# BANASTHALI VIDYAPITH

## Master of Technology (Nanotechnology)

### Curriculum Structure

First Semester Examination, December, 2019
Second Semester Examination, April/May, 2020
Third Semester Examination, December, 2020
Fourth Semester Examination, April/May, 2021

**BANASTHALI VIDYAPITH**
**P.O. BANASTHALI VIDYAPITH**
**(Rajasthan)-304022**

July, 2019 **143**

**No. F. 9-6/81-U.3**

**Government of India**
**Ministry of Education and Culture**
**(Department of Education)**

New Delhi, the 25th October, 1983

# NOTIFICATION

In exercise of the powers conferred by Section 3 of the University Grants Commission Act, 1956 (3 of 1956) the Central Government, on the advice of the Commission, hereby declare that BanasthaliVidyapith, P. O. BanasthaliVidyapith, (Rajasthan) shall be deemed to be a University for the purpose of the aforesaid Act.

Sd/-
**(M. R. Kolhatkar)**
Joint Secretary of the Government of India

# NOTICE

Changes in Bye-laws/Syllabi and Books may from time to time be made by amendment or remaking, and a Candidate shall, except in so far as the Vidyapith determines otherwise, comply with any change that applies to years she has not completed at the time of change.

## Programme Educational Objectives

BanasthaliVidyapith has made a significant contribution in the technology education by introducing the M. Tech. (Nanotechnology) programme. Nanotechnology is not being considered simply a technology like other technologies which are confined almost in a limited area. In fact, the nanotechnology leads to a mission through which the whole country can be promoted in terms of sciences and technology. Keeping in view such a mission, The M. Tech. (Nanotechnology) programme has been designed by the department of Physics. Actually, M. Tech. (Nanotechnology) is an umbrella programme for capacity building which envisages the overall development of this field of research in the country and to tap some of its applied potential for nation's development.

Keeping in views the entire scientific and technological development of the student through covering almost all the courses, the M. Tech. (Nanotechnology) programme has been designed. The present programme aims to train the students to acquire high level theoretical and experimental knowledge in the direction of technology through learning the designed courses with high quality and significance. However, the main objectives of the programmes are as follows:

- To prepare the students to outshine in academics and research in different motifs of Nanoscience and Nanotechnology.
- To train the students with good theoretical and practical knowledge so as to comprehend, analyze, design, and create novel products and solutions for the real life problems.
- To provide the knowledge of various new techniques by which the students can lead the cutting edge technologies
- To encourage research and development activities
- To prepare the competent technologists at national and international level
- To provide students with an academic environment aware of excellence, leadership, written ethical codes and guidelines, and the life-long learning needed for a successful professional career
- To produce the students who can think critically and creatively thus capable of generating and developing new knowledge, products, materials or methods for the benefits of mankind.
- To prepare the students with excellent communication skills, capable of communicating effectively in various context, thus sharing new knowledge with other researchers from other institutions, universities and also industrialists

- To develop gender –neutral attitudes and practices; respect for all races, nations, religions, culture, languages and traditions
- To coach students in professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, and an ability to relate nanotechnology to address environmental issues.
- To provide the ideas about environment sustainability and pollution control through exemplary and practical educations

**Programme Outcomes**

**PO1: Knowledge about Technology:** Able toapply knowledge and skills to solve complex technical problems which calls for insight into the latest technologies and best engineering practices including behavioral, social, and manufacturing practices.

**PO2: Planning Abilities-**Ability to demonstrate efficient planning including time management, resource management and organization skills

**PO3: Problem analysis ability-**Ability to apply scientific attitude to analyze the society problems and to apply information systematically for the solution

**PO4: Modern Tool usage:** Ability to handle new techniques and advanced tools like XRD, FESEM etc, which derive the nanosciences and nanotechnology

**PO5: Leadership Skills-** ability to have leadership skills with high regard for ethical values and social responsibility through the management related courses.

**PO6: Professional Identity-** able to show professional identity as competent technologists at national and international level

**PO9 7: Technology and society-**Ability to show the understanding of impact of nanomaterials on the society including environment, health and ecosystem. On the other side, the Graduates will be able to propagate their knowledge to address problems of social relevance such as energy, environment and medicine through their specific electives.

**PO8: Communication-**Possess effective communication skills, teamwork skills, multidisciplinary approach, and an ability to relate nanotechnology to address environmental issues.

**PO9: environment and sustainability-** Understanding about environment sustainability and pollution control through laboratory practices

**PO10: Life-long learning-** Possess the knowledge of contemporary issues and ability to engage in life-long learning

# Curriculum Structure

## Master of Technology (Nanotechnology)

**Semester - I (December, 2019)**

| Course | Code | Course Name | L | T | P | C * |
|---|---|---|---|---|---|---|
| | | Discipline Elective | 4 | 0 | 0 | 4 |
| ELE | 506 | Nano - Photonics and Optoelectronics | 4 | 0 | 0 | 4 |
| PHY | 502 | Advanced Synthesis Processes and Devices | 4 | 0 | 0 | 4 |
| PHY | 508 | Fundamentals of Nano - Science and Nano - Technology | 4 | 0 | 0 | 4 |
| PHY | 511 | Introduction to Material Science | 4 | 0 | 0 | 4 |
| PHY | 512L | Nano Fabrication and Characterization Lab-I | 0 | 0 | 6 | 3 |
| NANO | 502L | Simulation Lab - I | 0 | 0 | 6 | 3 |
| | **Semester Wise Total :** | | **20** | **0** | **12** | **26** |

**Semester - II (April/May, 2020)**

| Course | Code | Course Name | L | T | P | C * |
|---|---|---|---|---|---|---|
| | | Open Elective | 4 | 0 | 0 | 4 |
| ELE | 501 | Advanced Nano - Electronics | 4 | 0 | 0 | 4 |
| MATH | 514 | Mathematical Modeling and Simulation | 4 | 0 | 0 | 4 |
| NANO | 501 | Quantum Computations and Information Processing | 4 | 0 | 0 | 4 |
| PHY | 501 | Advanced Characterization Techniques | 4 | 0 | 0 | 4 |
| NANO | 503L | Simulation Lab - II | 0 | 0 | 6 | 3 |
| PHY | 513L | Nano Fabrication and Characterization Lab-II | 0 | 0 | 6 | 3 |
| | | **Semester Wise Total :** | **20** | **0** | **12** | **26** |

**Discipline Electives**

| Course | Code | Course Name | L | T | P | C |
|---|---|---|---|---|---|---|
| PHY | 531 | Surface, Interfaces and Thin Films | 4 | 0 | 0 | 4 |
| BT | 518 | Nano - Engineering of Biological Systems | 4 | 0 | 0 | 4 |
| CHEM | 508 | Organic and Polymer Technology | 4 | 0 | 0 | 4 |
| ELE | 504 | MEMS and NEMS Technology | 4 | 0 | 0 | 4 |

*** L - Lecture hrs/week; T - Tutorial hrs/week; P - Project/Practical/Lab/All other non-classroom academic activities, etc. hrs/week; C - Credit Points of the Course**

**Semester - III (December, 2020)**

| Course | Code | Course Name | L | T | P | C * |
|---|---|---|---|---|---|---|
| PHY | 601P | Project (Part - I) | 0 | 0 | 48 | 24 |
| | | Reading Elective - I | 0 | 0 | 0 | 2 |
| | | **Semester Wise Total :** | **0** | **0** | **48** | **26** |

**Reading Elective - I**

| Course | Code | Course Name | L | T | P | C |
|---|---|---|---|---|---|---|
| BT | 601R | Nanotechnology in Health Care and Environment | 0 | 0 | 0 | 2 |
| MGMT | 601R | Development of Nanotechnology: A Global Aspect | 0 | 0 | 0 | 2 |
| MGMT | 602R | Nanotechnology and Society | 0 | 0 | 0 | 2 |

**Semester - IV (April/May, 2021)**

| Course | Code | Course Name | L | T | P | C * |
|---|---|---|---|---|---|---|
| PHY | 602P | Project (Part - II) | 0 | 0 | 48 | 24 |
| | | Reading Elective - II | 0 | 0 | 0 | 2 |
| | | **Semester Wise Total :** | **0** | **0** | **48** | **26** |

**Reading Elective - II**

| Course | Code | Course Name | L | T | P | C |
|---|---|---|---|---|---|---|
| BIO | 604R | Tissue Engineering | 0 | 0 | 0 | 2 |
| CHEM | 601R | Nano - Catalysis | 0 | 0 | 0 | 2 |
| ELE | 601R | RF and MMIC design | 0 | 0 | 0 | 2 |

*** L - Lecture hrs/week; T - Tutorial hrs/week; P-Project/Practical/Lab/All other non-classroom academic activities, etc. hrs/week; C - Credit Points of the Course**

**Evaluation Scheme for Theory Courses**

| ContinuousAssessment(CA) (Max. Marks) | | | | | End-SemesterAssessment (ESA) (Max.Marks) | GrandTotal (Max. Marks) |
|---|---|---|---|---|---|---|
| Assignment | | PeriodicalTest | | Total (CA) | | |
| I | II | I | II | | | |
| 10 | 10 | 10 | 10 | 40 | 60 | 100 |

For laboratory and all non classroom activities (project, dissertation, seminar, etc.), the Continuous and End-semester assessment will also be of 40 and 60 marks respectively. Wherever desired, the detailed breakup of continuous assessment marks (40), for project, practical, dissertation, seminar, etc shall be announced by respective departments in respective student handouts.

Based on the cumulative performance in the continuous and end-semester assessments, the grade obtained by the student in each course shall be awarded. The classification of grades is as under:

| LetterGrade | GradePoint | Narration |
|---|---|---|
| O | 10 | Outstanding |
| A+ | 9 | Excellent |
| A | 8 | VeryGood |
| B+ | 7 | Good |
| B | 6 | AboveAverage |
| C+ | 5 | Average |
| C | 4 | BelowAverage |
| D | 3 | Marginal |
| E | 2 | Exposed |
| NC | 0 | NotCleared |

Based on the obtained grades, the Semester Grade Point Average shall be computed as under:

$$SGPA = \frac{CC_1 * GP_1 + CC_2 * GP_2 + CC_3 * GP_3 + ----+ CC_n * GP_n}{CC_1 + CC_2 + CC_3 + ----+ CC_n} = \frac{\sum_{i=1}^{n} CC_i * GP_i}{\sum_{i=1}^{n} CC_i}$$

Where n is the number of courses (with letter grading) registered in the semester, $CC_i$ are the course credits attached to the $i^{th}$ course with letter grading and $GP_i$ is the letter grade point obtained in the $i^{th}$ course. The courses which are given Non-Letter Grades are not considered in the calculation of SGPA.

The Cumulative Grade Point Average (CGPA) at the end of each semester shall be computed as under:

$$CGPA = \frac{CC_1 * GP_1 + CC_2 * GP_2 + CC_3 * GP_3 + ----+ CC_n * GP_n}{CC_1 + CC_2 + CC_3 + ----+ CC_n} = \frac{\sum_{i=1}^{n} CC_i * GP_i}{\sum_{i=1}^{n} CC_i}$$

Where n is the number of all the courses (with letter grading) that a student has taken up to the previous semester.

Student shall be required to maintain a minimum of 4.00 CGPA at the end of each semester. If a student's CGPA remains below 4.00 in two consecutive semesters, then the student will be placed under probation and the case will be referred to Academic Performance Review Committee (APRC) which will decide the course load of the student for successive semester till the student comes out of the probationary clause.

To clear a course of a degree program, a student should obtain letter grade C and above. However, D/E grade in two/one of the courses throughout the UG/PG degree program respectively shall be deemed to have cleared the respective course(s). The excess of two/one D/E course(s) in UG/PG degree program shall become the backlog course(s) and the student will be required to repeat and clear them in successive semester(s) by obtaining grade C or above.

**After successfully clearing all the courses of the degree program, the student shall be awarded division as per following table.**

| Division | CGPA |
|---|---|
| Distinction | 8.50andabove |
| FirstDivision | 7.00to8.49 |
| SecondDivision | 5.50to6.99 |
| ThirdDivision | 4.00to5.49 |

# First Semester

## Nano-Photonics and Optoelectronics

**ELE 506** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome**

After completion of this course, the students will be able to-
1. Understand the fundamental operating principles of photodevices
2. LED and heterojunction laser materials selection and design
3. Fundamentals of organic electronics and liquid crystal displays
4. An overview of photonic systems

### Section A

III-V semiconductors; Absorption in Semiconductors: Indirect Intrinsic transitions, Exciton absorption, Donor acceptor and Impurity Band Absorption; Effect of electric field on absorption: Franz Keldysh and Stark effect; Quantum confinement; Quantum Dots; Quantum wells; Absorption in Quantum Wells and Quantum Confined Stark effect; Radiation in Semiconductors: Relation between absorption and emission spectra, Near Bandgapradiative transitions, Deep-level transitions, Auger recombination; Dielectric confinement effect; Superlattices; Core shell Quantum Dots; Quantum confined structures as lasing media

### Section B

Introduction to Lasers; Gain in two level lasing medium; Lasing Condition and Gain in semiconductors; Selective Amplification and Coherence; Threshold condition for lasing; Lineshapefunction:Line broadening mechanisms: Natural Broadening, Collision Broadening, Doppler Broadening; Semiconductor Lasers: Basic principles; Heterojunction Lasers: Energy Band diagram and Power output; Quantum Well and Quantum Dot lasers; Multiple Quantum Well laser; Quantum Cascade laser: Structure and Principle of Operation

### Section C

Photonic Crystals: 1D,2D,3D Photonic crystals, Photonic Bandgap and defects in photonic crystals, Features of photonic crystals, Optical microcavites, Methods of Fabrication, Nonlinear Photonic crystals, Photonic Crystal Fibre, Photonic Crystal Sensor;

Surface Plasmons: Drude–Sommerfeldtheory,Surfaceplasmonpolaritons at plane interfaces, Properties of surface plasmonpolaritons, Surface plasmon sensors, Surface plasmons in nano-optics,Plasmons supported by wires and particles

**Recommended Books :**


1. Bhattacharya P. (2002) Semiconductor Optoelectronic Devices (Prentice Hall India, IIndedition )
2. Prasad P. N. (2004) Nanophotonics (Wiley Interscience, USA).
3. Silvfast W.T. (1998) Laser Fundamentals by, (Cambridge University Press, UK)
4. Ghatak A, Thyagarajan, K (2010) Lasers, Fundamentals and applications (Springer Science+Business Media, USA)
5. Novotny L., Hecht B. (2006) Principles of Nano-Optics (Cambridge University Press, UK)


**Suggested web-Resources:**

NPTEL : Semiconductor optoelectronics
https://nptel.ac.in/courses/115102103/
NPTEL :Nanophotonics
https://nptel.ac.in/courses/118106021/1

## Simulation Lab

**Learning Outcome**

After the course the student will be able to:
Learn programming language, use of various dynamic and static libraries and few package on simulations related to nano-materials.

## Simulation Lab-1

| **NANO 502L** | **L** | **T** | **P** | **C** |
|---|---|---|---|---|
| | **0** | **0** | **6** | **3** |

**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

Introduction to Programming, problem analysis and algorithms. One programming language (C++, Python, Fortran, Java), Programming Software: Mathematica, MATLAB, Visualisation packages.

1. Use of standard library functions.
2. Problems based on do, while, for loops.
3. Problems based on array, data type, data analysis.
4. Sorting of numbers and one dimensional array searching.

5. Problems based on pointer, parameter passing in function. Recursion
6. Problems based on object oriented programming. Classes, Modules, Subroutines.
7. Reading writing from/in files.
8. Use of dynamic and static libraries.

Command line arguments and shell scripting.
Introduction to some Open source simulation tools that are used to mode nanostructure at the levels of classical and quantum mechanics.

## Advanced Synthesis Processes and Devices

**PHY 502** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome**

1. Students will have a firm foundation in the fundamentals and application of current chemical and scientific theories including those in Analytical, Inorganic, Organic and Physical synthesis processes.
2. Students will be skilled in problem solving, critical thinking and analytical reasoning as applied to scientific problems.
3. Students will be able to clearly communicate the results of scientific work in oral, written and electronic formats to both scientists and the public at large.
4. Students will be able to explore new areas of research in both chemistry and allied fields of science and technology.

### Section A

Approaches for nanomaterial fabrication: Top Down and Bottom up, Physical vapour deposition (PVD): Plasma Arc Discharge and Sputtering (DC, RF and RF Magnetron sputtering), Chemical vapour deposition (CVD): LPCVD, PECVD and MOCVD, Crystal Synthesis: Epitaxy and Epitaxial Growth techniques (Homoepitaxial and Heteroepitaxial growth mechanism), Molecular Beam Epitaxy (MBE), Variants: Gas source MBE, Phase locked Epitaxy, Atomic Layer Epitaxy. Lattice mismatched heteroepitaxy

### Section B

Photolithography, E-beam lithography, X-ray and Ion-beam lithography: Resists and masks, process, types, problem, limitations and way out. Conventional and unconventional lithography,

Imprint or soft lithography: Printing/decal transfer, Molding/embossing, Phase-Shift Edge lithography and Nanoskiving (mechanical sectioning), Scanning probe lithography: Energy transfer: STM and AFM assisted lithography, local oxidation lithography, Replacement lithography (Nanoshaving, Nanografting and Nanopen reader and writer (NPRW)), and Passive technique: Dip-pen nanolithography, Nanolithography and nanomanipulation.

**Section C**

Metal-semiconductor junctions, Heterojunctions, High Speed electronic devices: FET, MESFET, HEMT, pHEMT and HBT, MESFET, HEMT and HBT equivalent circuits, Heterojunction Barrier varactor (HBV), Transferred electronic devices: Gunn diode, The SiGe and GaN systems: basic band structure and salient features.

## Recommended Books


1. Gabor L. Hornyak, Dutta J.  Tibbals H.F., RaoA .(2008) Introduction to Nanoscience (CRC Press)
2. Vajtai, R. (Ed.). (2013). Springer handbook of nanomaterials.Springer Science & Business Media.
3. Henini, M. (Ed.). (2012). Molecular beam epitaxy: from research to mass production. Newnes.
4. Jackson, M. J. (Ed.). (2005). Microfabrication and nanomanufacturing. CRC press..
5. Neamen, D. A. (2012). Semiconductor physics and devices: basic principles. New York, NY: McGraw-Hill,.
6. Manasreh, O. (2011). Introduction to nanomaterials and devices.John Wiley & Sons.


**Suggested –web resources**

https://nptel.ac.in/courses/117106109/1

https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-152j-micro-nano-processing-technology-fall-2005/lecture-notes/cvd.pdf

## Fundamentals of Nano-Science and Nano-Technology

**PHY 508** **L T P C**

**4 0 0 4**

**Max. Marks : 100**

**(CA: 40 + ESA: 60)**

**Learning Outcome:**

At the end of the course, Student will possess:

1. The knowledge of the general principles of physics, chemistry, electronics and biology that play a role on the nanometer scale

2. Insight into the materials, fabrication and other experimental techniques that can be used on the nanoscale, as well as their limitations
3. Understanding of theformation of complex macro systems which are unique in their operations and possess new functionalities
4. In-depth knowledge of at least one specialization area within the field of nanoscience and nanotechnology.

**Section A**

Nanostructures: Definition of nanoscience and nanotechnology, classification of the nano materials, zero dimensional nanostructures, one dimensional nanostructures-nanowires, nanorods and nanotubes, two dimensional nanostructures-graphene,Thinfilms.

Quantum Confinement: Quantum dots(QDs), Quantum wires (QWRs), Quantum wells (QWs). Density of states in QDs, QWRs, QWs.

**Section B**

Synthesis of Nanomaterials: Synthesis of nano-structured materials, sol-gel processing, microwave synthesis, self-assembly, Langmuir-Blodgett (LB) method, electrochemical deposition, chemical vapor deposition, Sputter deposition, pulsed laser deposition, magnetron sputtering, molecular beam epitaxy, lithography.

**Section C**

Properties of Nanomaterials. Shape and size dependant properties-electrical, linear and nonlinear optical properties, magnetic, thermal and mechanical properties of nanomaterials, melting point and lattice constants, surface plasma resonance.

**Applications:** Nano-Heterostructures and quantum dot (Photodetectors and lasers).

**Recommended Books:**

1. Sulabha, K., &Kulkarni, K. (2007). Nanotechnology: principles and practices.
2. Guozhong, C. (2004). *Nanostructures and Nanomaterials: synthesis, properties and applications*. World scientific..
3. Köhler, M., &Fritzsche, W. (2008). *Nanotechnology: an introduction to nanostructuring techniques*. John Wiley & Sons..
4. Roduner, E. (2015). *Nanoscopic materials: Size-dependent phenomena and growth principles*. Royal Society of Chemistry.

**Suggested –web resources:**

https://ocw.mit.edu/search/ocwsearch.htm?q=quantum%20dots
https://nptel.ac.in/courses/103103026/8

# Introduction to Material Science

**PHY 511** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

After the course the student will be able to:
1. Apply knowledge of mathematics, science, and engineering to solve problems related to materials science and engineering.
2. Design new nanomaterials, as well as characterize the new material.
3. Collaborate effectively on multidisciplinary teams.
4. Communicate effectively in written and oral formats.

## Section A

Need of material science and Engineering: Atomic bonding in solids, unit cells, primitive cell, crystal systems, Miller indices, crystallographic directions & planes, packing fraction, linear density, planer and theoretical densities of crystal structure, close-packed crystal structures, single crystal, polycrystals, amorphous structure, Introduction to XRD for the determination of crystal structure; Crystal imperfections: point defects, linear defects, surface defects, bulk and volume defects; Plastic deformation, plastic deformation by slip, shear strength, motion of dislocation: effect of stress, temperature, grain size, solute atoms, precipitate particles, multiplication of dislocations, basic concepts of creep and fracture.

## Section B

Introduction to Phase diagrams: Phase rule, Unary phase diagram, binary phase diagram (Al2O3, PbSn, Ag-Pt), Hume-Routhery rules for solid solutions, the lever rule. The tie line rule, the iron-carbon system Development of Microstructure in Iron-Carbon Alloys.

Diffusion: Diffusion mechanism, Fick's law of diffusion, steady state and non-steady state, applications based on Fick's second law, kirendall effect; Phase Transformations: Nucleation, homogeneous, heterogeneous growth, Transformation kinetics, Time-temperature-transformation (TTT) curves, applications of nucleations& growth, glass transition.

## Section C

Mechanical behavior: Elastic, anelastic, viscoelastic behavior of materials, Polymers: Introduction, classification, polymer structure, copolymers, tacticity, geometric isomerism, molecular weight, molecular weight distribution, molecular weight averages, polydispersity index; Ceramics: Introduction to ceramic structure and applications of ceramics.

Liquid Crystals and Quasi Crystals.Disposal of waste materials.
Composites: particle-reinforced composites, fiber-reinforced composites, structural composites

## Recommended Books:

1.Callister, W. D., &Rethwisch, D. G. (2007). *Materials science and engineering: an introduction* (Vol. 7, pp. 665-715). New York: John wiley& sons.
2. Jones, D. R., & Ashby, M. F. (2012). *Engineering materials 2: an introduction to microstructures and processing*. Butterworth-Heinemann.

**Suggested –web resources:**
https://ocw.mit.edu/courses/materials-science-and-engineering/3-012-fundamentals-of-materials-science-fall-2005/lecture-notes/lec17b.pdf
https://nptel.ac.in/courses/112104039/53

## Nano Fabrication and Characterization Lab-I

**PHY 512L**

| L | T | P | C |
|---|---|---|---|
| 0 | 0 | 6 | 3 |

**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

After the course the student will be able to:
1. Synthesize the nano-materials
2. Characterize the synthesized materials using several advanced characterizing tools
3. Seek potential of the materials for several industrial technological applications.

Synthesis of nanometer scale particles of colloidal semiconductors such as $TiO_2$, CdS, ZnO, $SnO_2$, $Cu_2S$, CuCNS, $Cu_2O$, $BaTiO_3$, $SrTiO_3$ by wet chemical methods, hydrothermal methods, and pyrolytic or high temperature methods.
Characterization of colloidal semiconductor materials by UV-visible spectroscopy, XRF studies, XRD methods and determination of particle size using XRD half peak width.

Determination of conductivity type by Mott-Shottky plots, cyclic voltammetry and AC-impedance analysis.

Deposition of thin films of semiconductor nanostructures by doctor blading, screen printing, and using the Langmuir-Blogett film casting techniques.

Dye sensitization of semiconductor nanosctructures and construction of solar cells.

Synthesis and characterization of nanoparticles of technologically valuable natural minerals such as hydroxyapatite, ferric phosphate, colloidal silica nanoparticles and their characterization by XRD, XRF, FT-IR methods.

Clay-polymer nanocomposites: Clay-ionically conducting polymer nanocomposites and determination of their ionic conductivities by AC impedance analysis, clay-electronically conducting polymer nanocomposites and determination of their electronic and ionic conductivities through AC impedance analysis and current-time plots at constant applied potential using blocking and non-blocking electrodes.

Synthesis of layered double hydroxides and investigation of anion separation using layered double hydroxides.

Pillard clays and clay-polystyrene, clay-poly (vinyl alcohol), clay-poly (methyl methacylate), clay-polyacylonitrile, clay-poly (ethylene oxide) nanocomposites and determination of their mechanical and thermal properties.

Covalent attachment of semiconductor nanoparticles into textile fibres and textile materials.Investigation of stain-resistant properties and antimicrobial activities.

Preparation of mosquito-repellent textiles.

## Surface, Interfaces and Thin Films

**PHY 531** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

After the course the student should be able to:
1. Understand and describe properties of free liquid surfaces, such as surface tension, capillarity, wetting and spreading.
2. Understand and describe electrical phenomena at surfaces, such as surface charge, surface potential, the electrical double layer, and basic electrochemical concepts.
3. Describe the phase behavior and aggregation of amphiphiles in solution and atinterfaces.
4. Describe intermolecular forces, forces acting between molecules and surfaces, and surface forces.

## Section A

Vacuum technologies: Introduction, Important areas of application basic definitions of vacuum technology, vacuum pumps: rotary Vane pumps, sorption pumps, Diffusion pumps, Turbo molecular pumps, Ion Pumps, cryogenic pumps, Vacuum gauges: Thermocouple gauge, McLeod gauge, Diaphragm gauge, Pirani gauge, Pennying gauge

## Section B

**Growth and Analysis:** Thin Film Deposition Mechanism: Homogeneous (Step propagation, Island growth) and heterogeneous (Frank-Vander Merwe Model, Volmer-Weber Model, Stanski-Krastanov model) film growth,

Analysis of surfaces: structure analysis using AFM (Principle, working and operational modes), STM: (Principle, working and operation modes), LEED, chemical analysis using XPS, AES, Capacitance-Voltage (C-V) measurement technique for the determination of interface quality.

Introduction to crystal lattice: Surface Energy, Wulff Construction and equilibrium shape for nanoparticles, Relaxation and reconstruction at surfaces, adsorption, physisorption and chemisorption, stepped and kinked surfaces.

## Section C

Liquid surfaces and morphology: Roughness and its statistical description, height probability distribution, Gaussian probability distribution, correlation functions, transformation to reciprocal surface, Fractals, fractal dimension, self-similarity, self-affinity, self-affine surfaces, Principles of characterization techniques: Grazing incidence x-ray scattering techniques and surface sensitivity, x-ray and neutron reflectivity.

**Recommended Books:**


1. Prutton M. (1994) Introduction to surface science, (Cambridge University Press)
2. Daillant, J., &Gibaud, A. (Eds.). (2008). *X-ray and neutron reflectivity: principles and applications* (Vol. 770). Springer
3. Delchar, T. A. (1993). *Vacuum physics and techniques*. Chapman and Hall.


**Suggested –web resources:**

https://nptel.ac.in/courses/112101004/downloads/(36-8-1)%20NPTEL%20-%20Vacuum%20Technology.pdf
https://ocw.mit.edu/search/ocwsearch.htm?q=stm

# Second Semester
## Advanced Nano-Electronics

**ELE 501** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

After the course the student will be able to:
1. Cope up with certain nanoelectronic systems and building blocks such as: low-dimensional semiconductors, heterostructures, carbon nanotubes, quantum dots, nanowires etc.
2. Set up and solve the Schrödinger equation for different types of potentials in one dimension as well as in 2 or 3 dimensions for specific cases.
3. Use matrix methods for solving transport problems such as tunneling, resonant tunneling and know the concept of quantized conductance.
4. Experimentally familiarized with AFM and PL methods and know their approximate performance as well as applications.
5. Familiarized with searching for scientific information in their subject area,practice report writing and presenting their project in a seminar

**Section A**

MOS structure, subthreshold characteristics, Short channel effects, punch through, velocity saturation, hot electron effects, CMOS scaling, device variability, interconnects; Bulk CMOS improvements: strained Si, high-K dielectrics metal gates, SOI MOSFETs, Double gate MOSFETs, FinFET, Memory devices: Phase change RAM, ferroelectric RAM, magnetic RAM.

**Section B**

Important quantities in mesoscopic transport, ballistic electron transport, Magneto-transport properties of quantum films: Landau quantization, two-dimensional electron gases in perpendicular magnetic fields, The quantum Hall effect, conductance quantization in quantum pint contacts, the Landauer-Büttiker formalism, Edge states and channels, Quantum point contact circuits, Electronic Phase Coherence: quantum interference and Aharanov-Bohm effect, weak localization, noise in nanostructures.

**Section C**

Limits of conventional microelectronics, Quantum tunneling, Resonant tunneling devices, hot-electron transistors, Coulomb-blockade effect and single-electron transistor, quantized conductance in CNTs, nanotubes, ballistic rectifiers, planar nano diode and nano MOSFET, Y-switches, molecular electronics: Introduction, Electrodes and Contacts, Functions and Devices-First Test Systems), carbon nanotube transistors, Organic

Semiconductors devices: Organic Light Emitting Diodes and Organic Displays.

**Recommended Books:**


1. Hu, C. C. (2011). Modern Semiconductor Devices for Integrated Circuits. *Part I: Electrons and holes in a semiconductor*.
2. Taur, Y., &Ning, T. H. (2013). *Fundamentals of modern VLSI devices*.Cambridge university press.
3. Heinzel, T. (2008). *Mesoscopic electronics in solid state nanostructures*.John Wiley & Sons.
4. Waser, R. (Ed.). (2012). *Nanoelectronics and information technology*. John Wiley & Sons..
5. Lundstrom, M., &Guo, J. (2006). *Nanoscale transistors: device physics, modeling and simulation*. Springer Science & Business Media.
6. Hanson, G. W. (2008). *Fundamentals of nanoelectronics*. Upper Saddle River: Pearson/Prentice Hall.
7. Heikkilä, T. T. (2013). *The physics of nanoelectronics: transport and fluctuation phenomena at low temperatures* (Vol. 21). Oxford University Press.
8. Park, B. G., Hwang, S. W., & Park, Y. J. (2012).*Nanoelectronic devices*. CRC Press.
9. Mitin, V. V., Kochelap, V. A., &Stroscio, M. A. (2008). Introduction to nanoelectronics. *Science, Nanotechnology, Engineering, and Applications (Cambridge Univ. press, Cambridge, 2008)*.
10. Chang, C. Y. (2000). *ULSI devices*.John Wiley & Sons.
11. Datta, S. (1997). *Electronic transport in mesoscopic systems*.Cambridge university press.


**Suggested –web resources**

https://nptel.ac.in/courses/113104004/

https://nptel.ac.in/courses/113104004/29

## Mathematical Modeling and Simulation

**MATH 514** **L T P C**

**4 0 0 4**

**Max. Marks : 100**

**(CA: 40 + ESA: 60)**

**Learning Outcome**:

After the course the student will be able to:

1. Characterize engineering systems in terms of their essential elements, purpose, parameters, constraints, performance requirements, sub-systems, interconnections and environmental context.

2. model and solve the relationship between theoretical, mathematical, and computational modelling for predicting and optimizing performance and objective.

3. Mathematical modelling real world situations related to engineering systems development, prediction and evaluation of outcomes against design criteria.
4. Develop solutions and extract results from the information generated in the context of the engineering domain to assist engineering decision making.
5. Interpret the model and apply the results to resolve critical issues in a real world environment.

## Section A

**Modeling:** Scientific Modeling, Mathematical modeling, Numerical Algorithms, Fundamental principles of numerical methods (Programs and Software, Approximations in Mathematical model building, Numerical integration, Numerical differentiation, Finite element method and Finite difference method, Raleigh's method, Ritz method), physical simulation, process control, transport phenomena, concept of physical domain and computational domain.

## Section B

Ab-Initio methods: Linear Combination of atomic orbtals method, Density function theory, Hartree and HartreeFock methods, mean field approximation, statistical methods for many body system, spin-polarized relativistic Korringa-Kohn-Rostoker Green's function, Augmented Plane Wave, Full Potential-APW, Projector Augmented Plane wave, linear muffin tin orbitals and k.p methods.

## Section C

**Simulation:** Basic concepts of simulation, data manipulation, data exchange of the structure, properties and processing of materials, Three dimensional model for capillary nanobridges, Molecular dynamics simulation.

**Monte Carlo methods:** Basics of the Monte Carlo method, Algorithms for Monte Carlo simulation, Applications to systems of classical particles. Quantum Monte Carlo (Variation MC Diffusion MC : An Introduection only)

**Recommended Books:**


1. Chapra. S.C.and Canale R.P.,Numerical methods for Engineers, Tata McGraw Hill, New Delhi, 2002.
2. Frenkel D. and Smith, B., Understanding molecular simulation from algorithm to applications, Kluwar Academic Press, 1999.
3. Ohno, K, Esfarjani. K. and Y. Kawazoe, Introduction to Computational Materials Science from ab-initio to Monte Carlo Methods, Springer-Verlag, 1999.

**Suggested –web resources:**
https://nptel.ac.in/courses/103106119/
https://ocw.mit.edu/search/ocwsearch.htm?q=ab%20initio

# Quantum Computations and Information Processing

**NANO 501** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

The students are expected to understand basic principles of the techniques presented in the course, their advantages and limitations. Furthermore, the student should understand the requirements for samples suitable for each technique. They should also be able to perform simple and routine operations on the experimental setups.

## Section A

Basics of Nanocomputing: Elements of Boolean Algebra and Binary System, Classical Logic Gates and Logic gate symbols (AND gate, OR gate, NOT gate, NAND gate, NOR gate, EXOR gate, EXNOR gate), Circuit Models. Linear Algebra and Dirac Notation : Hilbert Space, Operators, The Spectral theorem, Functions of Operators, Tensor Products, The Schmidt Decomposition Theorem.

## Section B

Qubits and hypothesis of Quantum mechanics: The state of a quantum system, Time evolution postulate, Superposition and composite System, Measurement postulate, Mixed states and general quantum operation

Quantum model of computation: Quantum gates (one qubit gates and Controlled-U Gates), Universal set of quantum gates, Measurements with quantum circuits. Superdense coding, Quantum Teleportation and it application, Quantum Entanglement.

## Section C

**Introduction to Quantum algorithms:** The Deutsch Algorithm, The Deutsch-Jozsa Algorithm, Quantum phase estimation and quantum Fourier Transformation, Eigenvalue Estimation and finding orders, Shor's algorithm, Grover's quantum Search algorithm,

Quantum Cryptography, Quantum Error Correction, Single-Qubit Measurement, Adiabatic Quantum Computation,

**Physical realizations of logic quantum gates in Quantum System:** Guiding Principles, Conditions for quantum computation, Harmonic oscillator quantum computer, Ion Trap Quantum Computer.

**Recommended Books**


1. Ajayan, P. M., Schadler, L. S., & Braun, P. V. (2006).*Nanocomposite science and technology*. John Wiley & Sons.
2. Wang Z.L (2000) Characterization of nanophase materials – (Wiley-VCH, New York).
3. Rao, C. N. R., Müller, A., &Cheetham, A. K. (Eds.). (2006).*The chemistry of nanomaterials: synthesis, properties and applications*. John Wiley & Sons.
4. Cullity, B. D. (1978). Elements of X-ray Diffraction.
5. Rose, R.M., Shepard L.A., and. Wulff, (1966) The Structure and Properties of Materials (Wiley Eastern Ltd.).


**Suggested –web resources**

https://nptel.ac.in/courses/117106109/1

https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-152j-micro-nano-processing-technology-fall-2005/lecture-notes/cvd.pdf

## Simulation Lab

**Learning Outcome:**

After the course the student will be able to write computer codes for scientific real problems using various numerical and simulation methods.

## Simulation Lab - II

**NANO 503L**

| L | T | P | C |
|---|---|---|---|
| **0** | **0** | **6** | **3** |

**Max. Marks : 100**
(CA: 40 + ESA: 60)

Learning coding programs in any one of the languages like Python, C++, Fortran, Mathematica etc.

Write the Computer program to:

1. Find the roots of a polynomial or transcendental equation using Bisection, Iteration, Newton-Raphson, Ramanujan’s, Quotient-difference methods.
2. Interpolate data using forward, backward and central difference, Newton’s general and Lagrange interpolation methods.
3. Find the least square fit using Straight line and polynomial.
4. Differentiate and integrate functions using Cubic spline, Trapezoidal, Simpson’s, Gaussian integration. To calculate double integral.

5. Simple Linear Algebra manipulations and calculating inverse and eigenvalue problems using inbuilt libraries.
6. Solve single and couple ordinary differential equations using Euler's and Runge-Kutta method.
7. Solving Partial differential equations.
8. One dimensional single orbital tight-bonding model, with random onsite energies. Calculate the eigenvalues, density of states and site dependent electronic occupation for given electron density.
9. Compare results for different strength of disorder.
10. Setup a metropolis algorithm based Monte Carlo simulation of 1d ferromagnetic ising model. Calculate temperature dependence of total energy, specific heat, magnetization and magnetic susceptibility.

## Advanced Characterization Techniques

**PHY 501** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

The students are expected to understand basic principles of the techniques presented in the course, their advantages and limitations. Furthermore, the student should understand the requirements for samples suitable for each technique.They should also be able to perform simple and routine operations on the experimental setups.

**Section A**

Diffraction techniques: Introduction to x-ray sources: sealed tube x-ray source, rotating anode x-ray source, synchrotron source, single crystal diffraction, powder diffraction, Low Energy electron diffraction (LEED), neutron diffraction: interaction of neutron with matter, scattering cross section, scattering length density, light scattering by colloidal dispersion, dynamic light scattering (DLS), static light scattering, hydrodynamic radius, zeta potential.

**Section B**

Microscopes: Optical microscopy, fluorescence and confocal microscopy, transmission electron microscopy (TEM), scanning electron microscopy (SEM), Thermal Analysis DTA, TGA, DSC techniques.

**Section C**

Spectroscopy Techniques: Ultraviolet (UV) and x-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), secondary ion mass spectroscopy (SIMS), Rutherford back scattering, FTIR, UV-VIS, cathode luminescence and photo luminescence.

**Recommended Books**


1. Ajayan, P. M., Schadler, L. S., & Braun, P. V. (2006).*Nanocomposite science and technology*. John Wiley & Sons.
2. Wang Z.L (2000) Characterization of nanophase materials – (Wiley-VCH, New York).
3. Rao, C. N. R., Müller, A., &Cheetham, A. K. (Eds.). (2006).*The chemistry of nanomaterials: synthesis, properties and applications*. John Wiley & Sons.
4. Cullity, B. D. (1978). Elements of X-ray Diffraction.
5. Rose, R.M., Shepard L.A., and. Wulff, (1966) The Structure and Properties of Materials (Wiley Eastern Ltd.)


**Suggested –web resources**

https://nptel.ac.in/courses/117106109/1

https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-152j-micro-nano-processing-technology-fall-2005/lecture-notes/cvd.pdf

## Nano Fabrication and Characterization Lab - II

**PHY 513L**

**L T P C**
**0 0 6 3**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

At the end of the course the student will have an idea of fabrication and characterization of nano-materials and devices.

Carbon nanotubes and carbon nanoparticles: Preparation of carbon nanotubes by pyrolysis of organic gases/Pyrolytic thermal treatment of graphite followed by annealing. Purification of carbon nanotubes, Investigation of extent of purification using XRD, SEM studies of carbon nanotubes (to be carried out elsewhere), Extraction of carbon nanoparticles from vehicle exhausts, Characterization and Particle size analysis using XRD.

Top-down approach to nanoparticles of local minerals: crushing, grinding and milling, Preparation of graphite nanoparticles.

Preparation of colloidal graphite nanoparticles and investigation of their technological uses as lubricants.

Preparation of self-assembled monolayers and their characterization using AFM, contact angle measurements, AC-impedance analysis.

**Recommended Books:**

1. Dutta J. &Hofman H.; Nano materials.
2. Cao G., Nano structures & Nano materials, Imperial college press.
3. Mahalik N.P., Micro manufacturing and Nano Technology.
4. Ratner M. & Ratner D., Nano Technology, Prentice Hall
5. Edelstein A.S. &Cammarata R.C., Nano materials, Institute of physics publishing, Bristol and Philadelphia.

# Elective
# Nano-Engineering of Biological Systems

**BT 518** **L T P C**

**4 0 0 4**

**Max. Marks : 100**

**(CA: 40 + ESA: 60)**

**Learning Outcome:**

Upon completion of the course the student should be able to-
1. explain the concepts of nanotechnology and nanoscience and account for the importance of which in the development of biomedical surface science,
2. explain the interdisciplinary nature of nanotechnology, using examples from biology, medicine, chemistry and physics,
3. evaluate the different technologies used in the synthesis and analysis of nanostructures, and also the phenomena that determine the interactions between nano objects and biological and artificial interfaces

## Section A

General Introduction, Cellular organization, tissues, major organ systems, homeostasis. Evolution of biomedical instrumentation, components of biomedical instrumentation system, transducers, biosignals, biosensors, biopotential and physical measurements, blood gases & pH sensors, bioanalytical sensors, optical sensors.

## Section B

Bioelectric phenomena-Neurons, basic biophysics tools and relationship, equivalent circuit model for the cell membrane, Hodgkin-Huxley model for the action potential, model of the whole neuron. Natural and biomimetic materials, biopolymer synthesis, phase separation in polymers, self assembly, biocompatibility, polymer degradation, biomedical applications including drug delivery, tissue regeneration.

## Section C

Cell structure and components, protein structure, cell membranes, dynamics & morphogenesis of tissue, Growth factor, cell-material interaction, role of mechanical and biochemical environment, bioreactor for tissue growth, tissue grafts ,Fundamental Laws of mechanics, muscle and joint reaction forces, stress and strain, material behavior, soft tissue mechanics, Orthopadic mechanics, cardiac mechanics, blood flow and pressure measurement,Computational biology, the modeling process, bio-networks Biomedical imaging, radiation imaging, diagnostic ultrasound imaging, X-ray, medical resonance imaging, comparison of imaging modes.

## Recommended Books


1. Enderle, J., &Bronzino, J. (2012). *Introduction to biomedical engineering*.Academic press.
2. Bronzino, J. D., & Peterson, D. R. (2014). *Biomedical engineering fundamentals*.CRC press.


**Supplementary Reading :**


1. Bronzino, J. D., & Peterson, D. R. (2014). *Biomedical engineering fundamentals*.CRC press.
3. Cromwell, L., Weibell, F. J., & Pfeiffer, E. A. (2018).*Biomedical instrumentation and measurements* (Vol. 1). Pearson.


## Suggested –web resources

https://ocw.mit.edu/search/ocwsearch.htm?q=ph%20sensorss
https://ocw.mit.edu/search/ocwsearch.htm?q=cell%20structure

## Organic and Polymer Technology

**CHEM 508** **L T P C**

**4 0 0 4**

**Max. Marks : 100**

**(CA: 40 + ESA: 60)**

**Learning Outcome:**

After studying this course, Student should be able to:
1. isolate the key design features of a product which relate directly to the material(s) used in its construction
2. indicate how the properties of polymeric materials can be exploited by a product designer
3. describe the role of rubber-toughening in improving the mechanical properties of polymers
4. identify the repeat units of particular polymers and specify the isomeric structures which can exist for those repeat units
5. estimate the number- and weight-average molecular masses of polymer samples given the degree of polymerisation and mass fraction of chains present.

## Section A

Introduction to polymers, Classification schemes, polymer structure and molecular weight and molecular averages. Polymer synthesis- Step growth, Chain Growth, Polymerization techniques, Synthetic polymers, Chemical structure determination. Ideal chain model, Random walk model, excluded volume effect. Self-avoiding random work, radius of gyration.

Conformations - Single chain conformation, Thermodynamics of polymer solutions

Measurements of Molecular weight - Osmometry, Light scattering, Intrinsic Viscosity measurement, Gel - permeation Chromatography.

Solid State Properties - Amorphous state, crystalline state, Thermal transition and properties.Rause Model, Reptation Model.

## Section B

Mechanical Properties- Mechanism of deformation and method of testing, Viscoelasticity and rubber elasticity. Degradation. Blends and composites- Additives, Polymer blends, Interpenetrating network. Introduction to polymer composites, introduction to Biopolymers, natural polymers and fibers.

Special Polymers- Engineering thermoplastics, polyimides, ionic polymers, polyaryletherketones, polyolifins, Inorganic polymers, liquid crystal polymers, conducting polymers, dendritic polymers, high performance fibers

Non linear Mechanical behavior - Basic processing operations, Polymer rheology: Non Newtonian flow, Viscosity Equation, Elastic properties of polymeric fluids, Melt instabilities, Drag reduction, analysis of simple flows, Rheometry, Modelling of polymer processing operation- Extrusion, Wire coating.

## Section C

Polymers for advanced technology- Membrane science and technology, Biomedical Engineering and drug delivery, applications in Electronics, photonic polymers.

Metal containing Polymers-Cryochemical synthesis, structure, physicochemical properties, Use of precursors in synthesis, optically anisotropic metal polymer nanocomposites,Plasmon absorption, Optical extinction by ion Implantationl.

**Recommended Books**


1. Nicolais, L., &Carotenuto, G. (Eds.). (2004). *Metal-polymer nanocomposites*. John Wiley & Sons..
2. Strobl, G. R., &Strobl, G. R. (1997). *The physics of polymers*(Vol. 2). Berlin: Springer.
3. Fried, J. R. (2014). *Polymer science and technology*.Pearson Education.

**Suggested –web resources**
https://nptel.ac.in/courses/113105028/
https://ocw.mit.edu/search/ocwsearch.htm?q=metal%20containing%20polymers

# MEMS and NEMS Technology

**ELE 504** **L T P C**
**4 0 0 4**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcome:**

1. Ability to understand the operation of micro devices, micro systems and their applications
2. Ability to design the micro devices, micro systems using the MEMS fabrication process.
3. Gain knowledge of basic approaches for various sensor designs
4. Develop experience on micro/nano systems for photonics.
5. Gain the technical knowledge required for computer-aided design, fabrication, analysis and characterization of nano-structured materials, micro- and nano-scale devices.
6. Describe the transduction principles and scaling effects
7. Design MEMS and NEMS and use multiphysics simulation softwares and tools

**Section A**

Introduction to MEMS and NEMS, MEMS Design, Scaling of Micromechanical Devices, Mechanical Properties of MEMS materials, Materials for MEMS, Micromachining Technologies: Bulk, Surface, LIGA, Microfabrication Techniques: Wafer level processes, Pattern Transfer, Process Integration: Developing a process.
Transduction Mechanism, Energy conserving transducers: Parallel plate capacitors, two port capacitors, Electrostatic and Magnetic actuators.

**Section B**

Elasticity: Constitutive equations of linear elasticity, Thermal expansion and thin film stress, Material behavior at large strains.
Structures: Axially loaded beams, bending of beams, Anticlastic curvature, bending of plates, Effects of residual stresses and stress gradients, Plates with in plane stress.
Energy Methods: Elastic energy, the principle of virtual work, Varaitional methods, large deflections of elastic structures.

**Section C**

Applications of MEMS: Inertial sensors, Micromachined pressure and thermal sensors, Microbridge gas sensor, Microrobotics, Microscale vacuum pumps, DNA amplification, brief introduction to micro fluidics.

Fabrication Issues for NEMS and Their applications.

**Recommended Books**


1. Senturia, S. D. (2007). *Microsystem design*.Springer Science & Business Media.
2. Alvi, P. A. (2014). MEMS Pressure Sensors: Fabrication and Process Optimization.
3. Gad-el-Hak, M. (2001). *The MEMS handbook*.CRC press.
4. Sze, S. M. (2008). *Semiconductor devices: physics and technology*. John Wiley & Sons.


**Suggested –web resources**

https://ocw.mit.edu/search/ocwsearch.htm?q=mems
https://nptel.ac.in/courses/105105108/24

## Reading Elective - I

## Nanotechnology in Health Care and Environment

**BT 601R** **L T P C**
**0 0 4 2**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcomes:**

1. Describe how the environment and human health interact at different levels.
2. Demonstrate the knowledge and skills needed to improve the environmental sustainability of health systems.
3. Discuss how the duty of a doctor to protect and promote health is shaped by the dependence of human health on the local and global environment.

Present status of pharmaceuticals and fine chemicals, outline of biochemistry of cells of living organisms. Concepts of nano medicines, physical properties of molecules and supermolecular complexes within cells. Molecular machinery and manufacturing with due stress on programmable medical micromachines, tiny supercomputers through molecular computing, concept of nano robots/ molecular robotics smaller than a cell and their role in elimination of cancer, infection, clogged articles etc., retardation of aging phenomenon. Role of nano technology in bio technology, engineered enzymes, coated colloids in cosmetics in pharmaceuticals, encapsulated drugs for sustained release, sunscreen and UV protective cosmetics, bio medical tagging and bio magnetic separation, diagnostic content agent, bio medical implants. Nanomaterials in Biomedical Applications – drug delivery, tissue regeneration, cancer detection, imaging and diagnostics, outlook for future.

Reduced waste and improved energy efficiency. Waste remediation: Nanoporous polymers and their applications in water purification, Photo-catalytic fluid purification. Energy conversion. Hierarchical self-assembled nano-structures for adsorption of heavy metals. Pollution by Nano-particles.

**Recommended Books**


1. Rao, C. N. R., Muller, A., &Cheetham, A. K. (2004). The chemistry of nanoparticles: synthesis, properties and applications.
2. Challa, K. (2006). Tissue, cell and organ engineering.
3. Challa, R. K., & Kumar, R. (2007). Nanomaterials for medical diagnosis and therapy. *Mass Spectrometry*, *1*, 2.


**Supplementary Reading:**


1. Goddard III, W. A., Brenner, D., Lyshevski, S. E., &Iafrate, G. J. (Eds.).(2007). *Handbook of nanoscience, engineering, and technology*.CRC press.
2. Bhushan, B. (Ed.). (2017). *Springer handbook of nanotechnology*.Springer.


**Suggested –web resources**

https://www.futurelearn.com/courses/nanotechnology-health
https://elearninguoa.org/course/health-nanotechnology-nanomedicine/nanotechnology-and-nanomedicine
https://www.edx.org/learn/nanotechnology

## Development of Nanotechnology: A Global Aspect

**MGMT 601R**

| L | T | P | C |
|---|---|---|---|
| 0 | 0 | 4 | 2 |

**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcomes:**

After completion of this course the student will be able to:

1. Understand the role of nanotechnology in various aspects globally
2. Cope up the advancement in new technologies using nanotechnology

Introduction: Nanotechnology and Geopolitics, Nanotechnology for agriculture and food, Nanotechnology and limits to growth, Nanotechnology and state regulation (India), Nanotechnology and global regulation, Nanotechnology without growth, nanotechnology and global health, How the nations prepare talent, intellectual property, capital and technical expertise to develop the petro-economy, healthcare products and power supply to the nation. Funding strategies/ Education policies in the world and India.Worldwide Research Activities.Tools and Nanoproduct Development. Present Global Nanotechnology efforts.

**Recommended Books**


1. Maclurcan, D., &Radywyl, N. (Eds.). (2011). *Nanotechnology and global sustainability*. CRC Press..
2. Fulekar,M.H. Pathak B., R K Kale (2013) Environment and Sustainable Development, (Springer Press).
3. Parker, R. A., &Appelbaum, R. P. (Eds.). (2013). *Can Emerging Technologies Make a Difference in Development?*.Routledge.


**Suggested –web resources**

http://www.greeknewsagenda.gr/index.php/topics/business-r-d/6583-university-of-athens-online-courses-on-nanotechnology-and-nanomedicine
https://www.coursera.org/learn/nanotechnology

## Nanotechnology and Society

**MGMT 602R** **L T P C**

**0 0 4 2**

**Max. Marks : 100**

**(CA: 40 + ESA: 60)**

**Learning Outcomes:**

After completion of this course the student will be able to:

1. Understand the impact of nanotechnology in routine life
2. Understand the impact of nanotechnology on society

This course integrates three broad areas: science and technology policy, ethics and science communication. Students are introduce to key general principles in each area, then investigate their relevance to nanotechnology. For instance we examine what kinds of policy regimes and ethical discussion influence current development in the world. We also consider frame works used in different settings for the public understanding of the nanotechnology. The overall aim of this course is to encourage critical reflection and discussion of the broader social and potential interests, values, and intuitions shaping development in the field.

**Recommended Books:**


1. Fritz, S., &Roukes, M. L. (2002). *Understanding nanotechnology: from the editors of Scientific American*. Warner Books..
2. Ratner, M. A., & Ratner, D. (2003). *Nanotechnology: A gentle introduction to the next big idea*. Prentice Hall Professional.

3. Jasanoff, S., Markle, G. E., Peterson, J. C., & Pinch, T. (Eds.). (2001). *Handbook of science and technology studies*. Sage publications..
4. MacKenzie, D., &Wajcman, J. (1999). *The social shaping of technology* (No. 2nd). Open university press.
5. Pickering, A. (Ed.). (1992). *Science as practice and culture*.University of Chicago Press.

**Suggested –web resources**

https://www.mrs.org/docs/default-source/programs-and-outreach/strange-matter.green-earth/nanotechnology-and-society-a-practical-guide-to-engaging-museum-visitors-in-conversations.pdf?sfvrsn=bf66fa11_0

http://www.cns.ucsb.edu/about/nanotechnology-society.html

## Reading Elective - II

## Tissue Engineering

**BIO 604R** **L T P C**

**0 0 4 2**

**Max. Marks : 100**

**(CA: 40 + ESA: 60)**

**Learning Outcomes:**

After completion of this course the student will be able to understand the basic mechanism of biological systems using nano-science and technology.

Introduction, structural and organization of tissues: Epithelial, connective; vascularity and angiogenesis, basic wound healing, cell migration, current scope of development and use in therapeutic and in-vitro testing. Cell culture- Different cell types, progenitor cells and cell differentiations, different kind of matrix, cell-cell interaction. Aspect of cell culture: cell expansion, cell transfer, cell storage and cell characterization, Bioreactors ; Molecular biology aspect- Cell signaling molecules, growth factors, hormone and growth factor signaling, growth factor delivery in tissue engineering, cell attachment: differential cell adhesion, receptor-ligand binding, and Cell surface markers.Scaffold and transplant- Engineering biomaterials, Degradable materials, porosity, mechanical strength, 3-D architecture and cell incorporation.Engineering tissues for replacing bone, cartilage, tendons, ligaments, skin and liver. Basic transplant immunology, stems cells ; Case study and regulatory issues-cell transplantation for liver, musculoskeletal, cardiovascular, neural, visceral tissue engineering. Ethical, FDA and regulatory issues.

**Recommended Books**

1. Palsson, B. O., Bhatia, S. N., & Prentice, P. (2004). Reviewed by Kam W. Leong. *Molecular Therapy*, *9*(4).
2. Vunjak-Novakovic, G., &Freshney, R. I. (Eds.). (2006). *Culture of cells for tissue engineering* (Vol. 7).John Wiley & Sons.

**Supplementary Readings:**

1. Joseph D., Bronzino (2006) The Biomedical Engineering –Handbook, (CRC; 3rd edition)

**Suggested –web resources**

https://nptel.ac.in/courses/102106036/
https://ocw.mit.edu/search/ocwsearch.htm?q=bio%20materials

## Nano-Catalysis

**CHEM 601R** **L T P C**
**0 0 4 2**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcomes:**

After completion of this course the student will be able to understand the basic mechanism of chemical reaction and the role of catalysis.

Review of techniques of interpretation of kinetic data, material and energy balance across reactors with reference to their design, Detail coverage of design of fixed, fluidized, trickle, moving bed reactors. Nanocatalysis: Role of transition metals & metal oxides in homogeneous and heterogeneous catalysis and their mechanism of catalysis, manufacture of these catalysts in nano-form and their characterization. Silica, alumina, carbon as high temperature carriers for catalysts.Use of nanocatalysts in automobile pollution control, photocatalysis of toxics in effluents, gas sensors. Reactor design for manufacture of nanocatalysts and nanosupports: Design of flame aerosol reactors, diffusion and premixed flame reactors, co precipitation reactors, hot wall flow reactors; their mechanical features, modeling and simulations. Catalytic vapour –liquid- solid growth mechanism for understanding particle formation and growth during chemical vapour deposition, particle dynamics and CFD simulations of flame process based on fundamental equations for flow, heat and mass transfer, aerosol dynamics in flames.

**Recommended Books**

1. Levenspiel, O. (1999). Chemical reaction engineering.*Industrial& engineering chemistry research*, *38*(11), 4140-4143..

2. Carberry, J. J. (2001). *Chemical and catalytic reaction engineering*. Courier Corporation.
3. Satterfield, C. N. (1970). *Mass transfer in heterogeneous catalysis*.The MIT Press.

**Suggested –web resources**

https://ocw.mit.edu/search/ocwsearch.htm?q=%20nano%20catalysis

https://nptel.ac.in/courses/103108097/28

## RF and MMIC design

**ELE 601R** **L T P C**
**0 0 4 2**
**Max. Marks : 100**
**(CA: 40 + ESA: 60)**

**Learning Outcomes:**

After completion of this course the student will be able to understand radio frequency systems and will also be able to design the new electronic devices.

RF transmitters and receivers, Device choices for circuits: MESFET, EMT, HBT, BiCMOS, BJT and LDMOS, RF circuit design techniques in MIC and MMIC form, Passive and ferrite components, Microwave filters, covering theory and techniques, including active techniques, Amplifier design: Impedance matching, stability, low noise techniques, power amplifier design and linearisation. Active non-reciprocal components: MMIC active isolators. Mixers and modulators, Oscillators: stability determination, phase noise analysis, injection and phase locking and frequency synthesis, Monolithic RF circuits, covering integration technology and design, CAD including MDS, Ultrafast opto-electronic driver and receiver circuits.

**Recommended Books**

1. Robertson, I. D., &Lucyszyn, S. (Eds.). (2001). *RFIC and MMIC Design and Technology* (No. 13). Iet.

**Suggested –web resources**

https://ocw.mit.edu/search/ocwsearch.htm?q=mesfet

https://nptel.ac.in/courses/117107095/20

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