# JNTUA College of Engineering (Autonomous), Ananthapuramu
## Department of Chemical Engineering
**M. Tech NANOTECHNOLOGY** (2015-16 Admitted Batch)
**Course Structure & Syllabus**

**SEMESTER-I**

| Course | Name of the course | Periods per week | | | Credits |
|---|---|---|---|---|---|
| | | Lec | Lab | Total | |
| Theory | Bottom Up Synthesis of Nanostructures | 4 | - | 4 | 4 |
| Theory | Physics and Chemistry of Materials | 4 | - | 4 | 4 |
| Theory | Synthesis and Applications of Nanomaterials | 4 | - | 4 | 4 |
| Theory | Nanobiotechnology, materials and devices | 4 | - | 4 | 4 |
| Theory | Mathematical Modeling and Simulation | 4 | - | 4 | 4 |
| Theory | Elective - I | 4 | - | 4 | 4 |
| Lab | Lab-I: Syntheses and Processing Lab | - | 4 | 4 | 2 |
| | **Total** | **24** | **4** | **28** | **26** |

**Elective – I**
1. Nanotechnology for energy systems
2. Surface sciences and advanced catalysis
3. Quantum Mechanics

**SEMESTER-II**

| Course | Name of the course | Periods per week | | | Credits |
|---|---|---|---|---|---|
| | | Lec | Lab | Total | |
| Theory | Nanosensors, Detectors and Their Applications | 4 | - | 4 | 4 |
| Theory | MEMS and NEMS | 4 | - | 4 | 4 |
| Theory | Physicochemical methods for characterization of Nanomaterials | 4 | - | 4 | 4 |
| Theory | Imaging techniques for Nanotechnology | 4 | - | 4 | 4 |
| Theory | Lithography and Nanofabrication | 4 | - | 4 | 4 |
| Theory | Elective-II | 4 | - | 4 | 4 |
| Audit | Research Methodology | 4 | - | 4 | 0 |
| Lab | Lab-II: Nanometrology and Microscopy | | 4 | 4 | 2 |
| | **Total** | **28** | **4** | **40** | **26** |

**Elective – II**
1. Nanocomposites-Design and Synthesis
2. Advanced Drug Delivery Systems
3. Carbon nanotubes and applications

**SEMESTER-III & IV**

| Course | Name of the course | Periods per week | | | Credits |
|---|---|---|---|---|---|
| | | Lec | Lab | Total | |
| | **III Semester**<br>Seminar-I (15D61301) | - | - | - | 2 |
| | **IV Semester**<br>Seminar-II (15D61401) | - | - | - | 2 |
| | **III & IV Semester**<br>Project Work (15D61302) | - | - | - | 44 |
| | **Total** | **-** | **-** | **-** | **48** |

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## BOTTOM UP SYNTHESIS OF NANOSTRUCTURES (15D61101)

**UNIT-1: THIN FILM TECHNOLOGIES – I:**

CVD Chemical vapor deposition –Atmospheric pressure CVD(APCVD) – Low pressure CVD (LPCVD) - Plasma enhanced chemical vapor deposition (PECVD) or - The HiPCO method - Photo-enhanced chemical vapor deposition (PHCVD)- LCVD Laser–Induced CVD.

**UNIT-2: THIN FILM TECHNOLOGIES – II:**

Physical vapor deposition- Sputter technologies- Diode sputtering - Magnetron sputtering. Ion beam (sputter) deposition, ion implantation and ion assisted deposition - Cathodic arc deposition- pulsed laser deposition.

**UNIT-3: EPITAXIAL FILM DEPOSITION METHODS:**

Epitaxy, Different kinds of epitaxy- Influence of substrate and substrate orientation, mismatch, MOCVD Metal Organic Chemical Vapor Deposition. CCVD Combustion Chemical Vapor Deposition - ALD Atomic Layer Deposition -LPE Liquid phase epitaxy -MBE Molecular Beam Epitaxy.

**UNIT-4: CHEMICAL METHODS:**

Sol-gel synthesis-different types of coatings –spin coating –self assembly-(periodic) starting points for self assembly –Directed self –assembly using conventional lithography –template self-assembly –Vapor liquid solid growth- Langmuir –Blodgett films –DNA self assembly.

**UNIT-5: PRINTING TECHNOLOGIES:**

Screen printing- Inkjet printing- Gravure printing and Flexographic printing- Flex graphic printing- Gravure printing- Roll-to-Roll techniques.

**Text Books & References:**

1. G. Cao, “Nanostructures & Nanomaterials: Synthesis, Properties &Applications” Imperial College Press, 2004.
2. W.T.S. Huck, “Nanoscale Assembly: Chemical Techniques (Nanostructure Science and Technology)”,
3. “Handbook of Nanoscience, Engineering and Technology”, Kluwer publishers, 2002.

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## PHYSICS AND CHEMISTRY OF MATERIALS (15D61102)

**UNIT-1: INTRODUCTION TO NANOMATERIALS:**

Bulk materials vs. nanomaterials, classification, unique properties of nanomaterials, applications, microstructure and defects in nanocrystalline materials: dislocations, twins, stacking faults and voids, grain boundaries, triple and disclinations.

**UNIT-2: EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOR:**

Elastic properties, melting point, diffusivity, grain growth characteristics, enhanced solid solubility, magnetic properties: soft magnetic nanocrystalline alloy, permanent magnetic nanocrystalline materials, giant magnetic resonance, electrical properties, optical properties, thermal properties and mechanical Properties.

**UNIT-3: PHYSICAL PROPERTIES:**

Melting point and phase transition processes- quantum-size-effect (QSE). Size-induced metal-insulator-transition (SIMIT)- nano-scale magnets, transparent magnetic materials, and ultrahigh-density magnetic recording materials-chemical physics of atomic and molecular clusters.

**UNIT-4: PHYSICAL CHEMISTRY OF SOLID SURFACES:**

Surface energy – chemical potential as a function of surface curvature-Electrostatic stabilization-surface charge density-electric potential at the proximity of solid surface-Van der Waals attraction potential.

**UNIT-5: CHEMISTRY ASPECTS:**

Photochemistry; Photoconductivity; Electrochemistry of Nanomaterials-Diffusion in Nanomaterials; Nanoscale Heat Transfer; Catalysis by Gold Nanoparticles; Transport in Semiconductor Nanostructures; Transition Metal Atoms on Nanocarbon Surfaces; Nanodeposition of Soft Materials; Nanocatalysis.

**References:**


1. Text book of Nanoscience and Nanotechnology by B. S. Murthy, P. Shankar, Baldev Raj, B B Rath, James Murday, Springer series, Universities Press,
2. K.W. Kolasinski, “Surface Science: Foundations of Catalysis and Nanoscience”, Wiley, 2002.
3. Joel I. Gersten, “The Physics and Chemistry of Materials”, Wiley, 2001.
4. A. S. Edelstein and R. C. Cammarata, “Nanomaterials: Synthesis, Properties and Applications”, Institute of Physics Pub., 1998.
5. S.Yang and P.Shen: “Physics and Chemistry of Nanostructured Materials”, Taylor & Francis, 2000.
6. G.A. Ozin and A.C. Arsenault, “Nanochemistry : A chemical approach to nanomaterials”, Royal Society of Chemistry, 2005.

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## SYNTHESIS AND APPLICATIONS OF NANOMATERIALS (15D61103)

### UNIT-1: BULK SYNTHESIS

Synthesis of bulk nano-structured materials –sol gel processing –Mechanical alloying and mechanical milling- Inert gas condensation technique – Nanopolymers – Bulk and nano composite materials.

### UNIT-2: CHEMICAL APPROACHES

Self-assembly, self-assembled monolayers (SAMs). Langmuir-Blodgett (LB) films, clusters, colloids, zeolites, organic block copolymers, emulsion polymerization, templated synthesis, and confined nucleation and/or growth. Biomimetic Approaches: polymer matrix isolation, and surface-templated nucleation and/or crystallization. Electrochemical Approaches: anodic oxidation of alumina films, porous silicon, and pulsed electrochemical deposition.

### UNIT-3: PHYSICAL APPROACHES

Vapor deposition and different types of epitaxial growth techniques- pulsed laser deposition, Magnetron sputtering - Micro lithography (photolithography, soft lithography, micromachining, e-beam writing, and scanning probe patterning).

### UNIT-4: NANOPOROUS MATERIALS:

Nanoporous Materials – Silicon - Zeolites, mesoporous materials - nanomembranes and carbon nanotubes - AgX photography, smart sunglasses, and transparent conducting oxides –molecular sieves – nanosponges.

### UNIT-5: APPLICATION OF NANOMATERIALS

Molecular Electronics and Nanoelectronics – Nanobots- Biological Applications – Quantum Devices – Nanomechanics - Carbon Nanotube – Photonics- Nano structures as single electron transistor –principle and design.

**References:**


1. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
2. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.
3. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
4. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties ications , Imperial College Press, 2004.
5. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.

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## NANO BIO-TECHNOLOGY-MATERIALS AND DEVICES (15D61104)

**UNIT-1: FUNDAMENTALS TERMS IN BIOTECHNOLOGY**

Biological building blocks: Sizes of building blocks Nanostructures, Polypeptide nanowire and protein nanoparticles.

**UNIT-2: NUCLEIC ACIDS**

– DNA Double Nano wire, Genetic code and protein synthesis.

**UNIT-3: BIOLOGICAL NANOSTRUCTURES**:

Bio-mimitics with examples, Bio compatible Bio sensors, Examples of proteins, vesicles, bilayers. Multilayer films, application of bio- nanotechnology: bio nano machines, molecular modeling.

**UNIT-4: APPLICATIONS TO NEMS AND NANO DEVICES**:

Nano bio-sensors and biomedical applications nano materials in drug del very, organic semiconductors, biological neurons and their functions**.** Bio-chemical and quantum mechanical computers: DNA computers, parallel processing, Bit and 'Q' bit, Quantum parallelism.

**UNIT-5: NANOSCALE PROCESSES IN THE ENVIRONMENT**

Nano technology for Immune system, clinical imaging, nano robots, Nano Fibres for Tissue Engineering.

**Text books:**

1. Bio Nano Technology by Good Sell, Wiley Liss
2. Introduction to Nanotechnology by Charles. P.Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
3.Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter, Pearson education
4 Nanotechnology – science, innovation and opportunity by Lynn E Foster, Prentice Hall – Pearson education.

**Reference books:**

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nanotechnology by M.Balakrishna Rao

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## MATHEMATICAL MODELING AND SIMULATION (15D61105)

**UNIT-1:Fundamentals of modeling:**
Principles & uses of modeling, classification of mathematical models-steady state Vs dynamic models, lumped Vs distributed parameter models, deterministic Vs stochastic models.
**Examples of mathematical models**-Two heated tanks, constant volume CSTRs, Gravity flow tank, Dynamics of first order & second order systems (Mercury in glass thermometer, Damped vibrator)
**UNIT-2:Empirical model building-** method of least squares, linear, polynomial and multiple regression, non-linear regression.**Solution of simultaneous algebraic equations***:* Direct methods: Gauss-elimination method, Gauss–Jordan method, Iterative methods: Jacobi's method, Gauss-Siedal method.
**UNIT-3:Solution of ODEs**:Euler method, Runge-Kutta method, Milne's Predictor-Corrector method **Solution of PDEs**: Elliptic equations-one dimensional, parabolic equation-hyperbolic equation- partial differential equations-separation of variables-wave equation.

**UNIT-4:Finite Difference:** Difference operator (? ), operator E, Interpolation, Formulation of linear and non-linear finite difference equations**Advanced methods for Differential Equations**: method of lines, Orthogonal Collocation, Finite Volume Method.

**UNIT-5:**
**Fourier series and Fourier integral**: Periodic function, Trigonometric series, Fourier series, Functions of any period, Even andodd functions, Half-range Expansion, Forced oscillations, Fourier integral. **Laplace Transforms and Applications**: Laplace transform, Inverse Laplace transform, Linearity, Shiftingtheorem, Transforms of derivatives and integrals, Differential equations, Unit step function, Second shifting theorem, Dirac's delta function.

**References:**


1. S.C. Chapra and R.P.Canale, "Numerical methods for Engineers", Tata McGraw Hill, New Delhi, 2002.
2. Erwin Kreyzig, "Advanced Engineering Mathematics", John Wiley & Sons, 2004.
3. Jenson and Jeffery, Mathematical Methods in Chemical Engineering,
4. Mickley, Reid and Sherwood, Applied Mathematics in Chemical Engineering, Tata-McGraw-Hill, New Delhi
5. Zill, Dennis and Cullen, Michael Advanced Engineering 3rd Edition, 2006, Jones and Bartlett, Publisher

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## NANOTECHNOLOGY FOR ENERGY SYSTEMS (15D61106)
## (Elective-I)

**UNIT-1: INTRODUCTION**

Nanotechnology for sustainable energy-Materials for light emitting diodes-batteries-advanced turbines-catalytic reactors-capacitors-fuel cells.

**UNIT-2: RENEWABLE ENERGY TECHNOLOGY:**

Energy challenges, development and implementation of renewable energy technologies - nanotechnology enabled renewable energy technologies - Energy transport, conversion and storage, Nano, micro and meso scale phenomena and devices.

**UNIT-3: MICRO FUEL CELL TECHNOLOGY:**

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems - thin film and microfabrication methods - design methodologies - micro-fuel cell power sources,

**UNIT-4: MICROFLUIDIC SYSTEMS:**

Nano-electromechanical systems and novel microfluidic devices - nano engines - driving mechanisms - power generation - microchannel battery - micro heat engine (MHE) fabrication - thermocapillary forces - Thermocapillary pumping (TCP) - piezoelectric membrane.

**UNIT-5: HYDROGEN STORAGE METHODS:**

hydrogen storage methods - metal hydrides - size effects - hydrogen storage capacity - hydrogen reaction kinetics - carbon-free cycle- gravimetric and volumetric storage capacities - hydriding/dehydriding kinetics - high enthalpy of formation - and thermal management during the hydriding reaction - distinctive chemical and physical properties - multiple catalytic effects - degradation of the sorption properties - hydride storage materials for automotive applications.

**References:**


1. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.
2. Hydrogen from Renewable Energy Sources by D. Infield,
3. Fuel Storage on Board Hydrogen Storage in Carbon Nanostructures by R.A. Shatwell,
4. Fuel cell technology handbook. Hoogers. CRC Press, 2003.

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**SURFACE SCIENCES AND ADVANCED CATALYSIS (15D61107)**

**(Elective-I)**

**UNIT-1:** Adsorption phenomenon: Chemisorption & Physisorption, orption isotherms and methods of determination of pore size and surface area of materials using the adsorption isotherms.Catalysis – Definition, types of catalysis with suitable examples, characteristics of a catalyst, selectivity or specificity of the catalyst, activation and deactivation of catalysts, catalytic poisoning

**UNIT-2:** Necessity for the alternate energy sources and the role of catalytic technology in the energy sector – Fuel cells, Solar cells, Biomass and Biofuels, New trends in heterogenous catalysis – catalytic sensors, membrane and monolithic reactors

**UNIT-3:** Catalysis in environmental protection & green process- Industrial catalytic wet air oxidation processes, water purification, synthesis of ity, commodity and fine chemicals, catalysis in automobiles : catalytic converter applications

**UNIT-4:** Important catalytic materials – Nanostructured metals like Pt, Pd and Fe. Nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials (viz. mesoporous materials)

**UNIT-5:** Mesoporous materials – Introduction, synthesis & characterization, properties and applications (with suitable examples), unipore size, b pore size, graphs., supramolecular chemistry, synthesis ( micelar rods).

**References**


1. Basic principles in applied catalysis – Manfredlaerns
2. Nanotechnology in Catalysis – Pinzhan
3. Introduction to Nanotechnology – Charles P Poole Jr & Frank J Owens
4. Nanoscale Materials –LM Liz Marzan & Prashant V. Kamat
5. Nanostructured catalysts – SL Scott, CM Crudden & CW Jones
6. Concepts of Modern Catalysis & kinetics - I. Chorkendorff, J.W. Niemantsverdriet
7. Chemistry of Nanomaterials: Synthesis, properties & applications, Volume-I – CNR Rao, A Muller & AK Cheetham

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**QUANTUM MECHANICS (15D61108)**
**(Elective-I)**

**UNIT-1: Introduction**

Wave-particle duality, Schrödinger equation and expectation values, Uncertainty principle

**UNIT-2: Basics of Quantum mechanics**

Solutions of the one-dimensional Schrödinger equation for free particle, particle in a box, particle in a finite well, linear harmonic oscillator.

3.Reflection and transmission by a potential step and by a rectangular barrier.

**UNIT-3: Solution of Time independent Schrödinger equation**

Particle in a three dimensional box, linear harmonic oscillator and its solution, density of states, free electron theory of metals. The angular meomentum problem. The spin half problem and properties of Pauli spin matrices.

**UNIT-4: Approximate methods**

Time independent and time dependent perturbation theor for non-degenerate and degenerate energy levels. The variational method, WKB approximation, adiabatic approximation, sudden approximations.

**UNIT-5: Quantum computation**

Concept of quantum computation, Quntum Qbits etc.

**Books and References:**


1. Modern Physics - Beiser
2. Quantum Mechanics - Bransden and Joachen
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, 2nd Edition by Eisberg, Robert; Resnick, Robert
4. Quantum Physics – A. Ghatak
5. Principles of Quantum Mechanics 2nd ed. - R. Shankar
6. Quantum Mechanics - Vol 1&2 - Cohen-Tannoudji

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**SYNTHESES AND PROCESSING LAB (15D61109)**

- Nano – Catalyst Preparation by Chemical methods
- Two methods for the synthesis of CNT's (CVD method and Flame Synthesis)
- Synthesis of oxide Nanostructures / nanocomposites by Sol - Gel Process
- Synthesis of nanocomposites by Sol - Gel Process

**Reference books**


1. Advanced catalysis and Nano structured material by WR Moser.
2. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens Wiley India Pvt Ltd.
3. Encyclopedia of Nanotechnology by H.S. Nalwa
4. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill

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## NANOSENSORS, DETECTORS AND THEIR APPLICATIONS (15D61201)

**Unit-I SENSOR CHARACTERISTICS AND PHYSICAL EFFECTS:** Active and Passive sensors – Static and dynamic characteristics - Accuracy, offset and linearity - First and second order sensors – Physical effects involved in signal transduction- Photoelectric and Photo dielectric effect – Photoluminescence–Electroluminescence – chemiluminescence effect – Doppler effect – Barkhausen effect – Hal effect – Ettinshausen effect – Thermoelectric effect – Peizoresistive effect – Piezoelectric effect – Pyroelectric effect –Magneto-mechanical effect (magnetostriction) – Magneto resistive effect.

**Unit-II NANO BASED INORGANIC SENSORS:** Density of states (DOS) – DOS of 3D, 2D, 1D and 0D materials – one dimensional gas sensors:- gas sensing with nanostructured thin films – absorption on surfaces – metal oxide modifications by additives – surface modifications – nano optical sensors – nano mechanical sensors – plasmon resonance sensors with nano particles – AMR, Giant and colossal magneto resistors – magnetic tunneling junctions.

**Unit-III THERMAL SENSORS:** Thermal energy sensors -temperature sensors, heat sensors- Electromagnetic sensors- electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetism sensors - Mechanical sensors -pressure sensors, gas and liquid flow sensors, position sensors - Chemical sensors - Optical and radiation sensors.

**Unit-IV ORGANIC / BIOSENSORS:** Structure of Protein – role of protein in nanotechnology – using protein in nanodevices – antibodies in sensing – antibody in nano particle conjugates – enzymes in sensing – enzyme nanoparticle hybrid sensors – Motor proteins in sensing – transmembrane sensors. Nanosensors based on Nucleotides and DNA – Structure of DNA – DNA decoders and microarrays – DNA protein conjugate based sensors – Bioelectronic sensors – DNA sequencing with nanopores – sensors based on molecules with dendritic architectures – biomagnetic sensors.

**Unit-V SENSOR DETECTORS AND APPLICATIONS:** Cantilever array sensors - for diagnosis of diabetes mellitus and cancer diagnosis - Nanotube based sensors - for DNA detection and capnography - Nanowire based sensors - Nanowire based electrical detection of single viruses - Nanowire based electrical detection of biomolecules. Bio receptors –Bio detectors - Nano array based detector - Nano Particle based detector - Ultra-sensitive detection of pathogenic biomarkers - Ultra-sensitive detection of single bacteria.

**Text Books & References:**

1.Kourosh Kalantar – Zadeh, Benjamin Fry, “Nanotechnology- Enabled Sensors”, Springer , 2008

2.H.Rosemary Taylor, “Data acquisition for sensor systems”, Chapman & Hall, 97.

3.Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, Dav J. Brady, Antonio J. Ricco, David R. Walt, Charles L. Wilkins, “Biosensing: International Research and Development”, Springer, 2006

4.Ramon Pallas-Areny, John G. Webster, “Sensors and signal conditioning” John Wiley & Sons, 2001.

5.Vijay.K.Varadan, Linfeng Chen, Sivathanupillai, “Nanotechnology Engineering in Nano and Biomedicine”, John Wiley & Sons, 2010.W. Ranier, “Nano Electronics and Information Technology”, Wiley, (2003).

5. K.E. Drexler, “Nano systems”, Wiley, (1992).

6. M.C. Pettey, “Introduction to Molecular Electronics”.

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## MEMS AND NEMS (15D61202)

**Unit-I** Development of micro electronics - Region of Nanostructures - methods and limits on microminiaturization in semiconductors- micro electro mechanical systems.

**Unit-II** Silicon micromachining- semiconductors and insulators - Microsystems fabrication techniques - Silicon MEMS fabrication technology - Single crystal reactive etching and metallization process.

**Unit-III** Non-silicon MEMS and fabrication techniques - SIC MEMS - Biomedical-MEMS techniques - Integration of microsystems with electronics – RF MEMS – Applications.

**Unit-IV** Polymers in Microsystems - Packaging of MEMS devices by anodic/fusion bonding - Pressure sensors and packaging - MEMS performance and evaluation.

**Unit-V** Nano electro mechanical systems - fabrication and process techniques - lntegration of nanosystems and devices - applications and future challenges.

**Text Books & References:**


1.W.R.Fahrner, “Nanotechnology and Nanoelectronics: Materials, Devices, Measurement Techniques”, Springer, 2005.

2.K.Goser, P.Glosekotter & J.Dienstuhl, “Nanoelectronic Nanosystems – From Transistors to Molecular Quantum Devices” Springer, 2004.

3.S. E. Lyshevski, “MEMS and NEMS: Systems, Devices and Structures”, CRC Press, 2002.

4.Gregory Timp, “Nanotechnology”, Springer, 1999.

5.Vijay K Varadan, K J Vinoy, S Gopalakrishnan, “Smart Material Systems and MEMS: Design and Development”, John Wiley &Sons, 2006

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## PHYSICOCHEMICAL METHODS FOR CHARACTERIZATION OF NANOMATERIALS (15D61203)

**Unit-I:**

**X-RAY DIFFRACTION-I:**

X-rays, electromagnetic radiation, characteristic spectrum, mosley law,scattering, Diffraction, condition for diffraction, X rays as source to see diffraction, Braggs Law, Diffraction directions, diffraction methods

**Unit-II:**

**X-RAY DIFFRACTION-II:**

single crystal diffraction techniques - Determination of accurate lattice parameters - structure analysis - -relaxation of Braggs law, powder diffractometer, determination of crystal structures,interpretation of diffraction pattern, particle size analysis using Scherer formula.

**Unit-III:**

**THERMAL ANALYSIS METHODS:**

Principle and Instrumentation of Thermogravimetry; Differential Thermal Analysis and Differential scanning calorimetry-Importance of thermal analysis for nanostructures.

**Unit-IV:**

**QUALITATIVE AND QUANTITATIVE ANALYSIS:**

Electron Energy Loss Spectroscopy; High Resolution Imaging Techniques- HREM, Atom probe field ion microscopy-X-Ray Photoelectron Spectroscopy, X-Ray Characterization of Nanomaterials – EDAX and WDA analysis – EPMA – ZAP corrections.

**Unit-V:**

**SPECTROSCOPIC TECHNIQUES:**

Introduction to Molecular Spectroscopy and Differences-With Atomic Spectroscopy-Infrared (IR) Spectroscopy and Applications- Microwave Spectroscopy- Raman Spectroscopy and CARS Applications-Electron Spin Resonance Spectroscopy; New Applications of NMR Spectroscopy.

**References:**


1. B. D.Cullity, “Elements of X-ray Diffraction”, 4th Edition, Addison Wiley, 1978.
2. M. H.Loretto, “Electron Beam Analysis of Materials”, Chapman and Hall, 1984.
3. R.M.Rose, L.A.Shepard and J.Wulff, “The Structure and Properties of Materials”, Wiley Eastern Ltd,
4. B.W.Mott, “Micro-Indentation Hardness Testing”, Butterworths, London, 1956.

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## IMAGING TECHNIQUES FOR NANOTECHNOLOGY (15D61204)

**Unit-I OPTICAL MICROSCOPY:**

Optical microscopy- Use of polarized light microscopy – Phase contrast microcopy – Interference Microscopy – hot stage microscopy - surface morphology – Etch pit density and hardness measurements.

**Unit-II SCANNING ELECTRON MICROSCOPY**

Basic design of the scanning electron microscopy – Modes of operation– Backscattered electrons – secondary electrons- X-rays – typical forms of contrast– Resolution and contrast – enhancement – Specimen Preparation, Replicas Various-application of SEM.

**Unit-III TRANSMISSION ELECTRON MICROSCOPY:**

Basic principles - Modes of operation – Specimen preparation – Diffraction in imperfect crystals – Dislocations – precipitates – Structure of Grain boundaries and interfaces- HRTEM use in nanostructures.

**Unit-IV ATOMIC FORCE MICROSCOPY:**

Basic concepts-Interaction force-AFM and the optical lever- Scale drawing- AFM tip on nanometer scale structures- force curves, measurements and manipulations-feed back control-different modes of operation –contact, non contact and tapping mode-Imaging and manipulation of samples in air or liquid environments-Imaging soft samples. Scanning Force Microscopy-Shear force Microscopy-Lateral Force Microscopy-Magnetic Force microscopy.

**Unit-V SCANNING TUNNELING MICROSCOPY:**

Principle- Instrumentation- importance of STM for nanostructures – surface and molecular manipulation using STM -3D map of electronic structure.

**References:**


1. J.Goldstein, D. E. Newbury, D.C. Joy, and C.E. Lym, “Scanning Electron Microscopy and X-ray Microanalysis”, 2003.
2. S.L. Flegler, J.W. Heckman and K.L. Klomparens, “Scanning and Transmission Electron Microscopy: A Introduction”, WH Freeman & Co, 1993.
3. P.J.Goodhew, J.Humphreys, R.Beanland, “Electron Microscopy and Analysis”,
4. R.Haynes, D.P.Woodruff and T.A.Talchar, “Optical Microscopy of Materials”, Cambridge University press, 1986.

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## LITHOGRAPHY AND NANOFABRICATION (15D61205)

**Unit-I PATTERNING OF THIN FILMS:**

Introduction - Necessity for a clean room- different types of clean rooms-construction and maintenance of a clean room- Lithography -Optical lithography- Optical projection lithography- Multistage scanners resolution- Photomask- Binary mask- Phase shift mask - Attenuated phase shift masks - alternating phase shift masks - Off axis illumination- Optical proximity correction - Sub resolution assist feature enhancement-Optical immersion lithography- Optical interferometric lithography- Holographic lithography.

**Unit-II MASKLESS OPTICAL LITHOGRAPHY:**

Maskless optical projection lithography - Zone plate array lithography-Extreme ultraviolet lithography.

**Unit-III ELECTRON BEAM LITHOGRAPHY:**

Scanning electron-beam lithography- maskless EBL- parallel direct-write e-beam systems- electron beam projection lithography - Scattering with angular limitation projection e-beam lithography- Projection reduction exposure with variable axis immersion lenses.

**Unit-IV X-RAY LITHOGRAPHY:**

Ion beam lithography- Focusing ion beam lithography - Ion projection lithography - Projection focused ion multi-beam - Masked ion beam lithography- Masked ion beam direct structuring- atom lithography.

**Unit-V NANOIMPRINT LITHOGRAPHY AND SOFT LITHOGRAPHY:**

Nanoimprint lithography (NIL)- NIL- hot embossing- UV-NIL- Soft Lithography- Moulding/Replica moulding: Printing with soft stamps- Edge lithography -Dip-Pen Lithography- set up and working principle. Etching techniques- Reactive Ion etching- RIE reactive ion etching- Magnetically enhanced RIE- IBE Ion beam etching- Other etching techniques.

References:


1. D. S. Dhaliwal et al., PREVAIL –"Electron projection technology approach for next generation lithography", IBM Journal Res. & Dev. 45, 615 (2001).
2. M. Baker et al., "Lithographic pattern formation via metastable state rare gas atomic beams", Nanotechnology 15, 1356 (2004).
3. H. Schift et al., "Fabrication of polymer photonic crystals using nanoimprint lithography", Nanotechnology 16, 261, (2005).
4. R.D. Piner, "Dip-Pen" Nanolithography, Science 283, 661 (1999).

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## NANOCOMPOSITES - DESIGN AND SYNTHESIS (15D61206)
## (ELECTIVE – II)

**Unit-1:** Introduction to Nanocomposites, Composite material, Mechanical properties of Nano composite material: stress - strain relationship, toughness, strength, plasticity. ic-Metal Nanocomposites, Ceramic based nanoporous composite, Metal matrix nanocomposites, Polymer-based nanocomposites

**Unit-2:** Carbon nanotube based nanocomposites and Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites.

**Unit-3:** Synthesis methods for various nanocomposite materials: mechanical alloying, thermal spray synthesis etc. properties of nanocomposites.

**Unit-4:** Nano composites for hard coatings; DLC coatings; Thin lm nanocomposites; Modeling of nanocomposites. Nano Indentation, Types of indentation: Oliver & Pharr, Joslin-Oliver, Vickers Indentation process.

**Unit-5:** Processing of polymer nanocomposites, Salt infiltration, Powder mixing, Intrusion method, Exfoliation & interaction, Gel-casting impregnation techniques: Hot melt impregnation, solution impregnation.

**Text Books & References:**

1. Nanocomposite Science & Technology by P.M. Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co.
2. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens; Wiley India Pvt Ltd.

3. Nanotechnology, A gentle introduction to the next big idea by Mark Ratner, Daniel Ratner Pearson education.

**Reference books:**

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nano Technology by M.Balakrishna rao K.Krishna Reddy, Vol I to X Campus books.

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## ADVANCED DRUG DELIVERY SYSTEMS (15D61207)
## (ELECTIVE-II)

**Unit-1:** Dendrimers- Synthesis -Nanoscale containers- Gene transfection. Nanoscafold systems-Biocompatibility of Dendromers

**Unit-2:** Microfabricated drug delivery systems – Microneedles- Micropumps-Microvalves-Implantable microchips – sustained chronic disease.

**Unit-3:** Properties of drug targeting delivery systems-ADME hypothesis-site specific drugs. Synthetic carrier for drugs-liposomes-Antidodies.

**Unit-4:** Targeted Nano particles for drug delivery-Polymers nanotubes-Issues for specific disease will be addressed.

**Unit-5:** Virus Based Nanoparticles - Modification by bioconjugation. Tumour targetting invivo – use in biomedical Imaging.

**Text Books & References:**


1. Drug Delivery: Engineering Principles for Drug Therapy, M. Salzman,

   Oxford University Press, 2001.

2. Drug Delivery and Targeting, A.M. Hillery, CRC Press, 2002.
3. Drug Delivery: Principles and Applications, B. Wang, Wiley Intersceince, 2005.

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## CARBON NANO TUBES AND APPLICATIONS (15D61208)
## (ELECTIVE-II)

**Unit-I:** Carbon Nano structures and types of Carbon Nano tubes, growth mechanisms. Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process.

**Unit-II:** Mechanical reinforcements, Solid Disordered carbon Nanostructures, Nano structured crystals. Graphene,Carbon nanofibers. Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs

**Unit-III:** Carbon clusters and Fullerenes.

**Unit-IV:** Lithium & Hydrogen adsorption & storages. Fuel cell applications and energy storage, Chemical Sensors applications of CNTs.

**Unit-V:** Computer applications (Nano chip), optical and telecommunication applications, Nano composites, silicon Nanowires.

**Text books:**

1. Introduction to Nanotechnology by Charles P. Poole and Frank J.Owens Wiley India Pvt Ltd.
2. Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springer publications

**Reference books:**

1. Encyclopaedia of Nanotechnology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X Campus books.
2. Encyclopedia of Nanotechnology by HS Nalwa
3. Nanotechnology – science, innovation and opportunity by Lynn E.Foster. Hall Pearson education.
4.Nano:The Essentials – Understanding Nano Scinece and Nanotechnology by T.Pradeep; Tata Mc.Graw Hill

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## RESEARCH METHODOLOGY (15D54201)

**(Audit Course For M.Tech. –II Semester Program from 2015 admitted batches onwards)**

### UNIT I

Meaning of Research – Objectives of Research – Types of Research – Research Approaches – Guidelines for Selecting and Defining a Research Problem – research Design – Concepts related to Research Design – Basic Principles of Experimental Design.

### UNIT II

Sampling Design – steps in Sampling Design –Characteristics of a Good Sample Design – Random Sampling Design.

Measurement and Scaling Techniques-Errors in Measurement – Tests of Sound Measurement – Scaling and Scale Construction Techniques – Time Series Analysis – Interpolation and Extrapolation.

Data Collection Methods – Primary Data – Secondary data – Questionnaire Survey and Interviews.

### UNIT III

Correlation and Regression Analysis – Method of Least Squares – Regression vs Correlation – Correlation vs Determination – Types of Correlations and Their Applications

### UNIT IV

Statistical Inference: Tests of Hypothesis – Parametric vs Non-parametric Tests – Hypothesis Testing Procedure – Sampling Theory – Sampling Distribution – Chi-square Test – Analysis of variance and Co-variance – Multi-variate Analysis.

### UNIT V

Report Writing and Professional Ethics: Interpretation of Data – Report Writing – Layout of a Research Paper – Techniques of Interpretation- Making Scientific Presentations in Conferences and Seminars – Professional Ethics in Research.

**Text books:**


1. Research Methodology:Methods and Techniques – C.R.Kothari, 2nd Edition,New Age International Publishers.
2. Research Methodology: A Step by Step Guide for Beginners- Ranjit Kumar, Sage Publications (Available as pdf on internet)
3. Research Methodology and Statistical Tools – P.Narayana Reddy and G.V.R.K.Acharyulu, 1st Edition,Excel Books,New Delhi.


**REFERENCES:**


1. Scientists must Write - Robert Barrass (Available as pdf on internet)
2. Crafting Your Research Future –Charles X. Ling and Quiang Yang (Available as pdf on internet)

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## NANOMETROLOGY AND MICROSCOPY LAB (15D61209)

- Preparation of any two types of Ceramic Powders, $BaTiO_3$ (ball milling) & Al2O3 (flame)
- Composite preparation (Ball Milling)
- X-ray Diffraction measurements of Nano Crystallites
- Nano Particle Size Analysis

**Reference books:**


1. Advanced catalysis and Nano structured material by WR Moser.
2. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens Wiley India Pvt Ltd.
3. Encyclopedia of Nanotechnology by H.S. Nalwa
4. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill


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