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:**Bohr's Theory of Hydrogen atom

**Introduction :**

- The Total energy of the electron in any orbit is the sum of its kinetic and potential energies. The potential energy of the electron is considered to be zero when it is at infinite distance from the nucleus.
- The angular momentum of an electron in a permitted orbit must be an integral multiple of $\frac{h}{2\pi}$ .

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- The electron has minimum energy when n=1 in the inner most orbit.
- The valuation of electron is inversely proportional to the principal quantum number n.

**Detailed content of the Lecture:**

**Bohr's Theory of Hydrogen atom**

According to Bohr's Postulate, We have,

$$\frac{mv^2}{r} = \frac{(Z_e)e}{4\pi\varepsilon_\circ r^2}$$

$$mrv^2 = \frac{{Z_e}^2}{4\pi\varepsilon_\circ} \rightarrow (1)$$

$$mvr = \frac{nh}{2\pi} \text{ or } v = \frac{nh}{2\pi mr} \rightarrow (2)$$

$$v^2 = \frac{n^2h^2}{4\pi^2m^2r^2} \rightarrow (3)$$

Or, $r = \frac{n^2 h^2 \varepsilon_\circ}{\pi Z_e^{\,2} \; m} \rightarrow (4)$

$r_n = \frac{n^2 h^2 \varepsilon_\circ}{\pi \;\; e^{\,2} \;\; m} (\therefore z = 1$ for hydrogen$) \rightarrow (5)$

$v \;\; = \frac{e}{2n \; h \;\; \varepsilon_\circ} \qquad \rightarrow (6)$

Equ (6) shown clearly that the valuation of electron is inversely proportional to the principal quantum number n.

Thus electron moves at a lower speed in higher orbits and vice-versa.

**Video Content / Details of website for further learning (if any):**https://www.khanacademy.org/science/physics/quantum-physics/atoms-and-electrons/a/bohrs-model-of-hydrogen

https://users.physics.ox.ac.uk/~smithb/website/coursenotes/qi/QILectureNotes2.pdf

**Important Books/Journals for further learning including the page nos.:**

Solid state physics by S.O.Pillai Page No.5

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**LECTURE HANDOUTS**

**L 31**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:**Bohr's Theory of Hydrogen atom

**Introduction :**

- The Total energy of the electron in any orbit is the sum of its kinetic and potential energies. The potential energy of the electron is considered to be zero when it is at infinite distance from the nucleus.
- The angular momentum of an electron in a permitted orbit must be an integral multiple of $\frac{h}{2\pi}$.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- The electron has minimum energy when n=1 in the inner most orbit.
- The valuation of electron is inversely proportional to the principal quantum number n.

**Detailed content of the Lecture:**

**Bohr's Theory of Hydrogen atom**

According to Bohr's Postulate, We have,

$$\frac{mv^2}{r} = \frac{(Z_e)e}{4\pi\varepsilon_\circ r^2}$$

$$mrv^2 = \frac{{Z_e}^2}{4\pi\varepsilon_\circ} \rightarrow (1)$$

$$mvr = \frac{nh}{2\pi} \text{ or } v = \frac{nh}{2\pi mr} \rightarrow (2)$$

$$v^2 = \frac{n^2h^2}{4\pi^2m^2r^2} \rightarrow (3)$$

$$\text{Or, } r = \frac{n^2h^2\varepsilon_\circ}{\pi {Z_e}^2 m} \rightarrow (4)$$

$$r_n = \frac{n^2 h^2 \varepsilon_\circ}{\pi \quad e^2 \quad m} \; (\therefore z = 1 \text{ for hydrogen}) \rightarrow (5)$$

$$v \quad = \frac{e}{2n\,h \quad \varepsilon_\circ} \qquad \rightarrow (6)$$

Equ (6) shown clearly that the valuation of electron is inversely proportional to the principal quantum number n.

Thus electron moves at a lower speed in higher orbits and vice-versa.

**Video Content / Details of website for further learning (if any):**https://www.khanacademy.org/science/physics/quantum-physics/atoms-and-electrons/a/bohrs-model-of-hydrogen

https://users.physics.ox.ac.uk/~smithb/website/coursenotes/qi/QILectureNotes2.pdf

**Important Books/Journals for further learning including the page nos.:**

Solid state physics by S.O.Pillai Page No.5

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**LECTURE HANDOUTS**

**L 32**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:**: Secondary bonds or Vander Waals Bonding

**Introduction :**

1. Secondary bonds are weak in comparison to primary bonds.

2. Hydrogen bonding is the strongest form of secondary bonding

3. Molecular bonding atomic structure

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Strengthen of materials
- Molecular interaction
- Sharing of ions

**Detailed content of the Lecture:**

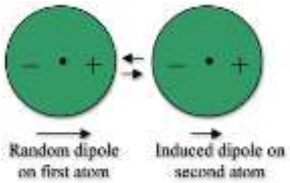
**Van Der Waals Bonding**

Secondary bonds are not bonds with a valence electron being shared or donated. They are usually formed when an uneven charge distribution occurs, creating what is known as a dipole (the total charge is zero, but there is slightly more positive or negative charge on one end of the atom than on the other).

These dipoles can be produced by a random fluctuation of the electrons around what is normally an electrically symmetric field in the atom.

Once a random dipole is formed in one atom, an induced dipole is formed in the adjacent atom.

This is the type of bonding present in N2 molecules, and is known as Van Der Waals Bonding.

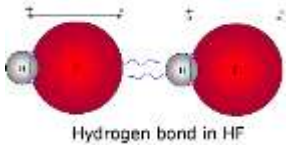



**Hydrogen Bonding**

Molecules with a permanent dipole can either induce a dipole in adjacent electrically symmetric molecules, or thus form a weak bond, or they can form bonds with other permanent dipole molecules.

Hydrogen bonding is the strongest form of secondary bonding and is formed from the polar nature of molecules containing hydrogen.

The hydrogen side of the molecule is more positive than the atom it is bonded to, allowing an attraction to form with the negative end of another molecule.



Hydrogen bond in HF

**Video Content / Details of website for further learning (if any):**

http://www.materials.unsw.edu.au/tutorials/online-tutorials/1-van-der-waals-bondinghttp://www.engineeringenotes.com/engineering/solids/bonds-in-solids-primary-and-secondary-engineering/42425

**Important Books/Journals for further learning including the page nos.:**

Solid state physics by S.O.Pillai Page No.74,75

Solid state physics by Gupta and Kumar Page No.130,134

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**LECTURE HANDOUTS**

**L 33**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:** Classification of Materials-Metals and their property

**Introduction :**

**1.** Classification of Materials

2. Types of metals

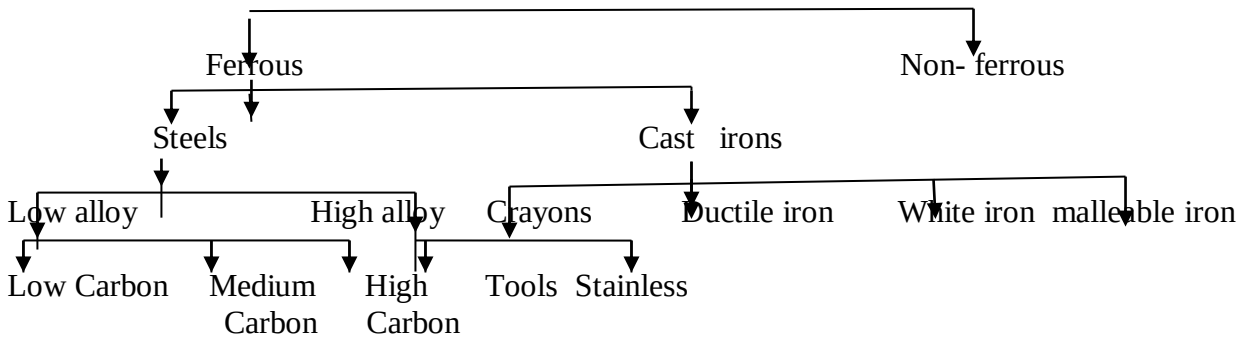
3.Properties of metals

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Internal structure of metals and their properties.
- Roll of metalsin engineering field.
- Mechanical, thermal, chemical, electrical and radiation properties.

**Detailed content of the Lecture:**

**Metals:**




- Metals are composed of elements which reading give up electrons to provide a metallic based for conductivities.
- Metals are generally classifiedinto ferrous and Non-ferrous materials.

**<u>Ferrous materials</u>**

- A ferrous material contains iron. They have small amount of other metals added to give the required properties.
- Ferrous materials are the most important metals in the mechanical industry because of their important application.

**Properties of metals**

- They are good conductors of heat and electric ties making valuable in electrical appliances and for carrying electric current over a distance with minimum energy loss.
- They have high resistant to shear, torque and deformation.
- Thermal conductivities in useful for containers to heat materials over a flame.
- They posses' magnetic properties and it make corrosion.
- Metals are shiny when scratched or polished.
- Metals are strange but malleable, easily based or shaped.
- It has high melting point.
- This can be drawn into thin wire.

**Video Content / Details of website for further learning (if any):**

https://www.morecambemetals.co.uk/different-metals-and-their-properties/https://maritime.org/doc/pdf/metal-properties.pdf

**Important Books/Journals for further learning including the page nos.:**

Material science and metallurgical engineering by O.P.Khanna Page No.5-1,6-1

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

**LECTURE HANDOUTS**

**L 34**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:** Ceramic and composite materials and their properties.

**Introduction :**

**1.** Classification of Ceramics

2. Types of composite

3.Properties of Ceramics and Composite

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Structure of ceramics and their properties.
- Roll of composite materialsinvariousfield.
- Mechanical, thermal, chemical, electrical and radiation properties.

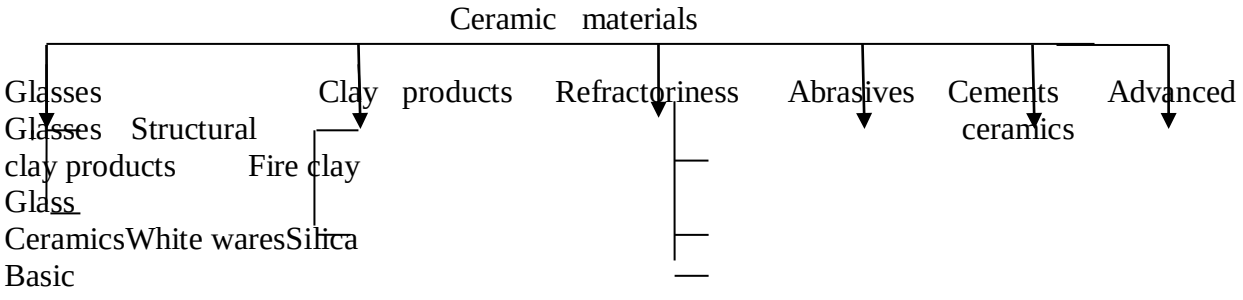
**Detailed content of the Lecture:**

**Ceramic Materials**

Earlier the term Ceramics was applied to products make from natural earth that have been Explored to high temperature.

- Ceramic covers indent group of products of industries , including glasses ,refraction, cornets, liners and plasters, structural clay products , white wares and abrasions.
- Ceramic are inorganic, non-metallic materials that are used of higher temperature. They have been subjected to heat treatment.
- They are generally brittle materials.

**Types of ceramics**



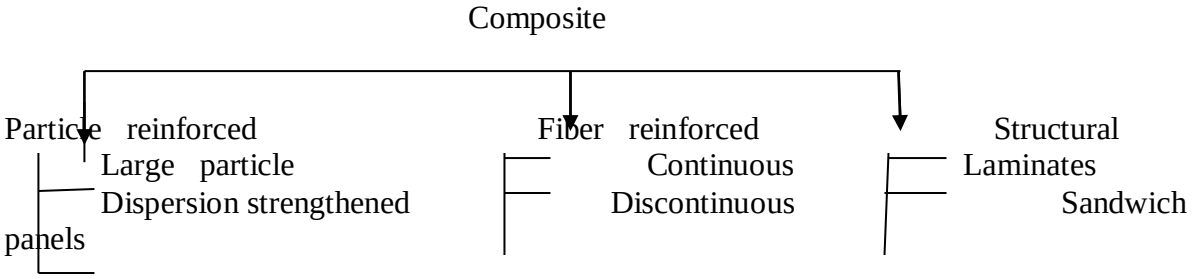

General properties of ceramics materials

1. Mechanical properties:
2. Electrical properties:
3. Chemical properties:

**Composite Materials**

Composite materials are produced by combination of two dissimilar materials into a new material that may be better suited for a particular application than the original materials alone.

Classification of composite materials:




**Video Content / Details of website for further learning (if any):**

https://www.sciencedirect.com/topics/materials-science/ceramic-

compositehttps://www.ceramtec.com/mmc-metal-ceramic-composite-materials/

**Important Books/Journals for further learning including the page nos.:**

Material science and metallurgical engineering by O.P. Khanna Page No.16-2,23-2

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**LECTURE HANDOUTS**

**L 35**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:** Phase diagram

**Introduction :**

- Phase diagram is a graphical representation of the physical states of a substance under different conditions of temperature and pressure

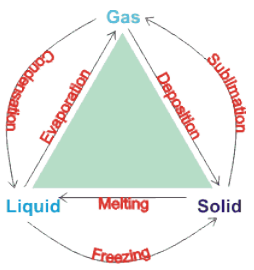
**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Phase diagrams are specific for each substance and mixture.
- Complex mixtures may require three-dimensional phase diagrams, which can be represented in two dimensions through use of perspective.
- Phase diagrams are widely used in studies of mineral equilibriums in connection with the conditions of formation of rocks and minerals within the Earth.

**Detailed content of the Lecture:**

**Phase diagram**

- A phase diagram is a chart showing the thermodynamic conditions of a substance at different pressures and temperatures. The regions around the lines show the phase of the substance and the lines show where the phases are in equilibrium.Phase diagrams show the preferred physical states of matter at different thermodynamic variables, such as temperatures and pressure. Within each phase, the material is uniform with respect to its chemical composition and physical state.




- Typically, a phase diagram includes lines of equilibrium or phase boundaries. On these lines, multiple phases of matter can exist at equilibrium. The lines also indicate where phase transition occur.
- Triple points occur where lines of equilibrium intersect. A triple point identifies the condition at which three phases of matter can coexist.

- The temperature below which a substance forms a stable solid is called the solidus. The temperature above which a substance forms a stable liquid is the liquidus.

**Video Content / Details of website for further learning (if any):**

https://www.askiitians.com/iit-jee-physical-chemistry/chemical-kinetics/molecularity-of-reaction.aspx

https://study.com/academy/lesson/what-is-molecularity-definition-examples.html

**Important Books/Journals for further learning including the page nos.:**

Principals of Physical Chemistry by Puri & Sharma - page no 934 to 943

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**LECTURE HANDOUTS**

**L 36**

**PHYSICS**

**I / II**

**Course Name with Code** :**BIO AND NANO MATERIALS SCIENCE/21BSS03**

**Unit** : **IV - Introduction to Materials** **Date of Lecture:**

**Topic of Lecture:** Significance of Phase Diagram

**Introduction :**

- Phase changes of solid ,Liquid and Gas
- Triple point

**Prerequisite knowledge for Complete understanding and learning of Topic:**

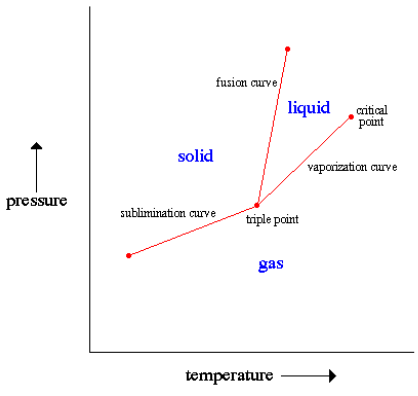
- Condition of phase changes
- Single or mixture of substance phase changes

**Detailed content of the Lecture:**

**Significance of Phase Diagram**

A phase diagram is a graph showing the limiting conditions for solid, liquid, and gaseous phases of a single substance or of a mixture of substances while undergoing changes in pressure and temperature.

The figure shown below displays a typical phase diagram for a one-component system, the curves having been obtained from measurements made at various pressures and temperatures.




At any point in the areas separated by the curves, the pressure and temperature allow only one phase (solid, liquid, or gas) to exist, and changes in temperature and pressure, up to the

points on the curves, will not alter this phase.

At any point on the curves, the temperature and pressure allow two phases to exist in equilibrium: solid and liquid, solid and vapor, or liquid and vapor.

**Video Content / Details of website for further learning (if any):**

http://abyss.uoregon.edu/~js/glossary/triple_point.html

https://www.sciencedirect.com/topics/earth-and-planetary-sciences/phase-diagrams

**Important Books/Journals for further learning including the page nos.:**

Material science and metallurgical engineering by O.P. Khanna Page No.39-2

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**LECTURE HANDOUTS**

**L 37**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture:** Bonding in carbon structures

**Introduction :**

- The carbon atom is unique among elements in its tendency to form extensive networks of covalent bonds not only with other elements but also with itself.
- Carbon most often forms a covalent bond with other atoms. If the bond is with another carbon atom, it is a pure covalent bond.
- In covalent bond, two atoms are sharing a pair of electrons.
- By forming four covalent bonds, carbon shares four pair of electrons, thus filling its outer energy level and achieving stability.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on carbon atom
- Carbon bonding
- Valance electrons

**Detailed content of the Lecture:**

**Carbon bonding**

- Until 1964 it was generally believed that no other carbon bond angles were possible in hydrocarbons, that is, compounds containing only carbon and hydrogen atoms.In that year Phil Eaton of the University of Chicago synthesized a square carbon molecule, $C_8H_8$ called cubane, shown in Fig. 1a. In 1983 L. Paquette of Ohio State University synthesized a $C_{20}H_{20}$ molecule having a dodecahedron shape. Shown in Fig.1b, formed by joining carbon pentagons, and having C-C bondangles ranging from 108" to 110".
- In order to understand the nature of the carbon bond it is necessary to examine theelectronic structure of the carbon atom. Carbon contains six electrons, which are distributed over the lowest energy levels of the carbon atom. The structure is designated as follows $ls^2$,2s, $2p_x$, $2p_y$,$2p_z$ when bonded to atoms in molecules.

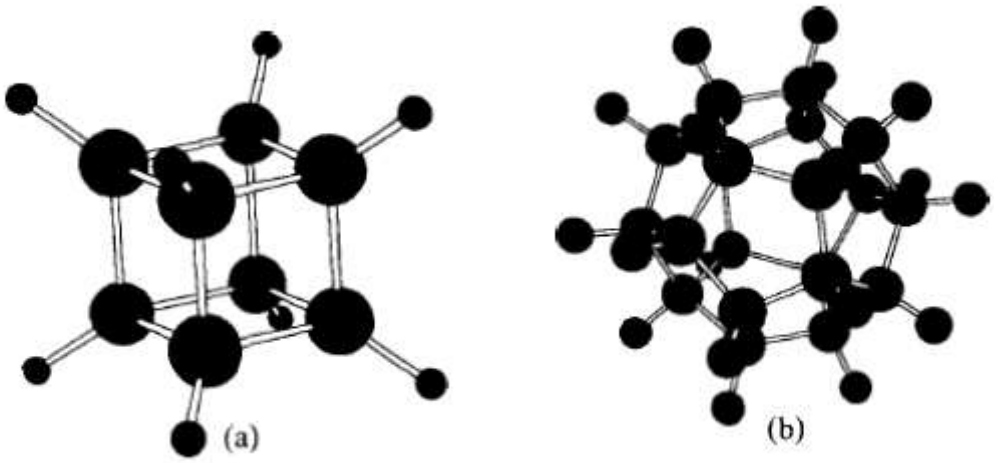
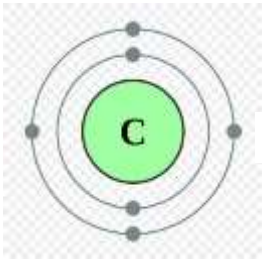



**Fig. 1 (a)** Carbon cube structure of cubane $C_8H_8$ and **(b)** carbon dodecahedron structureof $C_{20}H_{20}$.

**Valence electrons in carbon**

Carbon is a non-metal in group 14 of the periodic table. Like other group 14 elements, carbon has four valence electrons. Valence electrons are the electrons in the outer energy level of an atom that are involved in chemical bonds. The valence electrons of carbon are shown in the figure 2 below




4 Valence Electrons

**Fig. 2 Carbon atom**

**Video Content / Details of website for further learning (if any):**

- https://courses.lumenlearning.com/wm-nmbiology1/chapter/carbon-and-carbon-bonding/
- https://www.britannica.com/science/chemical-compound/Carbon-bonding

**Important Books/Journals for further learning including the page nos.:**

- Charles P. Poole, Jr. Frank J. Owens Introduction to Nanotechnology, A John Wiley 81 Sons, Inc., Publication, 2003, Page No. 106

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**LECTURE HANDOUTS**

**L 38**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture:** Introduction to carbon nano tubes

**Introduction :**

- Carbon nanotube is a new form of carbon.
- The CNTs are 50,000 times smaller than the width of human hair.

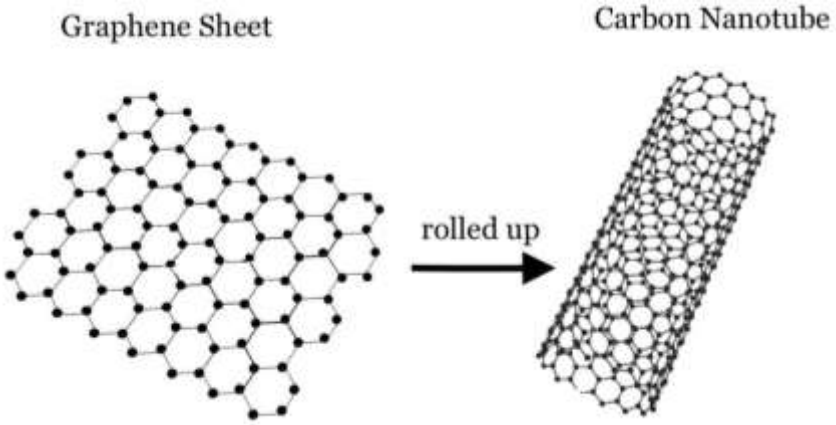
**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on carbon nanotube

**Detailed content of the Lecture:**

**Carbon nanotubes (CNT)**

- The conventional graphite consists of large number of sheets of carbon stacked one over the other and can easily slide over each other.
- When graphite consists of one atom thickness are rolled into a cylinder with a diameter in the order of few nanometers, the CNTs are formed.
- CNTs are extended tubes of rolled graphite sheets.
- CNTs are chemically bonded with $sp^2$ bonds, an extremely strong form of molecular interaction.




- This feature combined with carbon nanotubes natural inclination to rope together via van - der Waals forces, provide the opportunity to develop ultra-high strength, low-weight materials that possess highly conductive electrical and thermal properties. This makes them highly attractive for numerous applications.

**Video Content / Details of website for further learning (if any):**

- https://www.nanowerk.com/nanotechnology/introduction/introduction_to_nanotechnology_22.php
- https://www.hindawi.com/journals/isrn/2013/785160/

**Important Books/Journals for further learning including the page nos.:**

- Charles P. Poole, Jr. Frank J. Owens Introduction to Nanotechnology, A John Wiley 81 Sons, Inc., Publication, 2003, Page No. 115
- G. Sudarmozhi, Engineering Physics II, Bharathi publications, Page no. 5.23

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**LECTURE HANDOUTS**

**L 39**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano materials** **Date of Lecture:**

**Topic of Lecture:** Types of Carbon nanotubes

**Introduction :**

- Single walled carbon nanotubes
- Multi walled carbon nanotubes

**Prerequisite knowledge for Complete understanding and learning of Topic:**

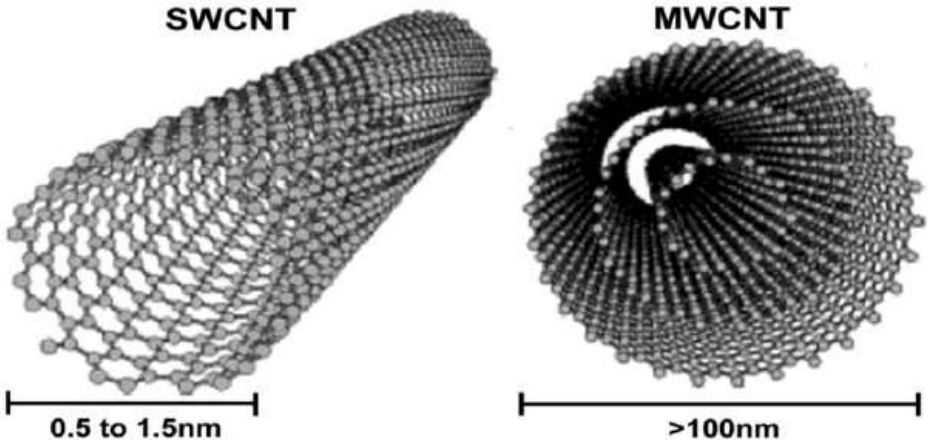
- Different types of carbon nanotubes and its properties

**Types of Carbon nanotubes**

Carbon nano tube is as stiff as diamond and exhibits extraordinary mechanical and electrical properties. The CNTs are classified into two types namely,

- ❖ Single walled carbon nanotube (SWCNT)
- ❖ Multi walled carbon nanotube (MWCNT)

Each type has its specific qualities which are used in numerous industrial applications.




- ❖ Single-Walled Carbon Nanotube (SWCNT) is a cylinder formed with only one layer (wall) of carbon molecules. When the roll is only one sheet of carbon atom thick, it is called as single walled carbon nano tubes.
- ❖ The SWCNT has a diameter close to 1 nm and with a tube length of several thousands of time longer. SWCNT with a length upto the order of centimeters have also been produced.
- ❖ They exhibit important electrical properties that are not shared by the multi walled carbon nanotubes.
- ❖ The diameters of SWCNTs determined by the range of temperature at which they synthesized.

Increasing the temperature results in larger-sized (wider) SWCNTs has incorporated.

- The structure of SWCNTs may vary and may either be zigzag, helical, armchair or chiral arrangement.
- The surface area of SWCNTs is also considerably higher, at 1300 $m^2/g$, which makes it ideal for nano-robotics and future of medicine administering.
- Multi-Walled Carbon Nanotubes (MWCNTs), differ with SWCNTs by the number of cylindrical walls they have.
- Multi-walled carbon nanotubes (MWCNTs) are elongated cylindrical nanoobjects made of sp2 carbon. Their diameter is 3–30 nm and they can grow several cm long.
- In MWCNTs, the carbon molecules form multiple concentric walls of consequentially increasing diameters around one another. ie MWCNT consists of multi layers of graphite rolled in on themselves to form a tube shape.
- Although there are numerous walls in MWCNTs, each wall is composed of an atom-thick structure only.
- The resistivity measurements on MWCNTs have revealed that some are metallic as much as graphite and the others are semiconducting having higher resistivity than SWCNTs.
- The structure of MWCNTs can be described with the models namely
  - Russian doll model
  - Parchment model
- In Russian doll model, Sheets of graphite are arranged in concentric cylinders.
- In Parchment model, Single sheet of graphite is rolled in around itself resembling a scroll of parchment or a rolled up newspaper.
- The interlayer distance MWCNT is close to the distance between grapheme layers in graphite approximately equal to 3.3Å

**Video Content / Details of website for further learning (if any):**

- https://www.nanowerk.com/nanotechnology/introduction/introduction_to_nanotechnology_22.php
- https://www.hindawi.com/journals/isrn/2013/785160/
- https://www.hindawi.com/journals/jchem/2019/4260153/

**Important Books/Journals for further learning including the page nos.:**

- Charles P. Poole, Jr. Frank J. Owens Introduction to Nanotechnology, A John Wiley 81 Sons, Inc., Publication, 2003, Page No. 116
- G. Sudarmozhi, Engineering Physics II, Bharathi publications, Page no. 5.23-5.24

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**LECTURE HANDOUTS**

**L 40**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture:** Comparison between SWCNT and MWCNT

**Introduction :**

- The difference between SWCNT and MWCNTs

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Comparison of electrical properties, purity, structure, synthesis conditions etc of SWCNT and MWCNTs

**Comparison between SWCNT and MWCNT**

| S. No | SWCNT | MWCNT |
|---|---|---|
| 1. | Single layer of graphene | Multiple layer of graphene |
| 2. | Catalyst is required for synthesis | Can be produced without catalyst. |
| 3. | Bulk synthesis is difficult as it requires proper control over growth and atmospheric condition | Bulk synthesis is easy. |
| 4. | Not fully dispersed, and form bundled structures | Homogeneously dispersed with no apparent bundled formation |
| 5. | Resistivity usually in the range of $10^{-4}$–$10^{-3}$ Ω·m. | Resistivity usually in the range of $1.8 \times 10^{-5}$–$6.1 \times 10^{-5}$ Ω·m |
| 6. | Purity is poor. Typical SWCNT content in as-prepared samples by chemical vapour deposition (CVD) method is about 30–50 wt%. However high purity up to 80% has been reported by using arc discharge synthesis method | Purity is high. Typical MWCNT content in as-prepared samples by CVD method is about 35–90 wt%. |
| 7. | A chance of defect is more during functionalization. | A chance of defect is less especially when synthesized by arc-discharged method. |
| 8. | Characterization and evaluation is easy | It has very complex structure |
| 9. | It can be easily twisted and are more pliable | It cannot be easily twisted |

**Video Content / Details of website for further learning (if any):**

- https://www.youtube.com/watch?v=oqcVYejHpw8
- https://www.khanacademy.org/science/biology/properties-of-carbon/carbon/v/carbon-as-a-building-block-of-life

- https://www.beilstein-journals.org/bjoc/articles/10/186

**Important Books/Journals for further learning including the page nos.:**

- Charles P. Poole, Jr. Frank J. Owens Introduction to Nanotechnology, A John Wiley 81 Sons, Inc., Publication, 2003, Page No. 116
- G. Sudarmozhi, Engineering Physics II, Bharathi publications, Page no. 5.23-5.24

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**LECTURE HANDOUTS**

**L 41**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture:** Structures of carbon nanotubes

**Introduction :**

- The structure of a carbon nanotube is formed by a layer of carbon atoms that are bonded together in a hexagonal (honeycomb) mesh. This one-atom thick layer of carbon is called graphene, and it is wrapped in the shape of a cylinder and bonded together to form a carbon nanotube.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Knowledge on different structures of CNT

**Detailed content of the Lecture:**

**Structures of carbon nanotubes**

There are various ways of defining the structure of carbon nanotubes. One possibility is to consider that CNTs may be obtained by rolling a graphene sheet in a specific direction,maintaining the circumference of the cross-section [1]. Since the microscopic structure of the CNTs is closely related to graphene, the tubes are usually labeled in terms of graphene lattice vectors. In addition, the reference to graphene allows the theoretical derivation of many properties of carbon nanotubes.

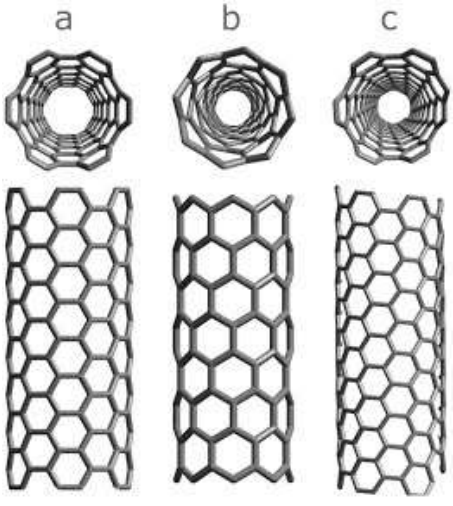


Fig. 1. Schematic model of (a) an armchair nanotube, (b) a zig-zag nanotube, and (c) a chiral nanotube

The atomic structures of the carbon nanotubes may be described by the tube chirality, or helicity,

defined by the chiral vector, Ch, and the chiral angle θ. In Fig. 1, a graphene sheet with defined chiral vector and angle may be seen. The chiral vector can be described in terms of the lattice translational indices (n,m) and the unit vectors a1 and a2 (see Fig.2)

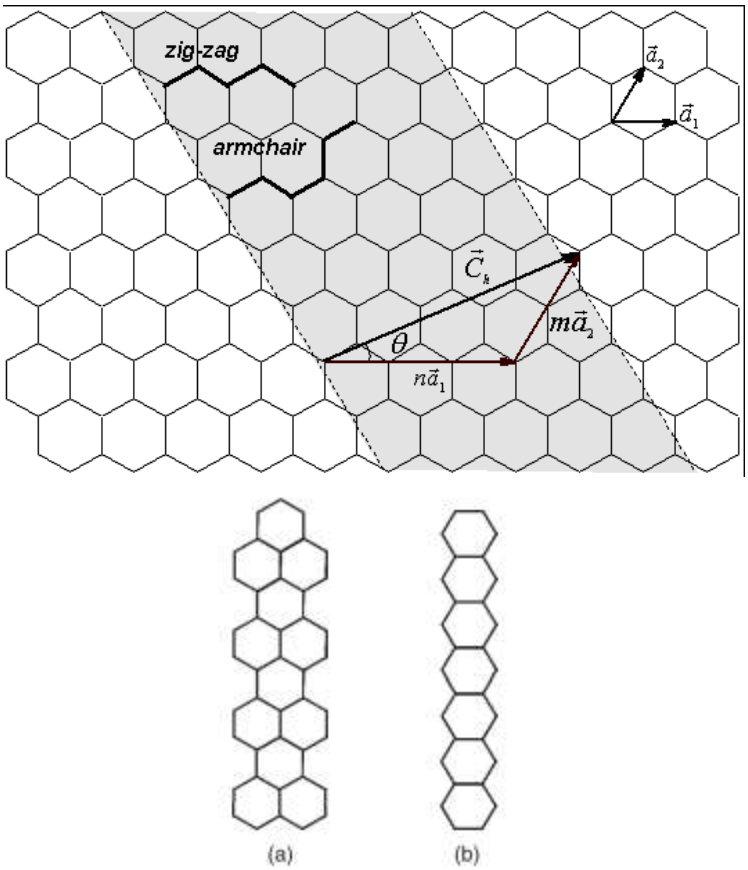


**Fig 2 Armchair and zigzag structure**

**Video Content / Details of website for further learning (if any):**

- https://personal.ems.psu.edu/~radovic/HarrisBook_Ch1.pdf
- britannica.com/science/graphite-carbon

**Important Books/Journals for further learning including the page nos.:**

- Charles P. Poole, Jr. Frank J. Owens Introduction to Nanotechnology, A John Wiley 81 Sons, Inc., Publication, 2003, Page No. 117

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**LECTURE HANDOUTS**

**L 42**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture**: Properties of carbon nanotubes

**Introduction :**

- The CNTs are highly elastic and it exhibits large strength in tension
- The unique electrical and mechanical properties of carbon nanotubes are in a large extent derived from their 1-D character and the peculiar electronic structure of graphite
- Chemically more inert and low density

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- The electrical and mechanical properties of CNT

**Detailed content of the Lecture:**

Properties of CNT

- Graphite is considered to be a semi-metal but, it has been shown that, depending on the chiral vector, Ch, related to the integers (n,m), CNTs may be either metallic or semiconducting . In all the other cases the nanotubes are semiconducting.
- On average, approximately 1/3 of SWCNTs are metallic and 2/3 semiconductor. In general, MWCNTs are quite often found to be one-dimensional conductors with a high electrical conductivity.
- Their metallic properties are due to their multiple-shell structure consisting of tubes with various electrical properties, where additional electronic coupling between shells takes place.
- In a 1-D conductor, electrons can travel only forward or backward. Under these circumstances, only back-scattering can lead to electrical resistance.
- As a consequence, CNTs display a very low resistance. In addition, they can carry the highest current density of any known material, measured as high as 109 A/cm2. Experimental results showed that the conductivity for metallic SWCNTs was between 105 to 106 S/m, and about 10 S/m for semiconducting tubes.
- The conductivity of bundles of SWCNTs has been found to be in the order of 104-106 S/m. For MWCNTs, the conductivity of individual tubes has been reported to range between 20 and 2·107 S/m. The effect of length, temperature and defects on the electrical conductivity of CNTs

has also been studied.

- Prior to carbon nanotubes, diamond was the best known thermal conductor. CNTs have been shown to have a thermal conductivity at least twice that of diamond. Thermal conductivity is a key factor for heat dissipation. Heat can be transported in a solid by phonons, which are quantized sound waves. In CNTs the specific heat and thermal conductivity are determined primary by phonons.
- Theoretical calculations suggest that the thermal conductivity for individual SWCNTs could be as high as 6000 W/m·K in the axial direction but has very small values in the radial direction. Experimental values for MWCNTs higher than 3000 W/m·K were already presented .In addition, CNTs are thermally stable up to 2800 C in vacuum.

**Video Content / Details of website for further learning (if any):**

- https://sites.google.com/site/cntcomposites/transport-properties
- https://www.slideshare.net/SagarPatel55/carbon-nanotube-33801296
- https://www.sciencedirect.com/science/article/pii/S1878535210001747

**Important Books/Journals for further learning including the page nos.:**

- Robert W. Kelsall, Ian W. Hamley , Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons Inc. Page no 327-330
- G. Sudarmozhi, Engineering Physics II, Bharathi publications, Page no. 5.23

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# MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)

Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

**LECTURE HANDOUTS**

**L 43**

**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture:** Synthesis of Carbon nanotubes-Arc discharge method

**Introduction :**

- The principle of this technique is to vaporize carbon in the presence of catalysts (iron, nickel, cobalt, yttrium, boron, gadolinium, and so forth) under reduced atmosphere of inert gas (argon or helium).

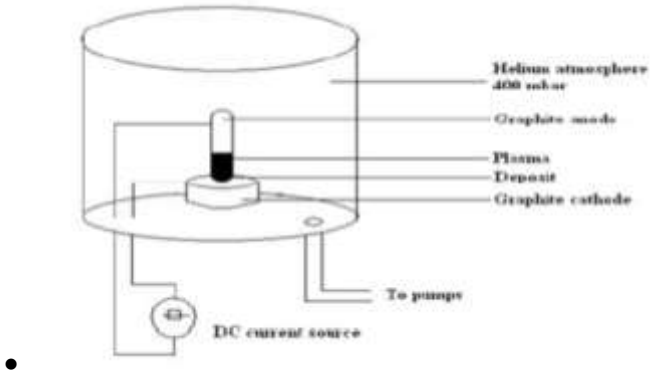
**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Arc discharge was the first recognized technique for producing MWNTs and SWNTs. The arc discharge technique generally involves the use of two high-purity graphite electrodes as the anode and the cathode. The electrodes were vaporized by the passage of a DC current (~100 A) through the two high-purity graphite separated (~ 1–2 mm) in 400 mbar of Helium atmosphere

**Detailed content of the Lecture:**

- After the triggering of the arc between two electrodes, a plasma is formed consisting of the mixture of carbon vapor, the rare gas (helium or argon), and the vapors of catalysts. The va- porization is the consequence of the energy transfer from the arc to the anode made of graphite doped with cata- lysts. The anode erosion rate is more or less important depending on the power of the arc and also on the other experimental conditions. It is noteworthy that a high an- ode erosion does not necessarily lead to a high carbon nanotube production.
- In the arc discharge method, a DC bias of 20–30 V is applied between two carbon electrodes in a helium atmosphere. Carbon atoms are ejected from the anode, and accumulate in the form of nanotubes on the cathode. The electrodes are typically 5–20 mm in diameter. As with laser evaporation, the anode includes small quantities of nickel, cobalt or iron, which are also deposited onto the cathode to act as a catalyst. Arc discharges tend to produce narrower and shorter tubes than those obtained from laser ablation (up to $5nm in diameter and around 1mm long). Like laser ablation, arc discharges tend to produce bundles of nanotubes.
- It consists of a cylinder of about 30 cm in diameter and about 1m in height, equipped with diametrically op- posed sapphire windows located so that they face the plasma zone in view of observing the arc. The reactor possesses two valves, one for carrying out the primary evacuation (0.1Pa) of the chamber, the other permit- ting it to fill with a rare gas up to the desired working pressure.
- Arc-discharge technique uses higher temperatures (above 1,700°C) for CNT synthesis which typically causes the expansion of CNTs with fewer structural defects in comparison with other methods. The most utilized methods use arc discharge between high-purity graphite (6 to 10-mm optical density (OD)) electrodes usually water-cooled electrodes with diameters between 6 and 12 mm and separated by 1 to 2 mm in a chamber filled with helium (500 torr) at subatmospheric pressure (helium can be replaced by hydrogen or methane atmosphere).

- The chamber contains a graphite cathode and anode as well as evaporated carbon molecules and some amount of metal catalyst particles (such as cobalt, nickel, and/or iron). Direct current is passed through the camber (arcing process), and the chamber is pressurized and heated to approximately 4,000 K.
- In the course of this procedure and arcing, about half of the evaporated carbon solidifies on the cathode (negative electrode) tip, and a deposit forms at a rate of 1 mm/min which is called 'cylindrical hard deposit or cigar-like structure', whereas the anode (positive electrode) is consumed.
- The remaining carbon (a hard gray shell) deposited on the periphery and condenses into 'chamber soot' nearby the walls of the chamber and 'cathode soot' on the cathode. The inner core, cathode soot and chamber soot, which are dark and soft, yield either single-walled or multiwalled carbon nanotubes and nested polyhedral graphene particles.
- By using scanning electron microscopy (SEM), two different textures and morphologies can be observed in studying of the cathode deposit; the dark and soft inner core deposits consist of bundle-like structures, which contain randomly arranged nanotubes and the gray outer shell, which is composed of curved and solid grapheme layers.




- In the arc discharge deposition and synthesis of CNTs, there are two main different ways: synthesis with use of different catalyst precursors and without use of catalyst precursors. Generally, synthesis of MWNTs could be done without use of catalyst precursors but synthesis of single-wall nanotubes (SWNTs) utilizes different catalyst precursors and, for expansion in arc discharge, utilizes a complex anode, which is made as a composition of graphite and a metal

**Video Content / Details of website for further learning (if any):**

- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4141964/
- https://www.researchgate.net/figure/Arc-discharge-method-29_fig5_259745248

https://sites.google.com/site/nanomodern/Home/CNT/syncnt/arc-discharge
https://shellzero.wordpress.com/2012/05/14/arc-discharge-method/

**Important Books/Journals for further learning including the page nos.:**

- Robert W. Kelsall, Ian W. Hamley , Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons Inc. Page no 326
- G. Sudarmozhi, Engineering Physics II, Bharathi publications, Page no. 5.26

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**LECTURE HANDOUTS**

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**Physics**

**I/II**

**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE/ 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture:** Chemical vapour deposition method

**Introduction :**

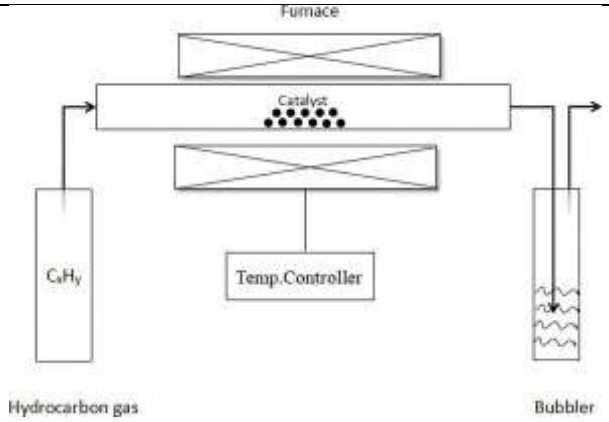
- At present, the preparation process of multi-walled CNTs is quite mature, and industrial production has been realized by the CVD. The production cost of single-walled CNTs is still quite high, and the preparation of macroscopic arrays of some oriented single-walled CNTs has not been realized.

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- It is important that large quality and high purity CNTs require highly reliable synthesis techniques. Understanding the influencing factors and control conditions of specific carbon nanotube synthesis is what we need.

**Detailed content of the Lecture:**

- The chemical vapor deposition method is to cleave a carbon atom-containing gas continuously flowing through the catalyst nanoparticle to generate carbon atoms and then generate CNTs on the surface of the catalyst or the substrate. The synthesis process is to let catalyst decompose carbon source (usually hydrocarbon gas) at a sufficiently high temperature in a tubular reactor
- Compared with other methods, chemical vapor deposition (CVD) is the most effective method that has broad prospects for large-scale control of CNTs in recent years due to its simple equipment, simple operation, and lower cost.
- In order to gain a comprehensive understanding of the controlling parameters about the formation of CNTs, this chapter reviews the latest progress in the preparation of CNTs by CVD from three of the most important influencing factors: carbon sources, catalysts, and substrates. Among them, the catalyst is the most influential factor for the morphology, structure, and properties of CNTs.
- It should be pointed out that many growth factors can control the particle size distribution, composition, and structure of the catalysts, such as catalyst substrate, metal transition components added, calcination temperature, etc




- Although the growth mechanism of CNTs has been controversial, there are currently two widely accepted mechanisms, and they can be summarized as follows. When a hydrocarbon vapor is contacted with heated metal nanoparticles, it is first decomposed into carbon and hydrogen. Hydrogen leaves with the passing carrier gas or reducing gas, and carbon dissolves in the metal catalyst. When the temperature reaches the carbon solubility limit of the metal, the decomposed carbon particles precipitate and crystallize to form CNTs. The decomposition of hydrocarbons is an exothermic process, carbon crystallization is an endothermic process, and the thermal gradient continues this process.

- When the catalyst interacts weakly with the substrate, carbon decomposed from the hydrocarbon diffuses from the metal catalyst to the bottom of the metal catalyst and precipitates between the substrate and the metal catalyst, thereby promoting the growth of the entire metal catalyst nanoparticles. When the metal particle is entirely covered by excess carbon, growth stops, which is called tip-growth.

- When the catalyst interacts strongly with the substrate, the carbon precipitates without pushing up the metal particles, so it is forced to precipitate from the top of the metal, which is called the "basic growth model," also called root growth

**Video Content / Details of website for further learning (if any):**

- https://www.sciencedirect.com/science/article/abs/pii/S1369800115301402
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5978199/
- https://www.intechopen.com/books/perspective-of-carbon-nanotubes/synthesis-of-carbon-nanotubes-by-catalytic-chemical-vapor-deposition

**Important Books/Journals for further learning including the page nos.:**

- Robert W. Kelsall, Ian W. Hamley , Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons Inc. Page no 326

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**Course Name with Code** : **BIO AND NANO MATERIALS SCIENCE / 21BSS03**

**Unit** : **V-Carbon Nano Materials** **Date of Lecture:**

**Topic of Lecture:** Applications of carbon nanotubes

**Introduction:**

- Due to the peculiar properties, CNTs are useful in wide variety of areas such as transistors, fuel cells, field emission, mechanical reinforcement, etc

**Prerequisite knowledge for Complete understanding and learning of Topic:**

- Basic knowledge on various applications of CNT

**Applications of CNT**

- One aspect of CNTs which has particularly captured the imagination of many is their remarkable mechanical strength; popular reviews often quote statements such as ‘a hundred times the strength of steel at one sixth of the weight.
- The strength of CNTs is directly related to the C ¼¼ C bond, which is one of the strongest of all chemical bonds, and to the relatively small number of crystalline defects present in the tubes. Evaluation of the tensile strength and the Young’s modulus of CNTs is obviously difficult, due to their small size, and a range of methods have been employed, including TEM monitoring of tube vibrations, AFM manipulation and computer simulation.
- CNTs may also be used as the basis of chemically sensitive FETs for sensing applications. For example, detection of NO2 by a CNT FET has been demonstrated; the NO2 molecules are adsorbed by the nanotube, creating additional free holes, which increase the tube conductivity.
- Field emission – the electric field induced emission of electrons from a solid – is readily
- obtained in CNTs.
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- Individual CNTs have excellent mechanical properties. However, the exploitation of these properties in bulk materials is a major challenge.
- One important approach is the formation of composite materials in which a small percentage of CNTs are incorporated into a metal or polymer host.
- This method has already been demonstrated for poly-propylene and aluminium, with a doubling in tensile strength observed in both cases.
- There has been great optimism that CNTs could be used as hydrogen storage vessels for application in non-fossil-fuel cells.
- Carbon is one of the most lightweight materials to remain solid at room temperature, and the graphene sheet presents a very high surface area to weight ratio. Graphite itself has not proved

useful for hydrogen adsorption, since only a small proportion of the surface interacts with hydrogen molecules; however, it was envisaged that CNTs would have the added benefit of capillary forces which would draw hydrogen inside.

**Video Content / Details of website for further learning (if any):**

- https://www.prescouter.com/2017/03/applications-carbon-nanotubes/#
- azonano.com/article.aspx?ArticleID=4842
- https://www.hindawi.com/journals/bmri/2013/578290/

**Important Books/Journals for further learning including the page nos.:**

- Robert W. Kelsall, Ian W. Hamley , Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons Inc. Page no 331
- Charles P. Poole, Jr. Frank J. Owens Introduction to Nanotechnology, A John Wiley 81 Sons, Inc., Publication, 2003, Page No. 125

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