JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

M. Tech in NANO TECHNOLOGY
Effective from Academic Year 2017- 18 admitted batch

COURSE STRUCTURE AND SYLLABUS

I Semester

Category	Course Title	Int. marks	Ext. marks	L	T	P	C
PC-1	Properties of Nano Structured Materials	25	75	4	0	0	4
PC-2	Synthesis of Nano materials	25	75	4	0	0	4
PC-3	Quantum Mechanics	25	75	4	0	0	4
PE-1	1. Numerical Methods and Advanced Computing Techniques 2. Nano Material Characterization Techniques	25	75	**3**	0	0	3
PE-2	1. Nano Bio-Technology, Materials And Devices 2. Environmental Nanotechnology	25	75	**3**	0	0	3
OE-1	***Open Elective - I**	25	75	3	0	0	3
Laboratory I	Synthesis ,Characterization and Simulation Lab	25	75	0	0	3	2
Seminar I	Seminar-I	100	0	0	0	3	2
Total		**275**	**525**	**21**	**0**	**6**	**25**

II Semester

Category	Course Title	Int. marks	Ext. marks	L	T	P	C
PC-4	Science and Technology of Thin films & Vacuum	25	75	4	0	0	4
PC-5	Carbon Nanotubes and Applications	25	75	4	0	0	4
PC-6	Nanocomposites – Design and Synthesis	25	75	4	0	0	4
PE-3	1. Nanoelectronics and Nanophotonics 2. Nano Sensors and Devices	25	75	**3**	0	0	3
PE4	1. Lithographic Techniques 2. Nanotechnolgy for Energy Systems	25	75	**3**	0	0	3
OE-2	***Open Elective - II**	25	75	3	0	0	3
Laboratory II	Fabrication, Characterization and Simulation Lab	25	75	0	0	3	2
Seminar II	Seminar-II	100	0	0	0	3	2
Total		**275**	**525**	**21**	**0**	**6**	**25**

III Semester

Course Title	Int. marks	Ext. marks	L	T	P	C
Technical Paper Writing	100	0	0	3	0	2
Comprehensive Viva-Voce	0	100	0	0	0	4
Project work Review II	100	0	0	0	22	8
Total	**200**	**100**	0	**3**	22	**14**

IV Semester

Course Title	Int. marks	Ext. marks	L	T	P	C
Project work Review III	100	0	0	0	24	8
Project Evaluation (Viva-Voce)	0	100	0	0	0	16
Total	**100**	**100**	**0**	**0**	**24**	**24**

***Open Elective subjects must be chosen from the list of open electives offered by OTHER departments.**

 # For Project review I, please refer 7.10 in R17 Academic Regulations.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – II Sem. (Nano Tech.)

SCIENCE AND TECHNOLOGY OF THIN FILMS AND VACUUM (PC – 4)

Course Objective:
The course covers the importance of thin film technology and nanofabrication, vacuum technology, various physical and chemical methods of thin film a fabrication and various applications of thin films including sensors

Course Outcomes:
1. Vacuum technology and principle of vacuum pumps- various types and ranges will be covered.
2. Various fabrication methods of thin films will be dealt in detail
3. Advantages, applications of thin films for devices also will be discussed

Prerequisite:
1. Vacuum pump technology
2. Basics of vacuum pump technology Perini and gauge technology

UNIT – I
Vacuum technology: principles of vacuum pumps in range of 10^{-2} torr to 10^{-11} torr, principle of different vacuum pumps: roots pump, rotary, diffusion, turbo molecular pump, cryogenic-pump, ion pump, Ti-sublimation pump, importance of measurement of Pressure, Concept of different gauges: Bayet- Albert gauge, Pirani, Penning and pressure control.

UNIT-II
Physical Vapor Depostion techniques: Thermal evaporation, resistive evaporation, e-beam evaporation, Electron beam evaporation, Laser ablation, Flash and Cathodic arc deposition, Electron beam, Ion beam lithography techniques and Pulsed LASER Deposition, Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, Ion plating, difference between thin films and coating.

UNIT–III
Electro deposition, molecular beam epitaxy and laser pyrolysis. Chemical vapor deposition techniques: Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, Boundaries, and flow, Different kinds of CVD techniques: Metallorganic CVD (MOCVD), Plasma Enhanced CVD (PECVD) Thermally activated CVD, CVD, Spray pyrolysis, etc.

UNIT – IV
Conditions for the formation of thin films: Environment for thin film deposition, deposition parameters and their effects on film growth, formation of thin films (sticking coefficient, formation of thermodynamically stable cluster – theory of nucleation), capillarity theory, Growth modes: zone model for sputtering and evaporation, Island growth, Volmer weber, Layer growth, Van Vawler Megrue, S.K. (Stranski – Krans Favour) mode. Microstructure in thin films, adhesion,

UNIT – V
Properties of thin films: Mechanical, electrical, and optical properties of thin films, few applications of thin films in various fields. Application to Renewable energy technology – Thin film solar cells, Quantum well and Quantum dot solar cells, dye – sensitized solar cells.

REFERENCES:

1. Materials Science of Thin Films: Milton Ohring.
2. Thin Film Phenomenon by K. L. Chopra, McGraw-Hill
3. Methods of Experimental Physics (Vol 14) by G. L. Weissler and R.W. Carlson “Vacuum Physics and Technology”
4. A User’s Guide to vacuum Technology by J. F. O’Hanlon, John Wiley, and Sons
5. Vacuum Physics and Techniques by T. A. Delchar, Chapman, and Hall
6. Evaporation: Nucleation and Growth Kinetics” by J.P. Hirth and G. M. Pound, Pergamon Press

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – II Sem. (Nano Tech.)

CARBON NANOTUBES AND APPLICATIONS (PC – 5)

Course Objective: The course covers the structural and electronic properties of CNTs apart from various synthesis and characterization methods and applications

Course Outcomes:
1. To understand the properties of CNTs as active component
2. To familiarize with controlled synthesis method
3. To identify applications of CNTs

Prerequisite:
Structure of carbon chemistry and importance and difference types of carbon like diamonds, graphite etc.

UNIT – I
Carbon Nano structures and types of Carbon Nano tubes, growth mechanisms Mechanical reinforcements, Solid Disordered carbon Nanostructures, Nano structured crystals. Graphene, Carbon nano-fibers.

UNIT –II
Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs

UNIT –III
Carbon clusters and Fullerenes, Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process.

UNIT –IV
Lithium ion based batteries, Hydrogen adsorption & Hydrogen storage technology, Fuel cell technology and applications, Chemical Sensor applications of CNTs,

UNIT – V
Computer applications (Nano chip), optical and telecommunication applications, CNT-Nano composites.

REFERENCE BOOKS:
1. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
2. Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springer publications
3. Encyclopedia of Nanotechnology by M. Balakrishna rao and K. Krishna Reddy, Vol I to X Campus books.
4. Encyclopedia of Nanotechnology by HS Nalwa
5. Nanotechnology – science, innovation, and opportunity by Lynn E.Foster. Prentice Hall Pearson education.
6. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology by T.Pradeep; Tata McGraw Hill
7. Fuel storage on Board Hydrogen storage in carbon nanostructures by R A Shatwell
8. Fuel Cell Technology Handbook by Hoogers, CRC presss
9. Hand book of fuel cells: Fuel cell technology and applications by Vielstich, Wiley: CRC press

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – II Sem. (Nano Tech.)

NANOCOMPOSITES - DESIGN AND SYNTHESIS (PC – 6)

Objective:
This course intended to cover nanocomposites, reinforcing nanostructures dispersed in various matrix materials like polymers, ceramics, metals, etc, The subject covers mainly the synthesis methods, modeling and evaluation of nanocomposites.

Outcome of the study:
1. To synthesize and evaluate nanostructure reinforce matrix material
2. To understand the importance of various nanomaterial matrix
3. To discuss various application including aerospace applications

Prerequisite:
1.Basics of composites, properties of bulk composites

UNIT – I
Introduction to Nanocomposites, Composite material, Mechanical properties of Nano composite material: stress - strain relationship, toughness, strength, plasticity.

UNIT – II
Ceramic-Metal Nanocomposites, Ceramic based nanoporous composite, Metal matrix nanocomposites, Polymer-based nanocomposites Carbon nanotube based nanocomposites and Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites.

UNIT – III
Synthesis methods for various nanocomposite materials: mechanical alloying, thermal spray synthesis etc. Nano composites for hard coatings; DLC coatings; thin film nanocomposites; Modeling of nanocomposites.

UNIT – IV
Types of indentation: Oliver & Pharr, Vickers indentation process, Nano Indentation by AFM

UNIT – V
Processing of polymer nanocomposites, properties of nanocomposites, Infiltration techniques, Stir mixing, Extrusion method, Exfoliation & intercalation, Solution casting method, impregnation techniques: Hot melt impregnation, solution impregnation.

REFERENCE BOOKS:
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.
4. Polyoxometalate Chemistry for Nano- Composite Design
5. Encyclopedia of Nanotechnology by H. S. Nalwa
6. Encyclopedia of Nano Technology by M. Balakrishna rao and K. Krishna Reddy, Vol I to X Campus books.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – I Sem. (Nano Tech.)

NANOELECTRONICS AND NANOPHOTONICS (Professional Elective – 3)

Course Objective:
This course is intended to cover basics of electronics, transistor, band structure models, nanocapacitors, coulomb blockade, single electron transistor and nanophotonics.

Course Outcomesy:

1. To know nanoelectronics holds the capacity for mass production of high-quality nanodevices with an enormous variety of applications from computers to biosensors, from cell phone to space shuttles and from large display screens to small electronic toys.
2. To know the scaling of transistors and other devices to smaller and smaller sizes, which has provided the basis for this exponential growth, has limits, physical (size of the atoms), technological (lithography) and economic, which will be reached by nanoelectronics in the next coming decade.
3. In the near future from photonics, molecular electronics or revolutionary engineering solutions, such as departure from two-dimensional ICs on the surface of silicon wafers to three-dimensional structures. All these gigantic challenges and potential nanotechnology solutions are actively debated.

Prerequisite: Basics of nano linear optics and electronics

UNIT- I:
Energy band structure of solids- Kronig Penny model, Effective mass approximation of Schrodinger equation, Single-electron and few-electron phenomena and devices: Tunnel junction and applications of tunneling, Tunneling Through a Potential Barrier, Potential Energy Profiles for Material Interfaces, Metal—Insulator, Metal-Semiconductor, and Metal-Insulator-Metal Junctions,

UNIT- II:
Applications of Tunneling; Field Emission, Gate—Oxide Tunneling and Hot Electron Effects in MOSFETs, Theory of Scanning Tunneling Microscope, Double Barrier Tunneling and the Resonant Tunneling Diode.

UNIT- III:
Coulomb Blockade: Coulomb Blockade, Coulomb Blockade in a Nanocapacitor, Tunnel Junctions, Tunnel Junction Excited by a Current Source, Coulomb Blockade in a Quantum Dot Circuit.

UNIT- IV:
The Single-Electron Transistor: The Single-Electron Transistor Single-Electron Transistor Logic, Other SET and FET Structures, Carbon Nanotube Transistors (FETs and SETs), Semiconductor Nanowire FETs and SETs, Molecular SETs and Molecular Electronics.

UNIT – V:
Nano-Photonics: Foundation of Nano- Photonics, Photonic band gap materials, quantum wells, wires, dots - optical applications, Plasmonics.

REFERENCE BOOKS:

1. Fundamentals of nano electronics by George W Hanson Pearson publications, India 2008{Unit-I- IV)

2. Introduction to photoelectron Spectroscopy (Chemical Analysis Vol. 67) by P.K. Ghosh; Wiley Interscience
3. Nanophotonics by P.N.Prasad – Springer Education series.
4. Nanotechnology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
5. Nanomaterials: Synthesis, properties and applications\edited by A S Edelstein and R C Cammarata (Institute of Physics, UK Series in Micro and Nanoscience and Technology)
6. Encyclopedia of Nano Technology by M. Balakrishna Rao and K. Krishna Reddy (Vol I to X) Campus books.
7. Nano: The Essentials – Understanding Nano Science and Nanotechnology by T. Pradeep; Tata McGraw Hill
8. Spin Electronics by M. Ziese and M. J. Thornton
9. Nanoelectronics and Nanosystems – From Transistor to Molecular and Quantum Devices by Karl Goser, Peter Glosekotter, Jan Dienstuhl
10. Silicon Nanoelectronics by Shunri Odo and David Feny, CRC Press, Taylor & Franicd Group
11. Nanotubes and nanowires by C. N. R. Rao and A. Govindaraj, RSC Publishing
12. Encyclopedia of Nanotechnology by H. S. Nalwa, American Scientific Publishers
13. Handbook of Nanoscience, Engineering, and Technology by W. Goddard, D. Brenner, S. Lyshevski, G.J.Iafrate, CRC Press (2000)
14. Quantum-Based Electronic Devices and Systems by M. Dutta and M.A. Stroscio, WorldScientific

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – I Sem. (Nano Tech.)

NANO SENSORS AND DEVICES (Professional Elective – 3)

Course Objective: This course is intended to know sensor and actuators characteristics, principle of operation and different types of micro and nano- sensor and also of Micro and Nano-actuators.

Course Outcomes:

1. To know the importance of physics behind sensor and actuator transduction.
2. To know working of linear, rotational, acceleration, force, torque, pressure, flow sensor, temperature, proximity, light, smart material, capacitive and inductive sensors in micro and nano dimensions
3. To know actuator operation and its characteristics such resolution, range, sensitivity, error, repeatability, linearity, accuracy and impedance etc.,

Prerequisite:

1. Basics of nano linear optics and electronics
2. Basic of sensors, physical, chemical, mechanics phenomenon's related to sensors.

UNIT- I:

Introduction & Sensor Characteristics: Nanotechnology, Sensors, Nanotechnology Enabled Sensors, Sensor Characteristics and Terminology, Static Characteristics, Dynamic Characteristics, Physical Effects Employed for Signal Transduction.

UNIT- II:

Sensors & Physical Effects: Photoelectric Effect, Photo-dielectric Effect , Photoluminescence Effect, Electroluminescence Effect , Chemiluminescence Effect, Doppler Effect , Barkhausen Effect, Hall Effect, Nernst/Ettingshausen Effect , Thermoelectric (Seebeck/Peltier and Thomson) Effect, Thermoresistive Effect, Piezoresistive Effect, Piezoelectric Effect, Pyroelectric effect, Magneto-Mechanical Effect (Magnetostriction) , Mangnetoresistive Effect, Faraday-Henry Law.

UNIT- III:

Mass-Sensitive & Conductivity Sensors: BAW Sensors, SAW Sensors Conductometric Sensors, Resistive and Capacitive Gas Sensors, Gas Sensors Based on Polycrystalline Semiconductors, Gas Sensors Made of Polymers and Gels, Resistive and Capacitive Sensors for Liquids.

UNIT- IV:

Electrochemical Sensors: Potentiometric Sensors , Selectivity of Potentiometric Sensor, Ion-Selective Electrodes, The Ion-Selective Field Effect Transistor (ISFET), Measurement with Potentiometric Sensors, Amperometric Sensors Selectivity of Amperometric Sensors, Electrode Design and Examples, Measurement with Amperometric Sensors, Sensors Based on Other Electrochemical Methods, Electrochemical Biosensors, Classes of Electrochemical Biosensors.

UNIT- V:

Thermometric & Optical Sensors: Sensors with Thermistors and Pellistors, Pyroelectric Sensors, Sensors Based on Other Thermal Effects, Optical Fibres as a Basis for Optical Sensors, Fibre Sensors Without Chemical Receptors (Mediators),Optodes: Fibre Sensors with a Chemical Receptor, Optodes with Simple Receptor Layers, Optodes with Complex Receptor Layers.

REFERENCE BOOKS:

1. Nanotechnology-Enabled Sensors, Kourosh Kalantar-zadeh, *Springer publications (2007)*
2. Chemical Sensors-An Introduction for Scientists and Engineers,*Peter Gr¨undler, Springer publications (2006)*

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – I Sem. (Nano Tech.)

LITHOGRAPHIC TECHNIQUES (Professional Elective – 4)

Course Objectives:

1. Able to define the concepts involved in physics and chemistry of surfaces along with the fundamental interactions amongst them.
2. Understand the key concepts of lithographic and microscopic resolution and apply this knowledge to estimate the intrinsic resolution limits for manipulation and imaging/inspection tools; Redefining the concepts of contrast and a transfer function for all systems and explain their role in both microscopy and lithography;
3. Evolve how processing tools are applied to transfer nanostructured patterns into useful materials based on device architectures; analyze and evaluate proposed approaches to material processing to device designs in advance

Course Outcomes:

The ultimate aim is to study about nanostructures fabrication and processing in detail and to exercise the learners' knowledge and imagination of nanoscience and nanotechnology toward engineering applications coupled with detailed justifications

Prerequisite: Clean room technology, thin films coating techniques

UNIT–I:

Introduction to lithography and Optical lithography: Introduction to lithography- Contact, proximity printing and Projection Printing, Resolution Enhancement techniques, overlay-accuracies, Mask-Error enhancement factor (MEEF), Positive and negative photoresists.

UNIT–II:

Electron Lithography: Electron optics, Raster scan and Vector scan, Electron proximity / Projection Printing, Direct writing, Electron resists, Electron Beam Applications.

UNIT–III:

X-ray Lithography: X-ray Proximity and projection printing X-ray masks, X-ray sources, X-ray resists.

UNIT–IV:

Ion Lithography: Focussed ion beam – Point sources of Ion, Ion Column, Beam writing, Focused Ion Beam Lithography, Masked Ion Beam Lithography, Ion Projection Lithography.

UNIT–V:

Lithography based on Surface Instabilities: Wetting, De-wetting, Adhesion, Limitations, Resolution and Achievable / line widths of each of the above techniques

REFERENCE BOOKS:

1. K. L. Chopra, "Thin Film Phenomenon", McGraw-Hill, 1968
2. John N. Helbert, "Handbook of VLSI Microlithography", Noyes Publication, USA, 2001.
3. James R Sheats and Bruce w. Smith, "Microlithography Science and Technology", Marcel Dekker Inc., New York, 1998.
4. S. Wolf "Silicon processing for the VLSI era", Vol-1 to 4, Lattice Press.
5. J.P. Hirth and G.M. Pound "Evaporation: Nucleation and Growth Kinetics" (Pergamon Press, Oxford, 1963

6. R. F. Bunshah and C. V. Deshpandey “Evaporation Processes” MRS Bulletin p. 33, Dec. 1988.
7. W. D. Westwood “Sputter Deposition Processes” MRS Bulletin p. 46, Dec. 1988.
8. P. Harris “Taking the Lead in Electron-beam Deposition” Vacuum & Thin Film, Feb. 1999, p. 26.
9. B. Heinz Sputter Target and Thin Film Defects” Vacuum & Thin Film, October 1999, p. 22.
10. G. S. Bales et al., “Growth and Erosion of Thin Splid Films”, Science, 249, 264 (1990).
11. C. R. M. Grovenor, H. T. G. Hentzell and D.A. Smith, “The Development of Grain Structure during Growth of Metallic Films” Acta Metallurgica 32, 773 (1984).
12. L. A. Stelmack, C. T. Thurman and G. R. Thompson “Review of Ion-assisted Deposition:
13. Research to Production”, Nuclear Instruments and Methods in Physics Research B, 37/38,787 (1989).

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – I Sem. (Nano Tech.)

NANOTECHNOLOGY FOR ENERGY SYSTEMS (Professional Elective – 4)

Course Objective:
The course covers the various energy forms, alternate and renewable energy system using nanotechnology.

Course Outcomes:
1. To cover various renewable energy technologies.
2. To study hydrogen production and storage techniques
3. To study solar energy generation and enhancement of conversation efficiency microfluidics and fuel cell technology will be covered.

UNIT– I
Battery materials and batteries: Lithium Ion based batteries.

UNIT– II
Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies,

UNIT– III
Solar cell structures: quantum well and quantum dot solar cells, photo- thermal cells for solar energy harvesting, Thin film solar cells, CIGS solar cells, Dye sensitized solar cells.

UNIT– IV
Hydrogen storage Technology: Hydrogen production methods, purification, hydrogen storage methods. Hydrogen storage materials: metal hydrides and metal-organic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalphy formations and thermal management during hydriding reaction, multiple catalytic – degradation of sorption properties, automotive applications.

UNIT– V
Fuel cell Technology: Fuel cell Principles, types of fuel cells (Alkaline Electrolyte, Phosphoric acid, Molten Carbonate, solid oxide and direct methanol and Proton exchange fuel cells), Principle and operation of Proton Exchange Membrane (PEM) fuel cell.

REFERENCES:
1. Renewable Energy Resources by J. Twidell and T. Weir, E & FN Spon Ltd.
2. Hydrogen from Renewable Energy Source by D. Infield
3. Fundamentals of Industrial Catalytic Process by C.H. Bartholomew and Robert J. Farraoto, John Wiley & Sons Inc.
4. Fuel storage on Board Hydrogen storage in Carbon Nanostructures by R.A. Shatwell
5. Fuel cell Technology Handbook by Hoogers, CRC Press
6. Hand book of fuel cells: Fuel cell technology and applications by Vielstich, Wiley: CRC Press

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. Tech – I Year – II Sem. (Nano Tech.)

FABRICATION, CHARACTERIZATION AND SIMULATION LAB

UNIT - I:
Preparation of any two types of Ceramic Powders – ball milling method (e.g., Magnesium ferrite)

UNIT - II:
a) Composite preparation (Ball Milling)
b) X-ray Diffraction measurements of Nano Crystallites

UNIT - III:
Nano Particle Size Analysis

Unit IV & V:
SIMULATION OF MATHEMATICAL MODELS LAB –I

1. Introduction to MATLAB Programming
2. Program assembly, Execution, Data processing and graphic analysis
3. Study of Fermi – Dirac distribution function
4. Introduction to symbolic math computations
5. MATLAB program to plot the one-dimensional rectangular potential well with infinite potential barrier
6. Introduction to Simulink and Simelectronics