

# M TECH - NANO TECHNOLOGY

M Tech (NT) 2007-08

## I Semester

S No	Code	Subject	Marks		Total	Credits
			Internal	External		
1.	NT11	Material Science	30	70	100	4
2.	NT12	Quantum Physics & Quantum Chemistry	30	70	100	4
3.	NT13	Nano Technology-1	30	70	100	4
4.	NT14	Engineering Materials	30	70	100	4
5.	NT15P	Materials Testing Lab	50	50	100	2
6.	NT16P	Metallography Lab	50	50	100	2
Total					600	20

## II Semester

S No	Code	Subject	Marks		Total	Credits
			Internal	External		
1.	NT21	Characterization of Materials	30	70	100	4
2.	NT22	Strengthening Mechanisms	30	70	100	4
3.	NT23	Nano materials Synthesis and Processing	30	70	100	4
4.	NT24	Micro and Nano fabrication	30	70	100	4
5.	NT25P	Synthesis of Nano powders using High Energy ball mills	50	50	100	2
6.	NT26P	Characterization of Nano powders	50	50	100	2
Total					600	20

## III Semester

S No	Code	Subject	Marks		Total	Credits
			Internal	External		
1.	NT31	Nanotechnology applications and Devices (Seminar Course)	50	--	50	3
2.	NT32	Mechanical behavior of Nano materials (Seminar Course)	50	--	50	3
3.	NT33	Minor Project	50	--	50	4
Total					150	10

## IV Semester

S No	Code	Subject	Marks		Total	Credits
			Internal	External		
1.	NT41	Dissertation	100	--	100	6

# **M TECH - NANO TECHNOLOGY**

(with effect from **2007-08**)

## **I - SEMESTER**

### **NT11 - MATERIALS SCIENCE**

Periods / week: **4**

Credits: **4**

Sessionals: **30**

Exam: **70**

Introduction, classification of materials, dislocations, types, Burgers' Vector, Dislocation movement by climb and cross slip. Dislocation sources, Dislocation point defect interaction and pileups.

Plastic deformation of single crystals. Deformation by slip, CRSS for slip. Deformation of single crystal. Deformation by twinning. Stacking faults, hot working, cold working. Recovery, recrystallization and grain growth. Grain size, Hall-Petch equation.

Mechanical properties. Tensile stress-strain diagrams, proof stress, yield stress diagrams, modulus of elasticity. Hardness Testing: -Rockwell, Brinell and Vickers.

Impact toughness, Charpy V-Notch, fracture, ductile, brittle, Griffith criteria for brittle failure, creep, creep mechanisms, fatigue-mechanism-factors to improve fatigue resistance.

Electrical and Electronic properties of materials, Electronic conductivity, free electron theory and band theory of solids. Intrinsic semi-conductors. Super conductivity. Magnetic properties, Dia, para, ferro, ferri magnetism. Soft and hard magnetic materials.

Optical properties of materials. Refractive index, absorption emission of light, optical fibers. Opto-electronic materials. Polymerization, cross linking, glass transition, classification of polymers. Uses of polymers.

Text books: 1. An introduction to material Science – V Raghavan.  
2. Mechanical Metallurgy – GE Dieter.  
3. Material Science – Callister.

References: 1. Material Science for Engineers – Vanvlack.  
2. Material Science for Engineers – Schackelford.

## NT12 - QUANTUM PHYSICS & QUANTUM CHEMISTRY

Periods / week: 4

Credits: 4

Sessionals: 30

Exam: 70

### **Crystal Structure**

Periodic arrays of atoms-Lattice translation vectors and lattices, Symmetry operations. The basics and crystal structure, primitive lattice cell. Fundamental types of lattices – two dimensional lattice types, three-dimensional lattice types. Index system for crystal planes. Simple crystal structures- Sodium chloride structure. Cesium Chloride structure. Hexagonal close-packed structure. Hexagonal zinc sulfide (Wurtzite) structure.

Diffraction of waves by crystals-Bragg law, Scattered wave amplitude-Fourier analysis, Reciprocal lattice vectors; Brillouin's zone-reciprocal lattice to sc lattice, reciprocal lattice to BCC lattice, Reciprocal lattice to FCC lattice point defects-lattice vacancies; diffusion metals; color centers-f centers, other centers in alkali halides.

### **Phonons and Lattice Vibrations**

Vibration of Monatomic lattices- First Brillouin zone, group velocity. Long wave length or continuum limit, derivation of force constants from experiment. Lattice with two atoms per primitive cell. Quantization of lattice vibrations. Phonon momentum. Inelastic scattering of neutrons by phonons.

### **Basic Physical and Quantum aspects of Chemistry**

Periodic table, surface energy of nanostructure materials, thermodynamic laws. Helmholtz equation, Gibbs free energy.

Basic postulates and Theorem of quantum mechanics. Quantum mechanics of particle in box, one dimensional harmonic oscillator, Rigid Rotator and Hydrogen-like atoms. Orbitals and shapes of orbital.

Theories of chemical bonding. Valence bond theory. Molecular orbital theory and LCAO approximation. MO theory of H<sub>2</sub> and H<sub>2</sub><sup>+</sup> ion. Electronic structure. Linear combination of atomic structure.

- References:
1. Introduction to solid state physics – C Kittel, Fifth edition
  2. Elements of solid state physics – JP Srivastava, 2001 published.
  3. Introduction of quantum chemistry – AK Chandra, 4<sup>th</sup> edition
  4. Quantum Chemistry - Eyring, Walter and Kimball.

## NT13 - NANOTECHNOLOGY-1

Periods / week: 4

Credits: 4

Sessionals: 30

Exam: 70

**Introduction**, Importance of Nano-technology, Emergence of Nano-Technology, Bottom-up and Top-down approaches,, challenges in Nano Technology.

**Zero Dimensional Nano-structures**, Nano particles through homogenous nucleation; Growth of nuclei, synthesis of metallic Nano particles, Nano particles through heterogeneous nucleation; Fundamentals of heterogeneous nucleation and synthesis of nano particles using micro emulsions and Aerosol.

**One Dimensional Nano-structures**, Nano wires and nano rods, Spontaneous growth: Evaporation and condensation growth, vapor-liquid-solid growth, stress induced recrystallization.

Template based synthesis: Electrochemical deposition, Electro-phoretic deposition. Electro-spinning and Lithography.

**Two dimensional nano-structures**, Fundamentals of film growth. Physical vapour Deposition(PVD): Evaporation molecular beam epitaxy (MBE), Sputtering, Comparison of Evaporation and sputtering.

Chemical Vapour Deposition (CVD): Typical chemical reactions, Reaction kinetics, transportant phenomena, CVD methods, diamond films by CVD.

**Thin films**, Atomic layer deposition (ALD), Electrochemical deposition (ECD), Sol-Gel films.

**Special Nano Materials**, Carbon fullerene and nano tubes: carbon fullness ,formation, properties and applications. Carbon nano tubes: formation and applications.

Text books:

1. Nano structures and Nano materials: Synthesis, properties and applications  
- Guozhong Cao- Imperial College press.

## NT14 – ENGINEERING MATERIALS

Periods / week: 4

Credits: 4

Sessionals: 30

Exam: 70

### **Engineering Alloys:**

Low carbon steels, Mild steels, Medium carbon steels, High strength structural steels, Tool steels, Stainless steels, High temperature alloys, Cast irons, The light alloys, Copper and its alloys, Bearing alloys

### **Composites:**

Introduction, Matrix materials, Reinforcements, Mechanical behaviour of composites, Metal matrix composites, Polymer matrix composites, Ceramic matrix composites, Carbon fiber composites

### **Ceramics:**

Silicate ceramics, Imperfections in ceramics, Diffusion in ionic materials, Brittle fracture, Stress - Strain behavior, Fabrication and processing of ceramics, Powder pressing, Refractories, Abrasives and Advanced ceramics

### **Smart Materials:**

Introduction to sensors and actuators, Piezo-electrics, shape memory alloys, Basics of MEMS

### Text Books:

1. Introduction to Physical Metallurgy - SH Avner
2. Materials Science and Engineering: An Introduction - William D Callister Jr
3. Composite Materials - Krishna K Chawla

### Reference Books:

1. Introduction to Ceramics - Kingery, Bowen and Uhlmann
2. ASM Handbook Volume 21: Composites

## **NT14P – MATERIALS TESTING LAB**

**Periods/week: 3P**

**Credits: 2**

**Sessionals: 50**

**Exam: 50**

### **List of Experiments:**

1. Dye-Penetrant Test.
2. Magnetic crack detector.
3. Ericsen Cupping Test
4. Tensile & Bend Testing
4. Coating thickness
6. Shore scleroscope hardness test
7. Testing of a welded joint
8. Poldi Testing
9. Cold working & annealing
10. Fatigue testing
11. Impact testing

## **NT16P – METALLOGRPAHY LAB**

**Periods/week: 3P**

**Credits: 2**

**Sessionals: 50**

**Exam:50**

About 12 experiments on the Metallography of common ferrous and Non-Ferrous metals and alloys, experiments on thermal analysis.

## M.Tech (Nano-Technology) II - SEMESTER

### NT21 - CHARACTERIZATION OF MATERIALS

Periods / week: 4

Credits: 4

Sessionals: 30

Exam: 70

**Introduction and Preliminary Concepts:** Macro-, Meso, Micro and Nanostructure of Materials, Fundamentals of crystallography and Crystal structures.

**X-Ray Diffraction Methods:** X-ray production, Bragg's Law, Laue's Equation, Diffraction Methods, Single Phase analysis, Multi-Phase Analysis, Particle size and strain, Orientation and Texture, Residual Stress.

**Optical Microscopy:** Geometry of Optics, Resolution, Construction of a Microscope, Image Contrast, Phase Contrast.

**Electron Microscopy - SEM:** Electron Optics - Cathodes, Electron Lenses, Aberrations, Resolution, Interaction of Electrons and Matter - Elastic and Inelastic Scattering, Backscattered Electrons, Secondary Electrons, Scanning Electron Microscopy - Image Formation, EPMA, Magnification, Depth of Field, Distortion, Detectors, Contrast, and Resolution.

**TEM:** Electron diffraction, reciprocal lattice, analysis of SAD patterns; different electron diffraction techniques.

**EDS:** X-ray microanalysis: Energy dispersive X-ray spectroscopy (EDS) and Quantitative microanalysis using EDS.

#### Text Books:

1. Microstructural Characterization of Materials - David Brandon and Wayne Kaplan, John Wiley and Sons, New York, NY, 1999.
2. Elements of X-ray Diffraction – BD Cullity and SR Stock, Prentice Hall, New Jersey, 2001.
3. Scanning Electron Microscopy and X-Ray Microanalysis - Joseph I Goldstein, 3rd ed., Dale E. Newbury Academic / Plenum Publishers, New York, 2003 .
4. Transmission Electron Microscopy - David B Williams and Barry Carter, Plenum Press, NY. London 1996 (or a newer edition).
5. Principles of Instrumental Analysis - Douglas A Skoog, F. James Holler and Timothy A. Nieman, 4th Edition ©1998.

## NT22 - STRENGTHENING MECHANISMS

Periods / week: **4**

Credits: **4**

Sessionals: **30**

Exam: **70**

Strengthening from grain boundaries, Hall-Petch relation, ASTM grain size measurement, yield-point phenomenon, strain aging, strengthening due to point defects.

Solid solution strengthening: Elastic interaction, modulus interaction, stacking fault interaction, electrical interaction, short range order interaction, long range order interaction.

Cold working, Strain hardening of single crystals, annealing of cold worked metal, recovery, recrystallization and grain growth.

Strengthening from fine particles, Principle, mechanisms and examples of Precipitation hardening (age hardening), Dispersion hardening. Fiber strengthening, strength and moduli of composites (Iso-strain and Iso-stress condition), influence of fiber length, orientation and concentration

Strengthening by phase transformations, annealing, normalizing and hardening. martensite strengthening.

### Text Books:

1. Mechanical Metallurgy - George E Dieter
2. Mechanical Behaviour of Materials - Thomas H Courtney
3. Materials Science and Engineering an Introduction - William D Callister Jr
4. Materials Science and Engineering – V Raghavan



## NT23 - NANOMATERIALS SYNTHESIS AND PROCESSING

Periods / week: 4

Credits: 4

Sessionals: 30

Exam: 70

Atoms, clusters and Nanomaterials Introduction, Melting point of Gold Nanocrystal, Vapour pressure of Nanocrystals.

**Nanomaterials Synthesis and Processing**, Methods for creating Nanostructures; Processes for producing ultrafine powders- Mechanical grinding; Wet Chemical Synthesis of nanomaterials- sol-gel process, Liquid solid reactions; Gas Phase synthesis of nanomaterials- Furnace, Flame assisted ultrasonic spray pyrolysis; Gas Condensation Processing(GPC), Chemical Vapour Condensation(CVC)- Cold Plasma Methods, Laser ablation, Vapour – liquid –solid growth, particle precipitation aided CVD, summary of Gas Condensation Processing(GPC).

**Nanocomposites Synthesis and Processing**, Introduction, Historical perspective, Different Synthesis methods of Nanocomposites- self Assembly or Bio-Mimetic processes, Film; Processing of Nanoparticles- Binding mechanisms in Nanoparticles, Dispersion of Nanoparticles, Stabilization of Nanoparticles; Special nanostructured materials- Fullerenes- Magnetism and tunneling, Fullerenes films, other applications; Nanotubes- carbon Nanotubes; Onions-carbon onions, Porous silicon- Preparation methods.

**Synthesis of Nanoparticles**, Zirconia and SiC, Microwave Sintering of Nanoparticles Preparation of Nanoparticles , Nanoparticles of SiC, Optimization of the Attritors Work, Purification of Nanoparticles; Sintering Of SiC- Role of Dopants, Role of carbon, Role of Sintering Atmosphere; Sintering of Nano Particles – Preparation of materials , Sintering of Nanoparticles of SiC.

**Microwave Sintering of Nanoparticles**, Microwave Sintering route, Sample preparation from Nanoparticles, Sintering produces of Nanoparticles, Sintering data of Nanoparticles of Alumina, Nanoparticles of Zirconia – Synthesis of Nanoparticles-Sol-Emulsion–Gel Technique, The sol-gel Technique, Sintering of Nanoparticles of Zirconia.

### References:

1. Nanomaterials – AK Bandyopadhyay, Newage International (p) limited publishers.
2. Nanomaterials- J Dutta and H Hofmann
3. Nanostructured materials processing, properties and applications- Carl C Koch, Jaico publishing house.
4. Nanotechnology- William Illsey Atkinson, Jaico publishing house.

## NT24 - MICRO AND NANO FABRICATION

Periods / week: 4

Credits: 4

Sessionals: 30

Exam: 70

Materials Aspects of Micro Electro Mechanical Systems (MEMS) and Nano Electro Mechanical Systems (NEMS), Silicon, Germanium-Based Materials, Metals, Harsh Environment Semiconductors, GaAs, InP, and Related III-V Materials, Ferroelectric Materials and Polymer Materials

Basic Micro-fabrication Techniques, Lithography, Thin Film Deposition and Doping, Etching and Substrate Removal, Substrate Bonding

MEMS Fabrication Techniques, Bulk Micromachining, Surface Micromachining, High-Aspect-Ratio Micromachining

Nanofabrication Techniques, E-Beam and Nano-Imprint Fabrication, Epitaxy and Strain Engineering, Scanned Probe Techniques, Self-Assembly and Template Manufacturing

Stamping Techniques for micro and nano-fabrication, High Resolution Stamps, Micro contact Printing and Nano transfer printing

Applications of printing techniques, Unconventional Electronic Systems, Lasers and Waveguide

### References

1. Springer's Hand book of Nano-technology - Bharat Bhusan (Ed.)
2. Nanotechnology and nanoelectronics – WR Fahrner, Springer International

## **NT25P – SYNTHESIS OF NANO POWDERS**

**Periods/week: 3P**

**Credits: 2**

**Sessionals: 50**

**Exam:50**

About 6 experiments on production of nano powders ball milling, PVD, CVD, solgel techniques.

## **NT26P – CHARACTERIZATION OF NANO POWDERS**

**Periods/week: 3P**

**Credits: 2**

**Sessionals: 50**

**Exam:50**

About 6 experiments on characterization of nano powders by XRD, AFM, LPA, SEM techniques.

### **III - SEMESTER**

#### **NT31 - NANOTECHNOLOGY APPLICATIONS AND DEVICES**

Periods / week: **4**

Credits: **3**

Sessionals: **50**

MEMS devices and applications: Pressure sensor, Inertial sensor, Optical MEMS and RF-MEMS

NEMS devices and applications

Nanotechnology for data storage applications, Millipede Concept of storage.

Micro-actuators for dual-stage servo systems: Design and fabrication

Innovative electronic devices based on Nano-structures: Resonant tunneling Diode, Quantum cascade laser, Single electron Transistor, Carbon nano-tube devices.

#### References

- 1) Springer's Hand book of Nano-technology- Bharat bhusan (Ed.)
- 2) Nanotechnology and nanoelectronics- WR Fahrner, Springer International

## **NT32 - MECHANICAL BEHAVIOR OF NANOMATERIALS**

Periods / week: **4**

Credits: **3**

Sessionals: **50**

### **Nano-mechanical properties of solid surfaces and thin films**

Instrumentation, AFM and Scanning Probe microscopy, Nano-indentation, Adaptations of Nano-indentation.

Complimentary techniques, bulge tests, Acoustic methods, Imaging methods.

Data Analysis, Elastic contacts, indentation of ideal plastic materials, Adhesive contacts, Indenter geometry, Analyzing Load/Displacement curves.

Modes of deformation: Defect nucleation, variations with depth, anisotropic materials, fracture and delamination, phase transformations.

Thin films and multi layers

### **Mechanical properties of Nanostructures**

Experimental techniques for measurement of mechanical properties of Nanostructures: Indentation and Scratch tests using Micro/Nano indentaters, bending tests of nanostructures using an AFM, Bending tests using a nano indenter.

Experimental results and discussion: Indentation and Scratch tests of various materials using Micro/Nano indenters, bending tests of Nanobeams using an AFM, bending tests of micro beams using a nano indenter.

#### References:

1. Springer's Hand book of Nano Technology
2. Nanostructured materials – Processing, properties and applications – Carl C. Koch

## **NT33 – MINOR PROJECT**

Periods / week: **12**

Credits: **4**

Sessionals: **50**

A technical / research problem to be handled by the candidate and submit a report.

## **IV – SEMESTER**

Periods / week: **Semester**

Credits: **6**

Sessionals: **100**

The student has to submit a comprehensive Design/Experimental project report on a selected topic in Nano Technology.