ANNA UNIVERSITY, CHENNAI
DEPARTMENT OF BIOTECHNOLOGY
CENTRE FOR NANOSCIENCE AND TECHNOLOGY
PROGRAM OFFERED: M. TECH. NANOSCIENCE AND TECHNOLOGY

VISION OF THE CENTRE:

The vision of the Centre for Nanoscience and Technology is to excel as one of the leading academic and research centers to carry out Advanced Nanoscale Research in diversified areas of Science and Technology and develop innovative products through technologies to confront the societal challenges.

MISSION OF THE CENTRE:

The mission of the Centre is:

- To provide students a unique and multidisciplinary learning experience that will foster the young minds to develop as a researcher, entrepreneur etc.
- To enhance academic and industrial collaborative research initiatives for the development of nanotechnology-enabled products.
- Amalgamating creative scientists, zealous students and industry professionals under one roof, solely dedicated for cutting-edge research on the advanced functional nanomaterials for the future.
- Contributing to the ethical, environmental, economic and societal implications of nanotechnology.

ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

M. TECH. NANOSCIENCE AND TECHNOLOGY

REGULATIONS – 2023

CHOICE BASED CREDIT SYSTEM (CBCS)

1. PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

Master of Nanoscience and Technology curriculum is designed to prepare the graduates to

1. Outshine in academics and research in different motifs of Nanoscience and Nanotechnology through post graduate education.
2. Build a solid foundation in Synthesis and Characterization of novel nanomaterials with multiple applications.
3. Develop good theoretical and practical knowledge so as to comprehend, analyze, design, and create novel products and solutions for real-life problems.
4. Imbibe professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, and an ability to relate nanotechnology to address environmental issues.
5. Augment leadership qualities, understand the ethical codes and guidelines, and create the urge to become a life-long learner in order to develop a successful professional career.

2. PROGRAMME OUTCOMES (POs):

PO	Program Outcome
1.	Ability to independently carry out research/investigation and development work to solve practical problems.
2.	Ability to write and present a substantial technical report/document.
3.	Able to demonstrate a degree of mastery over the area as per the specialization of the programme. The mastery shall be at a level higher than the requirements in the appropriate bachelor programme than the requirements in the appropriate bachelor program.
4.	Capability to demonstrate good academic knowledge relating to nanomaterials in order to identify engineering and research problems, explore opportunities, propose feasible solutions with environmental consciousness, and nurture a culture of scientific temper.
5.	Ability to design an experiment or prepare a nanomaterial as per needs and specifications, analyze and interpret data and display good verbal and written communication skills in English, ability to function in a multidisciplinary team and apply the learned principles to build the requisite competency for a professional environment and commit to professional ethics and responsibilities.
6.	Capability to instill the need and confidently engage in independent and life-long learning in the context of technological change.

3. MAPPING OF PROGRAMME EDUCATIONAL OBJECTIVES WITH PROGRAMME OUTCOMES

PEO	Program Outcome					
	PO1	PO2	PO3	PO4	PO5	PO6
1	2	2	2	2	2	2
2	3	3	3	3	3	3
3	3	3	3	3	3	3
4	2	3	2	2	3	3
5	1	2	2	2	2	3

4. MAPPING OF COURSE OUTCOME AND PROGRAMME OUTCOME

YEAR	SEMESTER	COURSE NAME	PROGRAMME OUTCOMES (POs)					
			PO1	PO2	PO3	PO4	PO5	PO6
YEAR 1	SEMESTER I	Mathematical modeling and Simulation	2	3	3	1	2	3
		Quantum mechanics	2	3	3	1	2	3
		Synthesis of nanomaterials	2.4	3	3	3	2.4	2.6
		Research methodology and IPR	2	3	1	-	2	3
		Biological nanostructures	2	3	3	3	2	3
		Lab I: Computation & simulation	2	3	3	3	2	3
	SEMESTER II	Imaging techniques for Nanotechnology	2	3	3	3	2	3
		Physicochemical methods for characterization of nanomaterials	2	3	3	2.6	2	2.6
		Physics and chemistry of nanomaterials	2	3	3	3	2	3
		Applications of nanomaterials	2	3	3	3	2	3
		PEC 1	-	-	-	-	-	-
YEAR 2	SEMESTER III	Regulatory perspectives in nanotechnology	2	3	3	3	2	3
		PEC 2	-	-	-	-	-	-
		PEC 3	-	-	-	-	-	-
		PEC 4	-	-	-	-	-	-
		Project Work I	2.5	3	3	3	2.5	3
	SEMESTER IV	Project Work II	2	3	3	3	2	3
			2.5	3	3	3	2.5	3

5. MAPPING OF COURSE OUTCOME AND PROGRAMME OUTCOME

	SUBJECTS	PROGRAMME OUTCOMES (POs)					
		PO1	PO2	PO3	PO4	PO5	PO6
ELECTIVES	Processing and properties of nanostructured materials	1.8	3	3	3	1.8	3
	Biophotonics	2	3	3	3	2	3
	Nanotechnology in health care	2	3	3	3	2	3
	Nanotechnology in agriculture and food industry	2	3	3	3	2	3
	Nanocomposite materials	2	3	3	3	2	3
	Lithography and nanofabrication	2	3	3	3	2	3
	Photonics for nanotechnology	2	3	3	3	2	3
	Semiconductor nanostructures	2	3	3	3	2	3
	Nanomaterials for energy and environment	2	3	3	3	2	3
	Advanced drug delivery system	1.8	3	2	3	1.8	3
	Nano-toxicology	1.8	3	2	3	1.8	3
	Nano biosensors	2	3	3	3	2	3
	Nanoelectronics and sensors	2	3	3	3	2	3
	MEMS and NEMS	2	3	3	3	2	3

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
M. TECH. NANOSCIENCE AND TECHNOLOGY
REGULATIONS – 2023
CHOICE BASED CREDIT SYSTEM
I TO IV SEMESTER CURRICULA & SYLLABI

SEMESTER I

S. NO.	CODE NO.	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	NT3101	Mathematical Modeling and Simulation	FC	4	0	0	4	4
2.	NT3102	Quantum Mechanics	PCC	3	1	0	4	4
3.	NT3103	Synthesis of Nanomaterials	PCC	3	0	4	7	5
4.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
5.	NT3104	Biological Nanostructures	PCC	3	0	0	3	3
PRACTICALS								
6.	NT3111	Computation and Simulation Laboratory	PCC	0	0	4	4	2
			TOTAL	**15**	**2**	**8**	**25**	**21**

SEMESTER II

S. NO.	CODE NO.	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	NT3201	Imaging Techniques for Nanotechnology	PCC	3	0	4	7	5
2.	NT3202	Physicochemical Characterization of Nanomaterials	PCC	3	0	4	7	5
3.	NT3203	Physics and Chemistry of Nanomaterials	PCC	3	0	0	3	3
4.	NT3204	Applications of Nanomaterials	PCC	3	0	0	3	3
5.		Professional Elective I	PEC	3	0	0	3	3
			TOTAL	**15**	**0**	**8**	**23**	**19**

SEMESTER III

S. NO.	CODE NO.	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	NT3301	Regulatory Perspectives in Nanotechnology	PCC	4	0	0	4	4
2.		Professional Elective II	PEC	3	0	0	3	3
3.		Professional Elective III	PEC	3	0	0	3	3
4.		Program Elective IV	PEC	3	0	0	3	3
PRACTICALS								
5.	NT3311	Project Work I	EEC	0	0	12	12	6
			TOTAL	**13**	**0**	**12**	**25**	**19**

SEMESTER IV

S. NO.	CODE NO.	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	NT3411	Project Work II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL CREDITS: 71

PROFESSIONAL CORE COURSES (PCC)

S. No.	COURSE CODE.	COURSE TITLE	PERIODS PER WEEK			CREDITS
			L	T	P	
1.	NT3101	Mathematical modeling and simulation	4	0	0	4
2.	NT3102	Quantum mechanics	3	1	0	4
3.	NT3103	Synthesis of nanomaterials	3	0	4	5
4.	NT3104	Biological nanostructures	3	0	0	4
5.	NT3111	Computation and simulation lab	0	0	4	2
6.	NT3201	Imaging techniques for nanotechnology	3	0	4	5
7.	NT3202	Physicochemical characterization of nanomaterials	3	0	4	5
8.	NT3203	Physics and chemistry of materials	3	0	0	3
9.	NT3204	Applications of nanomaterials	3	0	0	3
10.	NT3301	Regulatory perspectives in Nanotechnology	4	0	0	4

LIST OF PROFESSIONAL ELECTIVE COURSES (PEC)

S. N O.	COURSE CODE.	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	NT3001	Processing and Properties of nanostructured materials	PEC	3	0	0	3	3
2.	NT3002	Biophotonics	PEC	3	0	0	3	3
3.	NT3003	Nanotechnology in Health Care	PEC	3	0	0	3	3
4.	NT3004	Nanotechnology in Agriculture and Food Industry	PEC	3	0	0	3	3
5.	NT3005	Nanocomposite materials	PEC	3	0	0	3	3
6.	NT3006	Lithography and nanofabrication	PEC	3	0	0	3	3
7.	NT3007	Photonics for nanotechnology	PEC	3	0	0	3	3
8.	NT3008	Semiconductor nanostructures	PEC	3	0	0	3	3
9.	NT3009	Nanomaterials for energy and environment	PEC	3	0	0	3	3
10	NT3010	Advanced drug delivery system	PEC	3	0	0	3	3
11	NT3011	Nano-toxicology	PEC	3	0	0	3	3
12	NT3012	Nano biosensors	PEC	3	0	0	3	3
13	NT3013	Nanoelectronics and sensors	PEC	3	0	0	3	3
14	NT3014	MEMS and NEMS	PEC	3	0	0	3	3

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S. NO.	CODE NO.	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	NT3311	Project Work I	0	0	12	6	3
2.	NT3411	Project Work II	0	0	24	12	4

FOUNDATIONAL COURSE (FC)

S. NO.	CODE NO.	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	NT3101	Mathematical Modeling and Simulation	4	0	0	4	1

RESEARCH METHODOLOGY AND IPR COURSES (RMC)

S. NO.	CODE NO.	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	RM3151	Research Methodology and IPR	2	1	0	3	1

SUMMARY

S.NO.	Subject Area	Credits per Semester				Credits Total
		I	II	III	IV	
1.	FC	4	-	-	-	4
2.	PCC	14	16	4	-	34
3.	PEC	-	3	9	-	12
4.	EEC	-	-	6	12	18
5.	RMC	3	-	-	-	3
	TOTAL CREDIT	21	19	19	12	**71**

NT3101 MATHEMATICAL MODELING AND SIMULATION L T P C

4 0 0 4

COURSE OBJECTIVE:

- To impart knowledge on various mathematical modeling and simulation techniques.

UNIT I NUMERICAL METHODS 12

Mathematical problems and analytic solutions; numerical analysis and numerical methods – approximations of functions, Taylor's series applications; error analysis – numerical algorithms and examples; evaluation of functions – bisection method, iteration method, newton–raphson method; numerical differentiation, numerical integration; numerical linear algebra – solving systems of equations, Eigen vector and Eigen value of matrices.

UNIT II MATHEMATICAL MODELING AND ODE 12

Mathematical modeling – physical variables; parameters – stages of mathematical modeling and life cycle; advantages of modeling and limitations; ODE modeling equations and examples – numerical solutions of ODE (single step only), Taylor series method, Euler's method, modified Euler's method, Runge–Kutta 2nd and 4th order methods.

UNIT III PDE MODELING AND THEIR APPLICATIONS 12

Classification of second order PDEs – equations of mathematical physics and boundary values; finite difference approximations to partial derivatives – solving Laplace equation using standard five-point formula, solving Poisson equation, solution of one-dimensional heat conduction equation.

UNIT IV DATA PROCESSING AND SIMULATION 12

Data formats, data manipulation; curve fitting and interpolation techniques; structural and material properties – material databases; basic concepts of simulation – model descriptors; three-dimensional models examples; molecular dynamics (MD) simulation – trajectory, coordinates, velocity and acceleration, Newton's equation, energy conservation; MD Applications.

UNIT V COMPUTATION AND FIRST PRINCIPLE METHODS 12

Basics of the Monte Carlo method – algorithms for Monte Carlo simulation, applications to systems of classical particles; modified Monte Carlo techniques; diffusion Monte Carlo method; quantum Monte Carlo method; VASP; computation of dopant diffusion mechanism and pathways in semiconductor lattice, atomic scale modeling of dopant behavior in crystalline materials.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate knowledge of various numerical methods for solving mathematical problems

CO2: Solve ordinary and partial differential equations

CO3: Acquire knowledge about data manipulations, curve fitting and materials properties

CO4: Make use of molecular dynamics simulations and its applications

CO5: Understand scientific computing, simulation, and their applications

REFERENCES:

1. Chapra S.C. and Canale R.P., "Numerical methods for engineers", 6th Ed., Tata McGraw Hill, New Delhi, 2009.
2. Kreyzig E., "Advanced engineering mathematics", 10th Ed., John Wiley & Sons, London, 2011.
3. Schilling R.J. and Harris S.L., "Applied numerical methods for engineers using MATLAB and C", Thomson publishers, New Delhi, 2004.
4. Giordano F.R., Fox W.P., Horton S.B. and Weir M.D., "Mathematical modeling principles and applications", 5th Ed., Cengage Learning, New Delhi, 2014.
5. Leach A.R., "Molecular modeling – Principles and applications", Pearson, London, 2001.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	1	2	3
2	2	3	3	1	2	3
3	2	3	3	1	2	3
4	2	3	3	1	2	3
5	2	3	3	1	2	3
Avg.	2	3	3	1	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3102 QUANTUM MECHANICS L T P C
3 1 0 4

COURSE OBJECTIVE:

- To teach the basics of quantum mechanics, time-dependent Schrodinger equation for one-dimensional problems, time-independent Schrodinger equation for three-dimensional problems, the concept involved in various approximation methods and concept of quantum computation.

UNIT I BASICS OF QUANTUM MECHANICS 12
Inadequacy of classical mechanics; wave-particle duality; De-Broglie wavelength – group velocity, phase velocity; uncertainty principle and Schrödinger equation.

UNIT II TIME-DEPENDENT SCHRÖDINGER EQUATION 12
Solutions of the one-dimensional Schrödinger equation for free particle; particle in a box; particle in an infinitely deep well potential; linear harmonic oscillator; reflection and transmission by a potential step.

UNIT III TIME-INDEPENDENT SCHRÖDINGER EQUATION 12
Particle in a three-dimensional box; linear harmonic oscillator and its solution; density of states, free electron theory of metals; the angular momentum problem; The spin half problem – properties of Pauli spin matrices.

UNIT IV APPROXIMATION METHODS 12
Time-independent approximation methods; the variation or Rayleigh-Ritz method; WKB approximation; time-dependent perturbation theory; adiabatic approximation; sudden approximation, hydrogen atom.

UNIT V QUANTUM COMPUTATION 12
Concept of quantum computation – q-bits; introduction to nuclear spin; quantum confinement; quantum devices; single electron devices – single electron transistor.

TOTAL: 60 PERIODS

TUTORIAL
Solving the Schrodinger equation for particle in a box problem using MATLAB software.

COURSE OUTCOMES:

CO1: Understand basics of wave-particle duality and quantum mechanics.
CO2: Acquire knowledge about wave function and time dependent Schrödinger equation.
CO3: Perceive about the time-independent Schrödinger equation and free electron theory.
CO4: Interpret the ideas of quantum approximation methods.
CO5: Explain the concepts of quantum computation.

REFERENCES:

1. Bransden B.H. and Joachain C.J., “Quantum mechanics”, 2nd Ed., Pearson Education, 2008.
2. Ghatak A. and Loganathan S., “Quantum mechanics-theory and applications”, 5th Ed., Macmillan publishers, 2004.
3. Shankar R., “Principles of quantum mechanics”, 2nd Ed., Springer, 2013.
4. Claude C.-T., Bernard D. and Laloe F., “Quantum mechanics, volume 1: basic concepts, tools and applications, 2nd Ed., Wiley-VCH, 2019.
5. Prakash S. and Saluja S., ‘Quantum mechanics”, 2nd Ed., Kedarnath Ramnath & Co, 2005.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	2	2	3
2	2	3	3	2	2	3
3	2	3	3	2	2	3
4	2	3	3	2	2	3
5	2	3	3	2	2	3
Avg.	2	3	3	2	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3103 SYNTHESIS OF NANOMATERIALS L T P C

3 0 4 5

COURSE OBJECTIVE:

- To impart knowledge on the chemistry of nanoscale surfaces and synthesis approaches of nanomaterials by various chemical and physical methods and enable students to synthesize various nanomaterials.

UNIT I CHEMISTRY OF NANOSURFACES 9

Importance of nanomaterials – properties and applications; chemistry of small surfaces – curvature effects on chemical reactivity and equilibria (pKa's, redox potentials); surface science for nanomaterials – surface energy; stabilization mechanisms – electrostatic, Nernst equation, electric double layer, Debye-Huckel screening strength; Interaction between nanoparticles – DLVO Theory, steric stabilization, electrostatic stabilization, classical colloid theory; nucleation – homogeneous vs. heterogeneous nucleation, growth, Ostwald ripening.

UNIT II NANOMATERIAL SYNTHESIS – BOTTOM-UP APPROACH 9

Chemical approach – zero dimensional, one dimensional, and two-dimensional nanostructures; metal nanocrystals by reduction; sol–gel method; solvothermal and hydrothermal routes; electrospinning techniques; spin coating routes; self-assembled monolayers (SAMs); Langmuir–Blodgett (LB) films; micro emulsion polymerization; template based synthesis of nanomaterials – electrochemical deposition, electrophoretic deposition; photochemical synthesis; thermolysis routes; sonochemical routes; bio-synthesis – biological methods, use of bacteria, fungi, actinomycetes for nano-particle synthesis; magnetotatic bacteria for natural synthesis of magnetic nanoparticles.

UNIT III NANOMATERIAL SYNTHESIS – TOP-DOWN APPROACH 9

Physical vapor deposition – inert gas condensation technique, aerosol method, liquid-phase epitaxy, arc plasma; laser ablation, RF-plasma, plasma arc technique, gas-phase synthesis, spray pyrolysis; ball milling – types, process variables in milling, mechanism of alloying; mechanochemical processing, thermodynamic aspects in ball milling.

UNIT IV NANO FILM STRUCTURES AND LITHOGRAPHY 9

Evaporation – thermal evaporation; sputtering – glow discharge sputtering, magnetron sputtering, Ion beam sputtering; epitaxy – conditions for the formation of thin films, formation of thin films (sticking coefficient, formation of thermodynamically stable cluster – theory of nucleation), growth modes – island growth, Volmer–Weber, layer growth, Van Vawler Megrue, S.K. (Stranski – Krans favour) mode, molecular beam epitaxy; atomic layer deposition (ALD) – importance of ALD technique; fundamentals, advantages, and limitations of chemical vapor deposition (CVD) techniques; different kinds of CVD techniques – metallorganic (MO) CVD, lithography: photo/UV/EB/FIB techniques, dip-pen nanolithography, etching process – dry and wet etching.

UNIT V NANOPOROUS MATERIALS 9

Nanoporous zeolites; mesoporous materials – template-assisted synthesis, properties, and applications; carbon nanotubes-types, chirality, properties; graphene role of nanomaterials and nanomembranes in drinking water purification; core shell nanostructures and hybrid nanocomposites.

TOTAL: 45 PERIODS

LIST OF EXPERIMENTS

1. Chemical synthesis of Ag nanoparticles; UV–visible absorption of the colloidal sol Mie formalism; Estimation of size by curve fitting
2. Chemical synthesis of ZnS nanoparticles; Optical absorption spectra; Band gap estimation from the absorption spectral data
3. Aqueous to organic phase transfer of Ag and ZnS nanoparticles; Confirmation by UV-Visible absorption.
4. Green synthesis of nanoparticles (Ag, CuO) using different plant extracts and study functional groups using FTIR and morphology using SEM.
5. Study changes in size and stability of green-synthesized nanoparticles based on change in plant extract volume, pH, and temperature.
6. Microwave-assisted synthesis of ZnO nanoparticles.
7. Sol-gel synthesis of metal oxide (ZnO, TiO_2, CdO) nanoparticles using acid hydrolysis.
8. Sol-gel synthesis of metal oxide (ZnO, TiO_2, CdO) nanoparticles using base hydrolysis.
9. Sol-gel spin coating route to SnO_2 nanothin films: surface roughness measurement by AFM.
10. Electrospraying route to carbon nanofibers: surface morphology by SEM.
11. Hydrothermal synthesis of ZnO nanorods: Nanorods formation by SEM analysis.
12. Mechanical ball milling technique for oxide ceramics preparation: crystallite size measurement by XRD.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

CO1: Comprehend the chemistry of nanoscale surfaces
CO2: Design and develop nanoparticles via chemical approaches
CO3: Design and develop nanoparticles via physical approaches
CO4: Develop thin films with the concept of deposition, lithography, and etching techniques.
CO5: Formulate and develop products to facilitate various arenas of industrial research.
CO6: Demonstrate practical aspects of the different chemical and physical synthesis methods
CO7: Create various nanomaterials through hands-on training and knowledge gained
CO8: Formulate nanomaterials of different specifications by varying process parameters

REFERENCES:

1. Rao C.N.R., Muller A. and Cheetam A.K., “The chemistry of nanomaterials: synthesis, properties and applications”, Wiley- VCH Verlag GmbH & Co. KGaA, 2004.
2. Cao G., “Nanostructures and nanomaterials”, “Synthesis, Properties and Applications”, 2nd Ed., Imperial College Press, London, 2011.
3. Pradeep T., “Nano: The essentials: understanding nanoscience and nanotechnology”, Tata McGrawHill Publishing Company Limited, New Delhi, 2007.
4. Edelstein A.S. and Cammarata R.C., “Nanomaterials: synthesis, properties and applications”, 2nd Ed., CRC Press, 2014.

5. Owens F.J. and Poole C.P., “The physics and chemistry of nano solids”, Wiley-Interscience, 2008.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
6	3	3	3	3	3	2
7	3	3	3	3	3	2
8	3	3	3	3	3	2
Avg.	2.4	3	3	3	2.4	2.6

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

RM3151 RESEARCH METHODOLOGY AND IPR **L T P C**
2 1 0 3

OBJECTIVES:

To impart knowledge on

- Formulation of research problems, design of experiment, collection of data, interpretation and presentation of result
- Intellectual property rights, patenting and licensing

UNIT I RESEARCH PROBLEM FORMULATION 9

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II RESEARCH DESIGN AND DATA COLLECTION 9

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV INTELLECTUAL PROPERTY RIGHTS 9

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V PATENTS 9

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Upon completion of the course, the student can

CO1: Describe different types of research; identify, review and define the research problem

CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data

CO3: Explain the process of data analysis; interpret and present the result in suitable form

CO4: Explain about Intellectual property rights, types and procedures

CO5: Execute patent filing and licensing

REFERENCES:

1. Cooper Donald R, Schindler Pamela S and Sharma JK, “Business Research Methods”, Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, “Research methodology for natural sciences”, IISc Press, Kolkata, 2022,
3. Catherine J. Holland, “Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets”, Entrepreneur Press, 2007.
4. David Hunt, Long Nguyen, Matthew Rodgers, “Patent searching: tools & techniques”, Wiley, 2007.
5. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, “Professional Programme Intellectual Property Rights, Law and practice”, September 2013.

NT3104	**BIOLOGICAL NANOSTRUCTURES**	**L T P C**
		3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on the nanostructures and nanoscale phenomenon based on cells and other biomolecules.

UNIT I BIOINSPIRATION AND CELLULAR NANOSTRUCTURES 9

Bio-inspired nanostructures – lotus leaf, gecko feet, structural colors; functional nanostructures and nanomaterials at the cellular level; cytoskeletal proteins and their nanomechanics; nanostructures inspired from or harvesting bacterial and viral components; plant-derived nanostructures – types, phytochemicals involved, and applications.

UNIT II DNA NANOTECHNOLOGY 9

Genome structure and organization; structure and function of nucleic acids; the central dogma of life; aptamers; self-assembled DNA nanostructures; passive DNA nanostructures – DNA wires, DNA origami; active DNA nanostructures – tweezers, scissors, 3-state, DUTE, B-Z device, and applications; organic and inorganic DNA nanostructures.

UNIT III PROTEIN AND ENZYME NANOPARTICLES 9

Proteins – structure, classification, self-assembly, and functions; designer peptides – cyclic peptides, bola amphiphiles, molecular lego peptides, foldamers, phage display; protein-templated nanostructures; protein nanoparticle stabilization; enzymes; enzyme nanoparticles – preparation, properties, immobilization, and applications; synzymes, abzymes, ribozymes.

UNIT IV CARBOHYDRATES AND GLYCO NANOPARTICLES 9

Carbohydrates – classification, nomenclature, structure, function; glyco nanoparticles – preparation and applications; glyco-metal and glycocarbon conjugates; fate of glyco-based nanoparticles.

UNIT V LIPID-BASED NANOPARTICLES 9

Lipids – structure, types, properties, function, significance in membrane transport, packing parameter; lipid-based nanomaterials – self-assembly, micelles, vesicle types and preparation, lipid nanotubes and bilayer preparation, non-lamellar, and exotic structures.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Comprehend the nanoscale phenomenon of cellular nanostructures and develop bio-inspired solutions.
CO2: Perceive the applications of DNA passive and active nanostructures.
CO3: Design and utilize protein and enzyme-based nanostructures.
CO4: Classify glycol nanostructures based on their binding and applications.
CO5: Comprehend membrane transport and lipid-based nanostructures and their uses.

REFERENCES:

1. AlešIglič D.D., Kralj-Iglič V., "Nanostructures in biological systems: theory and applications", Pan Stanford Publishing, US, 2015.
2. Lee S.W., "Volume 3: Bio-Inspired nanomaterials: nanomaterials built from biomolecules and using bio-derived principles", 'Soft matter and biomaterials on the nanoscale', World Scientific Series in Nanoscience and Nanotechnology, 2020.
3. Ki Y., "3D DNA nanostructure", Humana Press Inc., New York, 2015.
4. Cortajarena A.L. and Grove T.Z., "Protein-based engineered nanostructures", Springer, Switzerland, 2016.
5. Stine K.J., "Carbohydrate nanotechnology", Wiley New Jersey, 2015.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3111 COMPUTATION AND SIMULATION LAB L T P C
0 0 4 2

COURSE OBJECTIVE:

- To teach modeling and simulation of mathematical equations using various softwares.

LIST OF EXPERIMENTS

Programmes using MATLAB software:

1. To plot the basic operation.
2. To plot the matrix solution.
3. To plot the solution of various numerical method problems.
4. To plot the first four Eigen functions of a one – dimensional rectangular potential well with infinite potential barrier.
5. To derive numerical solutions of the Schrodinger wave equation for a rectangular potential well with infinite potential barrier.
6. To study the I-V characteristics of nanoscale devices.

Studies using offline scanning probe imaging processor (SPIP) software:

7. To determine the lattice constant and lattice angles for atomically resolved STM image of HOPG (highly oriented pyrolytic graphite).
8. To determine the surface roughness of raw and processed AFM images of glass, silicon and films made by different methods.

Studies using exabyte software:

9. Various properties of semiconductor nanostructures.
10. Molecular structure of various materials.
11. Nanocluster formation.
12. Density of states variation for bulk and nanomaterials.

TOTAL:60 PERIODS

COURSE OUTCOMES:

CO1: Apply the knowledge in modeling and simulation of equations using MATLAB

CO2: Perceive techniques for image processing and analysis to interpret TEM, STEM and AFM images.

CO3: Explain and analyse molecular structures using Exabyte software.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

SEMESTER II

NT3201 IMAGING TECHNIQUES FOR NANOTECHNOLOGY L T P C
3 0 4 5

COURSE OBJECTIVE:

- To impart theoretical and practical knowledge on the imaging techniques of nanomaterials.

UNIT I OPTICAL MICROSCOPY 9

Concept of resolution and depth of field/focus in imaging; types of aberrations (spherical, chromatic, diffraction and astigmatism), optical microscopy (OM) – reflected/transmitted light microscopy; theoretical and practical resolution of an optical microscopy, numerical aperture, principles of image formation; dark field; polarized light microscopy; phase contrast microscopy; fluorescence microscopy – TIRF types; metallurgical light microscopy; applications of optical microscopy in metallurgical and materials engineering; sample preparation for optical microscopy and limitations.

UNIT II SCANNING ELECTRON MICROSCOPY 9

Advantages/disadvantages as compared to OM and other imaging techniques; mechanics of SEM, types of electron gun and comparison between them (in terms of resolution, brightness, efficiency and applications); SEM – working, construction, concept of magnification; electron-matter interaction; imaging modes (secondary and backscattered); effect of spot size; apertures, accelerating voltage on SEM imaging; signal detection (by using Everhart–Thornley, Robinson and solid-state detectors), atomic number and topological contrast; critical probe current; chemical analysis of phases using SEM (EDS); environmental SEM.

UNIT III TRANSMISSION ELECTRON MICROSCOPY 9

Principles of transmission electron microscopy – modes of operation, construction, working, imaging modes; electron scattering in amorphous and polycrystalline materials-condition for electron scattering; contrast mechanisms – mass-thickness, phase and diffraction contrast; selected area electron diffraction – interpretation, elemental mapping, lattice plane fringe width analysis; concept of real space and reciprocal lattice; electron diffraction condition; diffraction in imperfect crystals; HRTEM use in nanostructures, sample preparation techniques – biological specimen and non-biological specimen.

UNIT IV ATOMIC FORCE MICROSCOPY 9

Basic concepts – interaction force, AFM and the optical lever; force curves measurements and manipulations; modes of operation – contact, non-contact and tapping mode; imaging soft /biological samples- manipulation of samples in air or liquid environments; scanning force microscopy-types - magnetic force microscopy.

UNIT V SCANNING TUNNELING MICROSCOPY 9

Principles of operation – quantum mechanical tunneling phenomenon in STM, different modes of operation; role of STM in surface and molecular manipulation; 3D map of electronic structure.

TOTAL: 45 PERIODS

LIST OF EXPERIMENTS:

1. Determination of size and lateral dimensions of various samples (pollen grains, strands of hair) using a high magnification optical microscope.
2. Interpretation of optical microscope images of various samples.
3. SEM analysis of powder, thin films, porous materials
4. SEM interpretation of powder, thin films, porous materials
5. Surface topography analysis using AFM: powder, thin films, porous materials
6. Surface topography interpretation of powder, thin films
7. TEM analysis of powder, liquid, porous materials and biological samples.
8. Interpretation of HRTEM images of various nanostructures.
9. SAED analysis of various nanostructures.
10. Interpretation of SAED patterns of various nanostructures.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

CO1: Perceive various optical microscopic techniques to study the morphology.
CO2: Explain the use of scanning electron microscopy to study the morphology.
CO3: Explain the use of transmission electron microscopy to study the morphology and crystal structure.
CO4: Apply the probing method to construct a 3D profile of nanomaterials.
CO5: Acquire knowledge Tunneling concepts to manipulate the atomic world.
CO6: Perceive the working and handling of analytical instruments and techniques like SEM, AFM, and XRD.
CO7: Develop ability to independently use instrumentation facilities and obtain data.
CO8: Apply the gained knowledge for data interpretation of nanostructures and look on how to modify the surface morphology for various applications.

REFERENCES:

1. J. Goldstein, D. Newbury, D. Joy, C. Lyman, P. Echlin, E. Lifshin, L. Sawyer and J. Michael., “Scanning electron microscopy and X-ray microanalysis” 3rd Edition, Springer Science, Berlin 2003.
2. Egerton R., “Physical principles of electron microscopy”, Springer Science, Berlin, 2005.
3. Brandon D. and Kaplan W., “Microstructural characterization of materials”, John Wiley and Sons, London, 2008.
4. Murphy D.B., "Fundamentals of light microscopy and electronic imaging", John Wiley and Sons, London, 2001.
5. Eaton P., “Atomic force microscopy”, Oxford Press, 2010.

CO-PO MAPPING:

CO	PSO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3

6	2	3	3	3	2	3
7	2	3	3	3	2	3
8	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3202 PHYSICOCHEMICAL CHARACTERIZATION OF NANOMATERIALS **L T P C**
3 0 4 5

COURSE OBJECTIVE:

- To teach about the various spectroscopic techniques, x-ray diffraction methods, thermal properties, qualitative and quantitative analysis and the various nanomechanical analysis for nanomaterials and enable students to perform real-time analysis of nanomaterials and interpretation of data.

UNIT I SPECTROSCOPIC TECHNIQUES 9

Molecular spectroscopy – introduction; differences between molecular and atomic spectroscopy; UV–visible spectroscopy; infrared (IR) spectroscopy – instrumentation and applications; microwave spectroscopy – instrumentation and applications; raman spectroscopy – instrumentation and applications; CARS applications; electron spin resonance (ESR) spectroscopy– instrumentation and applications; NMR spectroscopy – instrumentation, types, and applications; dynamic light scattering (DLS); zeta potential analysis.

UNIT II DIFFRACTION METHODS 9

X-ray diffraction; powder diffraction technique – instrumentation and applications; single crystal diffraction techniques – instrumentation, applications, determination of lattice parameters, structure analysis, profile analysis; Scherrer formula – crystallite size analysis; electron diffraction – applications, neutron diffraction – applications.

UNIT III THERMAL ANALYSIS METHODS 9

Thermogravimetry (TG) – principle, instrumentation, types, and applications; differential thermal analysis (DTA) – principle, instrumentation, types, and applications; scanning calorimetry (DSC) – principle, instrumentation, types, and applications; importance of thermal analysis for nanostructures.

UNIT IV QUALITATIVE AND QUANTITATIVE ANALYSIS 9

Electron energy loss spectroscopy (EELS) – instrumentation and applications; high-resolution imaging techniques – SEM and TEM; atomic probe field ion microscopy – instrumentation and applications; X-Ray photoelectron spectroscopy– instrumentation and applications; X-ray fluorescence (XRF) – instrumentation and applications; EDAX and WDA analysis; electron probe micro analyzer (EPMA) – ZAP corrections.

UNIT V NANOMECHANICAL ANALYSIS 9

Mechanical properties of materials in small dimensions; nanoindentation – principle and applications, interpretation of load displacement curves, data analysis; elastic and plastic deformation; hardness test – types and applications; BET analysis.

TOTAL: 45 PERIODS

LIST OF EXPERIMENTS:

1. FTIR analysis of organic and inorganic nanostructures.
2. Raman analysis of carbon-based and crystalline nanostructures.
3. TGA-DTG analysis of metallic and ceramic nanomaterials.
4. TGA-DTG analysis of polymeric nanomaterials.
5. DSC analysis of metallic and ceramic nanomaterials.
6. DSC analysis of polymeric nanomaterials.
7. UV–vis analysis of metallic and semiconductor nanomaterials.
8. Particle size analysis of nanomaterials.
9. Zeta potential analysis of nanomaterials.

10. XRD analysis of a thin-film sample.
11. XRD analysis of powder samples: Determination of lattice parameters and crystallite size.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

CO1: Understand various spectroscopic techniques to study nanomaterials.
CO2: Apply various diffraction techniques for study of nanomaterials.
CO3: Comprehend and apply the techniques used for thermal analysis for nanomaterials.
CO4: Explain qualitative and quantitative analysis methods for nanomaterials.
CO5: Acquire knowledge about the nanomechanical analysis for nanomaterials.
CO6: Elaborate the working and handling of analytical instruments and techniques
CO7: Demonstrate ability to independently use instrumentation facilities and obtain data
CO8: Apply the gained understanding for data interpretation of nanostructures and perceive how to improve structure/behaviour of materials for various industrial applications

REFERENCES:

1. Cullity B.D. and Stock S.R., "Elements of X-ray diffraction", 3rd Ed., Pearson Publishers, 2013.
2. Amelinckx S., Dyck D.V., Landuyt J.V. and Tendeloo G.V., "Electron microscopy: principles and fundamentals", Wiley, 2008.
3. Gabbott P., "Principle and applications of thermal analysis", 1st Ed., Blackwell Publishing Ltd, 2008.
4. Johnson C., "Spectroscopy and dynamics of single molecules", Elsevier, 2019.
5. Yang F. and Li J.C.M., "Micro and nano mechanical testing of materials and devices", 1st Ed., Springer, 2008.

CO-PO MAPPING:

CO	**PSO**					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
6	1	3	3	1	1	1
7	2	3	3	2	2	2
8	3	3	3	3	3	3
Avg.	2	3	3	2.6	2	2.6

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3203 PHYSICS AND CHEMISTRY OF NANOMATERIALS L T P C
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on the physical and chemical aspects of nanomaterials.

UNIT I PHYSICS ASPECTS OF NANOMATERIALS 9

Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials; band gap energy – quantum confinement, size effect; inter band and intra band transitions – surface to volume ratio.

UNIT II CHEMISTRY ASPECTS OF NANOMATERIALS 9

Photochemistry and electrochemistry of nanomaterials – Ionic properties of nanomaterials; nanocatalyst – kinetics of photocatalysis; nanoscale heat transfer – transition metals and metal oxides, electron transport in transition metals, and semiconducting nanostructures.

UNIT III DIFFUSION AND SURFACE DEFECTS 9

Fick's law – mechanisms of diffusion, influence of pressure and temperature; Kirkendall effect – Hartley–Kirkendall effect; defects in a material – surface defects in nanomaterials, effect of microstructure on surface defects, interfacial energy.

UNIT IV NANOSTRUCTURES 9

Classifications of nanomaterials – zero-dimensional, one-dimensional and two-dimensional nanostructures; kinetics in nanostructured materials – multilayer thin films and superlattice, clusters of metals, semiconductors, and nanocomposites.

UNIT V NANOSYSTEMS 9

Nanoparticles through homogeneous and heterogeneous nucleation – growth controlled by surface and diffusion process; Oswald ripening process – influence of reducing agents, solid-state phase segregation; mechanisms of phase transformation; grain growth and sintering; precipitation in solid solution – Hume–Rothery rule.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Discuss about physical aspects of nanomaterials.
CO2: Perceive chemical aspects of nanomaterials.
CO3: Explain about the diffusion and surface defects in nanomaterials.
CO4: Demonstrate knowledge of various kinds of nanostructures.
CO5: Develop understanding about various kinds of nanosystems.

REFERENCES:

1. Kolasinski K.W., “Surface science: foundations of catalysis and nanoscience”, Wiley, London, 2002.
2. Cao G., “Nanostructures and nanomaterials”, “Synthesis, Properties and Applications”, 2nd Ed., Imperial College Press, London, 2011.
3. Yang S. and Shen P., “Physics and chemistry of nanostructured materials”, Taylor & Francis, New York, 2000.
4. Ozin G.A. and Arsenault A.C., “Nanochemistry: A chemical approach to Nanomaterials”, Royal Society of Chemistry, London, 2005.
5. Atkins P., Paula J. and Keeler J., “Atkin’s physical chemistry”, 12th Ed., Oxford University Press, UK, 2022.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3204 APPLICATIONS OF NANOMATERIALS L T P C
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on the applications of nanomaterials in different fields.

UNIT I HEALTH AND HYGIENE 9

Nanomaterials for smart drug delivery systems – supplements, treatment for cancer and other diseases; diagnosis and kits; nanomaterial-based cosmetics – sunscreens, moisturizer, anti-aging; hygienic applications – respirators, masks, wound dressing, other coatings; veterinary science; commercial nanomaterials – liposomal formulations, nanoemulsions, colloidal silver ions.

UNIT II ENERGY AND ENVIRONMENT 9

Nanomaterials for energy – fuel cells, solar cells, supercapacitors, hydrogen storage; nanomaterials for environment – pollutant degradation, nanoabsorbents, nanomembranes and filters; nanosensor for monitoring pollutants.

UNIT III AUTOMOTIVE AND AEROSPACE APPLICATIONS 9

Structural materials – super-alloys and amorphous metals, nanocarbon reinforced polymers, improved properties, bonding between materials, speciality coatings (anticorrosion, super paints, insulator, radar absorbing, antifouling); light-weight and stronger materials; antiballistic materials; nanofuel and propellants, lubricants, fire retardants, clothes and equipments, miniaturization of monitoring and control systems.

UNIT IV AGRICULTURE AND FOOD 9

Nanofertilizer – nanourea and other nanomaterials, soil conditioners, anti-transpirants, nanopesticides – herbicide, fungicide, safety of nontarget; nanobased smart delivery system for nutraceuticals; nanomaterials for food – packaging, preservation, monitoring.

UNIT V TEXTILE INDUSTRY 9

Techniques for producing nanofibres – electrospinning, electrospraying, drawing, self-assembly, others; nanopolymers for textile fabrication; addition of nanotubes and fibres to polymer fibres – rheological analysis; coating and structuring of textiles with nanomaterials; different properties and applications – anti adhesive, superhydrophobic self-cleaning (oil/water-repellent), bullet-proof vests, wearable energy harvesting and electronic sensors.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Generate ideas for applications of nanomaterials for health care and cosmetic fields.
CO2: Utilize nanomaterials for energy harvesting/storage and environmental applications.
CO3: Determine how nanomaterials are used for different sectors in automobile and aerospace applications.
CO4: Perceive the usage of nanomaterials for agriculture and food industry.
CO5: Explain the usage of nanomaterials for the textile industry.

REFERENCES:

1. Khan F.A., “Applications of nanomaterials in human health”, 1st Ed., Springer, Singapore, 2020.
2. He, J. “Nanomaterials in energy and environmental applications”, 1st Ed., Pan Stanford Publishing, 2016.
3. Ramsden, J.J., “Applied nanotechnology”, 3rd Ed., William Andrew, 2018.
4. Thangadurai, D., Sangeetha,J. and Prasad, R., “Nanotechnology for food, agriculture, and environment”, 1st Ed., Springer Cham, New York, 2020.
5. Sharma, P., Singh, D. and Dave, V., “Fundamentals of nano-textile science”, 1st Ed., Apple Academic Press, 2022.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

SEMESTER III

NT3301 REGULATORY PERSPECTIVES IN NANOTECHNOLOGY **L T P C**
4 0 0 4

COURSE OBJECTIVE:

- To impart knowledge on the impact of nanomaterials on the environment and the regulations available for nanomaterials.

UNIT I INTRODUCTION TO NANOTOXICOLOGY 12

Aspects of nanotoxicology; nanomaterials in the environment – sources, dynamics and analytical tools; portal entry and biological fate of nanoparticles; cellular uptake strategies; mechanism of toxicity; toxicokinetics and toxicodynamics.

UNIT II REGULATORY ASPECTS AND PRINCIPLES 12

Principles of nanotechnology regulation; exposure assessment and control; risk assessment; safety cum precautionary guidelines; hazard identification and assessment; OECD elements of regulations; principles to guide nanotechnology aspects; advantages & disadvantages of regulatory framework; justification of NTR; European and US regulation; main regulatory challenges in nanotechnology; standards for nanotechnology (ISOs); regulations pertaining to testings in animal models.

UNIT II REGULATORY BODIES 12

Regulatory bodies involved in framing guidelines; regulatory framework governing nanomaterials production and commericalisation of nano-products; institutional framework and challenges; nanomedicines approved by regulatory agencies; regulatory challenges for nanomedicine; legal and ethical issues associated with NT.

UNIT IV REGULATORY FRAME WORK FOR SPECIFIC NANOTECHNOLOGY ENABLED PRODUCTS 12

Regulatory aspects of nanotechnology in food and agricultural sectors; OECD regulatory framework for nanotechnology in nanomedicines and medical products including medical devices; Regulatory challenges posed by nanomedicines; guidelines for polymeric products and commercialization; regulatory principles guiding nanobiotechnological process.

UNIT V INDIAN REGULATORY GOVERNANCE FOR NANOTECHNOLOGY APPLICATIONS 12

Indian regulatory framework for assisting research in nanotechnology; legal regulation and ethics for nanobiotechnology and nanomedicines in India; shortcomings of Acts; guidelines for manufacture and commercialization of nanomaterials containing products in India.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

CO1: Apply the basics of nanotoxicology.
CO2: Perceive the principles, advantages, and disadvantages of regulatory aspects.
CO3: Comprehend the role of national and international regulatory bodies towards nanotechnology.
CO4: Perceive the usage of regulatory guidelines for industrial products.
CO5: Explain the role of Indian regulatory framework for assisting research in nanotechnology.

REFERENCES:

1. Gupta P.K., “Nanotoxicology in nanobiomedicine”, Springer, Netherlands, 2023.
2. Gehrke, P.J., “Nano-publics: communicating nanotechnology applications, risks, and regulations”, 1st Ed., Palgrave Pivot, 2018.
3. Gad S.C., “Animal models in toxicology”, 3 Ed., Taylor & Francis Group, LLC 2013.
4. Bawa, R., Audette, G. F. and Reese, B. E., “Handbook of clinical nanomedicine: law, business, regulation, safety and risk”, Pan Stanford Publishing, Singapore, 2016.
5. Donald M., “Nanotechnology and global sustainability”, CRC press, 2011.
6. Houdy C.C.P., Lahmani, M., Marano, F., “Nanoethics and nanotoxicology”, Springer-Verlag, Berlin, Heidelberg, 2011.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3311 PROJECT WORK I L T P C
0 0 12 6

OBJECTIVES:

The course aims to enable the students to identify the research problem relevant to their field of interest, search databases to define the problem, design experiment, conduct preliminary study and report the findings.

COURSE CONTENT

Individual students will identify a research problem relevant to his/her field of study with the approval of project review committee. The student will collect, and analyze the literature and design the experiment. The student will carry out preliminary study, collect data, interpret the result, prepare the project report and present before the committee.

TOTAL: 180 PERIODS

OUTCOMES:

At the end of the course the students will be able to
CO1: Identify the research problem
CO2: Collect, analyze the relevant literature and finalize the research problem
CO3: Design the experiment, conduct preliminary experiment, analyse the data and conclude

CO4: Prepare project report and present

COURSE ARTICULATION MATRIX:

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	3	3	3	3	2	3
2	3	3	3	3	2	3
3	2	3	3	3	3	3
4	2	3	3	3	3	3
Avg.	2.5	3	3	3	2.5	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3411 **PROJECT WORK II** **L T P C**
0 0 24 12

I. Continuation of Project Work I (at Institution/Industry)

OBJECTIVES:
The course aims to enable the students to conduct experiment as per the plan submitted in Project work I to find solution for the research problem identified.

COURSE CONTENT
The student shall continue Project work I as per the formulated methodology and findings of preliminary study. The student shall conduct experiment, collect data, interpret the result and provide solution for the identified research problem. The student shall prepare the project report and present before the committee.

TOTAL: 360 PERIODS

OUTCOMES:
At the end of the course the students will be able to
CO1: Conduct the experiment and collect data
CO2: Analyze the data, interpret the results and conclude
CO3: Prepare project report and present

COURSE ARTICULATION MATRIX

CO	PO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

II. Not the continuation of Project Work I (at Industry)

OBJECTIVES:
The course aims to enable the students to identify the research problem at the company, search databases to define the problem, design experiment, and conduct experiment to find the solution.

COURSE CONTENT
Individual students will identify a research problem relevant to his/her field of study at the company and get approval of project review committee. The student will collect, and analyze the literature and design the experiment. The student will carry out the experiment, collect data, interpret the result, prepare the project report and present before the committee.

TOTAL: 360 PERIODS

OUTCOMES:
At the end of the course the students will be able to
CO1: Identify the research problem
CO2: Collect, analyze the relevant literature and finalize the research problem
CO3: Design and conduct the experiment, analyse the data and conclude
CO4: Prepare project report and present

COURSE ARTICULATION MATRIX:

CO	PO					
	1	2	3	4	5	6
1	3	3	3	3	2	3
2	3	3	3	3	2	3
3	2	3	3	3	3	3
4	2	3	3	3	3	3
Avg.	2.5	3	3	3	2.5	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

ELECTIVES

NT3001 PROCESSING AND PROPERTIES OF NANOSTRUCTURED MATERIALS **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on the processing techniques for different types of nanomaterials, effect on their microstructural properties and their applications.

UNIT I DEFORMATION PROCESSING AND METAL FORMING 9
Classification of engineering materials; tensile testing – stress strain curve, flow stress, mechanical properties; deformation processes – formability, mechanics of metal working; metal forming - forging, rolling, extrusion, drawing; sheet metal working; superplastic forming; bulk nanostructured materials by severe plastic deformation (SPD) – comparison of processes.

UNIT II MICROSTRUCTURAL PROPERTIES 9
Classifications of defects – point, line, surface, and volume defects; microstructure – grain size, grain boundary, effects of processing and defects on microstructure and mechanical property correlation; grain size growth mechanism and grain size control; plastic deformation mechanisms – slip and twin; strengthening mechanisms – grain size reduction/Hall–Petch relation, Peierls-Nabarro strengthening, work hardening, solid solution strengthening, precipitation hardening, dispersion/fibre strengthening.

UNIT III PROCESSING OF POLYMERS 9
Polymer – classifications, properties, glass transition, melting temperature, melt flow index; engineering plastics – types, properties, applications, and limitations; pellets and sheets; additives; polymer processing tools and process conditions – injection moulding, thermoforming (assisted by vacuum/pressure), and other methods.

UNIT IV PROCESSING OF POWDERS OF METALS AND CERAMICS 9
Metal/Ceramic powder preparation; characterization of powders; compacting and sintering methods for production of porous and dense components; advanced composite materials – metal-, polymer-, and ceramic-based composites and their properties – fabrication of composite materials.

UNIT V PROCESSING OF FUNCTIONAL NANOMATERIALS 9
Properties of nanocrystalline materials required for structural, energy, environmental, textile, and catalytic applications; processing techniques and considerations for retaining the nanocrystalline structure in service.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate knowledge about the deformation processes and metal forming techniques
CO2: Determine the effect of microstructure of materials with its physical properties.
CO3: Choose polymer and their appropriate processing suitable for applications based on their structure–property relationship
CO4: Compare and analyse different powder processing and characterization methods and comprehend fabrication techniques for composites
CO5: Perceive the functional properties of nanomaterials for various applications

REFERENCES:

1. Bruno G., Stefani A.D. and Gracco A., "Mechanical properties of materials", MDPI, Switzerland, 2021.
2. Yinquan Yu Y. and Zhang S., "Materials in advanced manufacturing", CRC Press, US, 2023.
3. Ward I.M. and Sweehey J., "Mechanical properties of solid polymers", 3rd Ed., Wiley, New Jersey, US, 2012.
4. Badhuri A., "Mechanical properties and working of metals and alloys", Springer Singapore, 2018.
5. Hussain C.M., "Handbook of nanomaterials for manufacturing applications", Elsevier, 2020.
6. Swain B.P., "Nanostructured materials and their applications", Springer, Singapore, 2021.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	1	3	3	3	1	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	1.8	3	3	3	1.8	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3002 BIOPHOTONICS L T P C
3 0 0 3

COURSE OBJECTIVE:

- To teach about the fundamentals of light and optics, various imaging techniques for biological structures, single molecule spectroscopy and optical force microscopy for biological systems and recent development in optical sensors.

UNIT I BASICS OF LIGHT AND OPTICS 9

Interaction of light with cells and tissues; laser beams – linear and non-linear optical processes; light-induced effects in various biological systems.

UNIT II IMAGING TECHNIQUES 9

Light microscopy – principle; instrumentation and types; confocal microscope; flourescence resonance energy transfer (FRET) microscopy; frequency-domain lifetime imaging; cellular imaging – imaging of soft and hard tissues and other biological nanostructures.

UNIT III SINGLE MOLECULE SPECTROSCOPY 9

UV–vis spectroscopy for biological nanostructures; single molecule spectroscopy – various characteristics; infra-red (IR) and Raman – principle, instrumentation, types and applications in biological nanostructures.

UNIT IV OPTICAL FORCE SPECTROSCOPY 9

Generation of optical forces; optical trapping and manipulation of single molecules and cells;

optical confinement – laser trapping and dissection for biological nanostructures; single molecule biophysics – DNA protein interactions.

UNIT V SENSORS AND OPTICAL TECHNIQUES 9

Biosensors – instrumentation and applications; fluorescence immuoassay; flow cytometry; fluorescence correlation spectroscopy – principle and applications; fluorophores as cellular and molecular tags.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate knowledge on basics of light and optics.
CO2: Explain various imaging techniques used for biological nanostructures.
CO3: Comprehend basics on single molecule spectroscopy.
CO4: Explain the use of optical force microscopy for biological structures.
CO5: Apply concepts on sensors and optical techniques for biological nanostructures.

REFERENCES:

1. Keiser G., “Biophotonics: concepts to applications”, 2nd Ed., Springer, 2022.
2. Gennerich A., “Optical tweezers: methods and protocols”, Springer, NY, 2017.
3. Prasad P.N., “Introduction to biophotonics”, 1st Ed., John Wiley publishers, 2003.
4. Phillips J., “Fundamentals of enzymology”, ED Tech Press, 2021.
5. Johnson C., “Spectroscopy and dynamics of single molecules”, Elsevier, 2019.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3003 NANOTECHNOLOGY IN HEALTH CARE L T P C
3 0 0 3

COURSE OBJECTIVE:

- To introduce recent advancements in nanomedicine.

UNIT I TRENDS IN NANOBIOTECHNOLOGY 9

Nanotechnology in gene therapy; stem cell technology; PCR, ELISA, DNA profiling, and blotting techniques; nanoprobes.

UNIT II NANOIMMUNOTECHNOLOGY 9

Nano-immuno assays sensors; bio-barcode assay; use of magnetic and gold nanoparticles; peptides and antibodies; immunodiagnostics for cancer and central nervous system disorders.

UNIT III NANOTECHNOLOGY BASED MEDICAL DIAGNOSTICS 9

Improved diagnosis by *in vivo* imaging – detection of tumors, plaques, and genetic defects; nanobot medical devices; cantilever sensors.

UNIT IV PROSTHETIC AND MEDICAL IMPLANTS 9

Prosthesis and implants – neural, ocular, cochlear, dental implants; Implants and prosthesis of skin, limb, bone; artificial organ and organ transplant; nano-fibre scaffold technology.

UNIT V BIOMEDICAL APPLICATIONS OF NANOTECHNOLOGY 9

Nano-bioconjugates and their significance; drug delivery systems; nanoscaffolds; magnetic nanoparticles; multifunctional inorganic and organic nanoparticles and their biomedical applications.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate understanding of the nanoparticle-based gene therapy, nanoprobing and profiling techniques, and their application

CO2: Explain the use of metal nanoparticles and antibodies in diagnosis of biomarkers with high sensitivity

CO3: Perceive the principle and uses of cantilever sensors and imaging of plaques and tumors

CO4: Comprehend the use of ocular, cochlear, dental implants, and nanofiber technology

CO5: Perceive knowledge on functionalised nanoscaffolds, magnetic, organic, and inorganic nanoparticles

REFERENCES:

1. Sahoo S.K., "Nanotechnology in health care", Taylor & Francis, Florida, US, 2012.
2. Altintas, Z., "Biosensors and nanotechnology: applications in health care diagnostics", Wiley, New Jersey, US, 2018.
3. Khondakar K.R. and Kaushik A.K., "Nanotechnology in cancer management: precise diagnostics toward personalized health care", Elsevier Inc., Netherlands, 2021.
4. Hakeem K.R., Kamli M., Sabir J.S.M. and Alharby H.F., "Diverse applications of nanotechnology in the biological sciences: an essential tool in agri-business and health care systems", CRC Press, Florida, 2022.
5. Chandra P., "Nanobiosensors for personalized and onsite biomedical diagnosis", IET, UK, 2016.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3004 NANOTECHNOLOGY IN AGRICULTURE AND FOOD INDUSTRY **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on the role of nanotechnology in crop production, pest management, food processing, smart and active food packaging concepts, and fate of nanomaterials.

UNIT I NANOTECHNOLOGY IN CROP PRODUCTION 9

Fertilizer – types and mode of action; nanofertilizer – nanourea and mixed fertilizers; nanomaterials as soil conditioners – zeolites, nanoclays, superabsorbent polymers, nanocomposites; nanoemulsion-based antitranspirants; nanosensors for monitoring soil moisture; effect of nanoparticles in seed – carbon based, TiO_2, aluminium, silver, copper, ZnO nanoparticles; smart delivery systems for nanofertilizer release.

UNIT II NANOTECHNOLOGY IN PEST MANAGEMENT 9

Introduction to pest management; nanomaterials for pest management – nanoherbicide, nanopesticide, nanofungicide, and their application, mode of action and evaluation; nanoparticles and mesoporous nano materials for smart delivery; nanosensors for pest management; assessment of efficacy and safety on nontarget organisms.

UNIT III NANOTECHNOLOGY IN FOOD PROCESSING 9

Introduction and scope; nanobased smart delivery system for nutraceuticals and its release mechanism; nano cochleates – formulation methods and mechanism of release; nanoclusters; nanolaminates – properties, preparation, and application; nanoemulsions – preparation and application; nanoencapsulation technology – materials used, principle, release mechanism, and advantages.

UNIT IV NANOTECHNOLOGY IN FOOD PACKAGING 9

Nanocomposites; nanostructured layers; nanomaterials for food preservation; nanopackaging for enhanced shelf life; nanotechnology in intelligent packaging; nanosensors for food safety monitoring.

UNIT V IMPACTS OF NANOAPPLICATION 9

Nanoparticles – mode of action, bioaccumulation, and its interaction with biological systems; fate of nanoparticles in the environment; health hazards of nanomaterials in the workplace; nanoethics, safe handling, and precautionary protocol.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Perceive the impact of nanomaterials and devices in precision farming.
CO2: Analyse the impact of nanotechnology in pest management.
CO3: Evaluate the importance of nanomaterials in food processing.
CO4: Explain the use of nanotechnology in food packaging.
CO5: Perceive the fate of bioaccumulated nanoparticles.

REFERENCES:

1. Chaudhary P., Chaudhary A., Nadda A.K. and Khati P., “Advances in nanotechnology for smart agriculture”, 1st Ed., CRC press, 2023.
2. Subramanian S., Gunasekaran K., Natarajan N., Chinnamuthu K.C.R., Lakshmanan A. and Rajkishore S.K., “Nanotechnology applications in agriculture”, New India Publishing Agency, New Delhi, 2008.
3. Choudary S., “Applied nanotechnology in agriculture”, Arise Publications, 2011.
4. Monteiro-Riviere N.A., Tran C.L., “Nanotoxicology: characterization, dosing and health effects”, Informa Healthcare publishers, New York, 2007.
5. Axelos M.A.V., Voorde M.V.D., “Nanotechnology in agriculture and food science”, Wiley-VCH, 2017.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3005 NANOCOMPOSITE MATERIALS L T P C
3 0 0 3

COURSE OBJECTIVE:

- To explore the difficulties, fabrication technologies and properties of nanocomposite materials.

UNIT I CERAMIC-BASED NANOCOMPOSITES 9

Composites – nomenclature, properties; classification of ceramic nanocomposites; challenges with bulk nanoceramics/nanoceramic composites; problems associated with synthesis of nanosize powders – chemical /physical methods of synthesis of nanoscaled ceramic powders, challenges posed by the typical properties of nanoscaled powders, Challenges faced during processing/ sintering; various processing techniques, spark plasma sintering; properties of nanoceramics – hardness, tensile; superplasticity – superplastic forming applications; superhard nanocomposites – properties, bottle neck, industrial applications.

UNIT II METAL-BASED NANOCOMPOSITES 9

Processing of metal-matrix nanocomposites – liquid metallurgy processing techniques, thermal spray techniques, cold spray, powder metallurgy (PM) techniques, difficulties, applications of metal matrix nanocomposites – Cu–Ni alloy nanocomposites, magnesium metal–matrix nanocomposites- implants, titanium nanocomposites; fractal-based glass-metal nanocomposites, its designing and fractal dimension analysis; core–shell structured nanocomposites; bio-medical imaging, environmental remediation applications, semiconductor core–shell nanomaterials, heterojunction photocatalyst.

UNIT III POLYMER-BASED NANOCOMPOSITES 9

Block copolymer nanocomposites – features, advantage over homopolymer composites; fundamentals of block copolymer; nanoparticle co-assembly; particle–polymer enthalpic interactions; particle surface chemistry – grafting suitable polymeric ligands, entropic interactions, mechanism of nanoparticle incorporation; applications of block copolymers nanocomposites – Textile fabric, bulk heterojunction (BHJ) organic photovoltaic (solar cell) devices, drug delivery; polymer and carbon nanotube–based composites, their mechanical properties, and industrial possibilities.

UNIT IV BIOMEDICAL NANOCOMPOSITES 9

Natural nanocomposite systems – spider silk, bones, shells; ceramic nanocomposites – biomedical applications; toughening mechanisms; alumina and zirconia ceramics, alumina–zirconia nanocomposites; tooth nanocomposites and dental implants; organic–inorganic nanocomposite formation through self-assembly; biomimetic synthesis of nanocomposites material.

UNIT V NANOCOMPOSITE TECHNOLOGY 9

Nanocomposite membrane structures – preparation and applications; nanotechnology in textiles and cosmetics; nano-fillers embedded polypropylene fibers – soil repellency, lotus effect; nano finishing in textiles (UV resistant, anti-bacterial, hydrophilic, self-cleaning, flame-retardant finishes); sun-screen dispersions for UV protection using titanium oxide – colour cosmetics; nanotechnology in food technology – nanopackaging for enhanced shelf life, smart/intelligent packaging.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Explain the fabrication technologies, properties and drawbacks of ceramic nanocomposites

CO2: Explain the fabrication technologies, properties and drawbacks of metal matrix nanocomposites

CO3: Explain the fabrication technologies, properties and drawbacks of block copolymer nanocomposites

CO4: Comprehend biomimicry and evaluate them in load bearing arena for bone tissue engineering

CO5: Design nanocomposite materials for engineering applications

REFERENCES:

1. Twardowski T.E., “Introduction to nanocomposite materials: properties, processing, characterization”, DES Tech Publications, USA, 2007
2. Ajayan P.M., Schadler L.S. and Braun P.V., “Nanocomposites science and technology”, 2006.
3. Sadasivuni K.K., Ponnamma D., Rajan M., Ahmed B. and Al-Maadeed M.A.S.A., “Polymer nanocomposites in biomedical engineering”, Springer Nature, Switzerland, 2019.
4. Basu B. and Balani K., “Advanced structural ceramics”, John Wiley & Sons, 2011.
5. Brown P. and Stevens K., “Nanofibers and nanotechnology in textiles”, Woodhead

publication, London, 2006.

CO-PO MAPPING:

CO	PSO					
	1	**2**	**3**	**4**	**5**	**6**
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3006 LITHOGRAPHY AND NANOFABRICATION L T P C
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on basic and advanced lithographic and nanofabrication techniques.

UNIT I SEMICONDUCTOR PROCESSING AND MICROFABRICATION 9

Introduction to semiconductor device processing; necessity and different types of clean rooms – construction and maintenance of a clean room; microfabrication process flow diagram – chip cleaning, coating of photoresists, patterning, etching, inspection; process integration; etching techniques – reactive Ion etching (RIE), magnetically-enhanced RIE, ion-beam etching (IBE).

UNIT II PHOTOLITHOGRAPHY AND PATTERNING OF THIN FILMS 9

Lithography – optical lithography, different modes; optical projection lithography; multistage scanners; resolution and limits of photolithography – resolution enhancement techniques; 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.

UNIT III DIRECT WRITING METHODS-MASKLESS OPTICAL LITHOGRAPHY 9

Maskless optical projection lithography – types, advantages and limitations; required components – zone plate array lithography, extreme ultraviolet lithography; light sources – optics and materials issues.

UNIT IV ELECTRON BEAM, X-RAY, AND ION BEAM LITHOGRAPHY 9

Scanning electron-beam lithography – electron sources and electron optics system; mask-less EBL; parallel direct-write e-beam systems; electron beam projection lithography; scattering with angular limitation projection e-beam lithography (SCALPEL); projection reduction exposure with variable axis immersion lenses; XRPP; ion beam lithography; focusing ion beam lithography; ion projection lithography.

UNIT V NANOIMPRINT LITHOGRAPHY AND SOFT LITHOGRAPHY 9

Nanoimprint lithography (NIL) – hot embossing, UV–NIL, soft lithography; moulding/replica moulding – PDMS stamps, printing with soft stamps; edge lithography; dip-pen lithography – set-up and working principle; self-assembly – LB films; rapid prototyping.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Perceive the importance of semiconductor processing and microfabrications.
CO2: Explain the various types of masking, patterning, and optical lithographic techniques.
CO3: Analyse the advantages and limitations of maskless optical lithography.
CO4: Demonstrate knowledge on the advanced lithographic techniques.
CO5: Perceive soft lithographic techniques and self-assembly.

REFERENCES:

1. Mack C., “Fundamental principles of optical lithography: the science of microfabrication”, Wiley, 2008.
2. Kondoh E., “Micro- and nanofabrication for beginners”, Jenny Stanford Publishing, Singapore, 2021.
3. Teresa J.M.D., “Nanofabrication: nanolithography techniques and their applications”, IOP Publishing Ltd, 2020.
4. Goodnick S.M., “Semiconductor nanotechnology: advances in information and energy processing and storage”, Springer, 2018.
5. Mühlberger M., “Nanoimprint lithography technology and applications”, MDPI, Switzerland, 2022.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3007 **PHOTONICS FOR NANOTECHNOLOGY** **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To teach the quantum-confined materials, plasmonics, nanophotonics, photonic crystals and basic concepts in biophotonics in nanotechnology.

UNIT I QUANTUM CONFINED MATERIALS 9

Quantum confinement; optical transition – absorption, inter and intra band transitions; fluorescence – basics and applications; luminescence – basics, types, and applications, photoluminescence emission, electroluminescence emission.

UNIT II PLASMONICS 9

Plasmonics – basics; types and applications; surface plasmon resonance (SPR) – types and applications in nanomaterials; internal reflections of waves; attenuated total reflection (ATR) of waves; evanescent waves.

UNIT III NANOPHOTONICS 9

Near-field optics – aperture near-field optics, apertureless near-field optics; near-field scanning optical microscopy (NSOM or SNOM) – principle and instrumentation, application of SNOM in detection of plasmonic energy transport and visualization of waveguide structures, SNOM in nanolithography.

UNIT IV PHOTONIC CRYSTALS 9

Photonic crystals – basics, important features and applications, photonic band gap; anomalous group velocity dispersion; effects of microcavity in photonic crystals; fabrication of photonic crystals – dielectric mirrors and interference filters; photonic crystal laser; photonic crystal-based LEDs; photonic crystal fibers (PCFs); photonic crystal sensors.

UNIT V BIOPHOTONICS 9

Biophotonics – basics and applications; interaction of light with cells and tissues; Nonlinear optical processes with intense laser beams; photoinduced effects in biological systems; generation of optical forces – optical trapping and manipulation of single molecules and cells in optical confinement, laser trapping and dissection for biological systems; single molecule biophysics – DNA-protein interactions.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate knowledge on basics of quantum confined materials.
CO2: Perceive concepts on plasmonics for nanomaterials.
CO3: Develop understanding on various concepts in nanophotonics.
CO4: Explain the basics of photonic crystals and its applications.
CO5: Apply the basic concepts of biophotonics for various fields in nanotechnology.

REFERENCES:

1. Masuhara H., Kawata S. and Tokunaga F., " Nanobiophotonics: science and technology", 1st Ed., Elsevier, 2007.
2. Shalaev V. and Kawata S., " Nanophotonics with surface plasmons", 1st Ed., Elsevier, 2006.
3. Saleh B.E.A., Teich M.C., "Fundamentals of photonics", 2nd Ed., Wiley Blackwell Publishers, 2007.
4. Prasad P.N., "Introduction to biophotonics", 1st Ed., John Wiley publishers, 2003.
5. Joannopoulos J.D., Johnson S.G., Winn J.N. and Meade R.D., "Photonic crystals: molding the flow of light", 2nd Ed., Princeton University Press, 2008.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3008 SEMICONDUCTOR NANOSTRUCTURES L T P C
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge about the basics of semiconductor nanomaterials and their applications.

UNIT I SEMICONDUCTOR FUNDAMENTALS 9

Introduction to semiconductor physics; fabrication techniques; semiconductor nanostructures; electronic structure and physical process; principles of semiconductor nanostructure-based electronic and electro-optical devices; semiconductor quantum dots – quantum lasers, quantum cascade lasers, quantum dot optical memory.

UNIT II PREPARATION METHODS FOR SEMICONDUCTOR NANOSTRUCTURES 9

Cluster compounds; quantum-dots from MBE and CVD; epitaxial growth – homo epitaxy and hetero epitaxy; wet chemical methods, reverse micelles, electro-deposition, pyrolytic synthesis, self-assembly strategies.

UNIT III PHYSICAL PROPERTIES 9

Melting point, solid-state phase transformations; excitons, band-gap variations – quantum confinement; effect of strain on band-gap in epitaxial quantum dots; lattice mismatch with substrates; single particle conductance.

UNIT IV SEMICONDUCTOR NANOPARTICLES – APPLICATIONS 9

Optical luminescence and fluorescence from direct band gap semiconductor nanostructures; surface-trap passivation in core–shell nanoparticles; carrier injection; polymer nanoparticles; LED and solar cells; electroluminescence; barriers to nanoparticle lasers; doping nanoparticles; Mn–Zn–Se phosphors; light emission from indirect semiconductors, light emission from Si nanodots.

UNIT V SEMICONDUCTOR NANOWIRES 9

Fabrication strategies; quantum conductance effects in semiconductor nanowires, porous silicon, nanobelts, nanoribbons, nanosprings; VLS growth of nanowires.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Explain about the basics of semiconductors.
CO2: Choose from the various preparation methods for semiconductor nanostructures.
CO3: Develop ideas about physical properties of semiconductor nanostructures.
CO4: Evaluate the use of semiconductor nanostructures for different applications.
CO5: Will learn about the fabrication and significance of semiconductor nanowires.

REFERENCES:

1. Ihn T., “Semiconductor nanostructures”, Oxford University Press, USA, 2010.
2. Nalwa H.S.., “Encyclopedia of nanotechnology”, American Scientific Publishers, 2004.
3. Bhusan B., “Springer handbook of nanotechnology”, 3rd Ed., Springer, 2010.
4. Balandin A. and Wang K. L., “Handbook of semiconductor nanostructures and nanodevices, Vol 1-5”, American Scientific Publishers, Los Angeles, CA, 2006.
5. Cao G., “Nanostructures and Nanomaterials”, “Synthesis, Properties and Applications”, 2nd Ed., Imperial College Press, London, 2011.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3009 NANOMATERIALS FOR ENERGY AND ENVIRONMENT L T P C
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on the use of nanomaterials for renewable energy applications and environmental remediation.

UNIT I INTRODUCTION 9

Greenhouse effect – CO_2 emission, global warming; nanomaterials for CO_2 capture; energy demand and challenges; sustainable and renewable energy – nanomaterials for renewable energy.

UNIT II RENEWABLE ENERGY TECHNOLOGY 9

Development and implementation of renewable energy technologies; nano, micro, and mesoscale phenomena and devices; energy conversion, transport, and storage; high-efficiency photovoltaic cells; thermoelectrics – high-performance thermoelectric systems, nanostructured thermoelectric materials; integration and performance of DSSC; quantum dots–based solar cells; perovskite solar cells; hybrid and stacked solar cells.

UNIT III NANOMATERIALS IN FUEL CELL AND STORAGE TECHNOLOGIES 9

Micro-fuel cell technologies – integration and performance of micro-fuel cell systems; thin-film and microfabrication methods – design methodologies and micro-fuel cell power sources; types of fuel cells; supercapacitors – specific energy and power densities, charging/discharging, EIS analysis.

UNIT IV HYDROGEN STORAGE AND PHOTOCATALYSIS 9

Hydrogen storage methods; metal hydrides; size effects; hydrogen storage capacity; hydrogen reaction kinetics; carbon-free cycle; gravimetric and volumetric storage capacities; hydriding/dehydriding kinetics; catalytic materials – degradation of the dyes; nanomaterial-based photocatalyst design – kinetics of degradation.

UNIT V ENVIRONMENTAL APPLICATIONS & IMPACTS OF NANOMATERIAL 9

Nanomaterials as adsorbents – nanocomposite membrane systems for water remediation, membrane fabrication; membrane reactors & active membrane systems; ecotoxicological impacts of nanomaterials, lifecycle assessment of nanomaterials.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Determine the challenges and demand for energy.

CO2: Perceive the use of renewable energy technologies updated with nano devices and different fabrication methodologies.

CO3: Demonstrate knowledge on fuel cell and storage technologies.

CO4: Improve the knowledge on hydrogen storage and kinetic studies of dye degradation using nanophotocatalysts.

CO5: Evaluate nanomaterials for various applications and perceive its environmental impacts.

REFERENCES:

1. Twidell J. and Weir T., “Renewable energy resources”, 4th Ed., Taylor & Francis Group, 2014.
2. Gupta R.B., “Hydrogen fuel”, CRC Press, Taylor and Francis Group, New York, 2009.
3. Vielstich W., Lamm A., Gasteiger H.A., Yokokawa H., “Hand book of fuel cells: fuel cell technology and applications”, Wiley, London, 2003.
4. Fang Z., Smith R.L., Qi X., “Production of hydrogen from renewable resources”, Springer, London, 2016.
5. Wiesner M.R., Bottero J.Y., “Environmental nanotechnology: applications and impacts of nanomaterials”, McGraw Hill, New York, 2007.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3010 ADVANCED DRUG DELIVERY SYSTEMS L T P C
3 0 0 3

COURSE OBJECTIVE:

- To teach the fundamentals of drug delivery systems using different nanocarriers and discuss the recent developments.

UNIT I T HEORY OF ADVANCED DRUG DELIVERY 9

Advanced biomaterials; fundamentals of nanocarriers – size, surface, magnetic and optical properties, biocompatibility, pharmacokinetics, and pharmacodynamics of nano drug carriers; administration route; stealth nanocarriers; critical factors in drug delivery; Transport of nanoparticles – in vitro and ex vivo models; delivery systems integrating drug modifications and environmental modifications.

UNIT II POLYMERS 9

Dendrimers – synthesis, nanoscale containers; dendritic nanoscafold systems – biocompatibility of dendrimers, gene transfection; smart drug delivery systems – chitosan and alginate; copolymers in targeted drug delivery – PCL, PLA, PLGA; commercialized drug delivery systems.

UNIT III LIPID BASED NANOCARRIERS 9

Liposomes, niosomes and solid lipid nanoparticles; liposomal preparation; ligand-based delivery by liposomes and cubosomes; commercialized drug delivery systems.

UNIT IV MICROBES AND ANTIBODY–BASED NANOCARRIERS 9

Bacterial-based delivery of vaccines; drug delivery and subcellular targeting by virus; drug packaging and drug loading; delivery of therapeutics by antibodies and antibody bioconjugates.

UNIT V DEVICES FOR DRUG DELIVERY 9

Fabrication and applications of microneedles, micropumps, and microvalves; implantable microchips; advanced 3-D printed nanosystems.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate knowledge in basics of drug delivery systems.
CO2: Acquire idea about use of polymers and dendrimers for drug coating and delivery.
CO3: Explain the importance of lipid nanomaterials for biocompatible drug delivery.
CO4: Perceive the different methods of targeting using microbes and antibodies.
CO5: Develop understanding about recent trends and equipment for drug delivery.

REFERENCES:

1. Toit L., Kumar P., Choonara Y. and Pillay V., "Advanced 3D-printed systems and nanosystems for drug delivery and tissue engineering", Woodhead Publishing, Cambridge, 2020.
2. Dua K., Mehta M., Pinto T.J.A., Pont L.G., Williams K.A. and Rathbone M., "Advanced drug delivery systems in the management of cancer", Academic Press, Cambridge, 2021.
3. Nayak A.K. and Hasnain M.S., "Advanced biopolymeric systems for drug delivery", Springer Nature, Netherlands, 2020.
4. Vyas S.P., Agrawal U. and Sharma R., "Smart polymeric nano-constructs in drug delivery: concept, design and therapeutic applications", Academic Press, Cambridge, 2023.
5. Joshy K.S., Thomas S. and Thakur V.K., "Nanoparticles for drug delivery", Springer, Singapore, 2021.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	2	3	2	3
2	2	3	2	3	2	3
3	2	3	2	3	2	3
4	2	3	2	3	2	3
5	1	3	2	3	1	3
Avg.	1.8	3	2	3	1.8	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3011 NANO-TOXICOLOGY L T P C
3 0 0 3

COURSE OBJECTIVE:

- To impart knowledge on nanotoxicity at various physiological levels, different nanotoxicological assessment protocols and recommendations to control nanoparticle exposure.

UNIT I INTRODUCTION TO TOXICOLOGY 9

Principles and concepts of toxicology; routes of exposure (inhalation, dermal, ocular, enteral and parenteral) and spectrum of adverse effects; toxicokinetics – liberation, absorption (uptake), distribution, biotransformation, elimination and toxicity (ladmet); toxicodynamics – dose vs response relationships, NOAEL, NOEL, LOAEL, LOEL determination; genetic toxicology and carcinogenicity – mechanisms and testing methodologies; target organ toxicity.

UNIT II NANOTOXICOLOGY 9

Characteristics determining potential toxicity of nanoparticles; bio-distribution of nanoparticles; interaction of nanoparticles with biomembrane and genes; evaluation of nanoparticle transfer using placental models; nanomaterial toxicity – respiratory, cardiac, hepatic, neuro, nephro and dermal; estimation of nanoparticle dose in humans; in-vitro toxicity studies of ultrafine diesel exhaust particles; toxicity studies of engineered nanoparticles and fibres.

UNIT III PROTOCOLS IN TOXICOLOGY STUDIES 9

Experimental design and evaluation of toxicology endpoints; introduction to toxicokinetic (DMPK) profiling; assessment of oxidative stress and antioxidant status; imaging techniques to asses biodistribution of nanomaterials; toxicity testing using OECD test guidelines for in-vivo and in-vitro toxicity potential of nanomaterials; biocompatibility screening tests.

UNIT IV ANIMAL MODELS 9

Selection of animal models for toxicity testing; dose calculation and dosing animal models through various routes; humane endpoints and ethical usage of laboratory animals; in-life and post-life (pathology) endpoints and analysis; laws and regulations governing animal care and use program; alternative testing methods – in silico, in vitro, organ-on-chip.

UNIT V RISK ASSESSMENT AND EXECUTION 9

Risk vs benefit – concept and analysis; hazard identification and risk assessment of nanoparticle exposure; prevention and control of nanoparticle exposure – regulations and recommendations.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate knowledge on toxicology and their effects on human and animals
CO2: Explain toxicity potential, biodistribution, and other effects of nanoparticles
CO3: Compare different protocols and methodologies for toxicity assessment
CO4: Compare toxicity testing methods in animal models and the laws governing animal use
CO5: Perceive ways to minimize nanoparticle exposure and learn regulations for nanotoxicology

REFERENCES:

1. Gupta P.K., "Nanotoxicology in nanobiomedicine", Springer, Netherlands, 2023.
2. Lead J.R., Doak S.H., Clift M.J.D., "Nanotoxicology in humans and the environment", Springer, Netherlands, 2021.
3. Bidoia E.D., Montagnolli R.N., "Toxicity and biodegradation testing", Humana Press, 2018.
4. Gad S.C., "Animal models in toxicology", 3 Ed., Taylor & Francis Group, LLC 2013.
5. Houdy C.C.P., Lahmani, M., Marano, F., "Nanoethics and nanotoxicology", Springer-Verlag, Berlin, Heidelberg, 2011.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	2	3	2	3

2	2	3	2	3	2	3
3	2	3	2	3	2	3
4	2	3	2	3	2	3
5	1	3	2	3	1	3
Avg.	1.8	3	2	3	1.8	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3012 NANO BIOSENSORS L T P C
3 0 0 3

COURSE OBJECTIVE:

- To teach the principles, components, types, and fabrication of different nanobiosensors using different sensing elements.

UNIT I ESSENTIALS OF BIOSENSORS 9

Biosensors – general principle, components, characteristics; types – based on receptor and transducer; calorimetric biosensor, electrochemical biosensor, optical biosensor, piezo-electric biosensor, magnetic biosensor; detection systems; techniques used for microfabrication; microfluidics-based detection; lateral flow strips.

UNIT II PROTEIN BASED BIOSENSORS 9

Immunoassays and types – labeled and label-free; protein stabilization; nanostructures for enzyme stabilization – inorganic nanoparticles, nanofibres, nanotubes, porous silica, nanocrystalline diamonds; enzyme nanoparticles; single enzyme nanoparticles.

UNIT III DNA BASED BIOSENSOR 9

DNA biosensors – principle, DNA immobilization, types; hybridization labels; label-free sensing; DNA microarrays; biosensor with other nucleic acids – peptide nucleic acids, ribozymes, DNAzymes, Aptamers; metal detection with DNA; sensing in water and food samples.

UNIT IV SENSING OF CELLS AND PATHOGENS 9

Nanoscale cell biosensors – cell immobilization methods; bioluminescence – bacterial engineering, caged luciferin for sensing; cellular biosensors for heavy metals, biomolecules, rare cells; detection of pathogens or contaminants in food and water samples.

UNIT V APPLICATIONS OF BIOSENSORS 9

Nanobiosensors – types, design, and strategies; protein pores and protein cages as components of biosensors; biosensors for pharma and medicine, bioremediation, defense, and food technology; wearable biosensor.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Demonstrate knowledge in basics of biosensors and fabrication techniques
CO2: Perceive the strategies used for making protein-based nanobiosensors
CO3: Explain the use of nucleic acids like aptamers and DNAzymes for metal and biomolecule detection
CO4: Identify ways to use bioluminescence and other properties of whole cells to detect cancer, pathogens and environmental toxins
CO5: Analyse the recent trends in nanobiosensors in various fields and applications

REFERENCES:

1. Singh R.P., Ukhurebor K.E., Singh J., Adetunji C.O. and Singh K.R.B., “Nanobiosensors for environmental monitoring: fundamentals and application”, Springer, Switzerland, 2022.
2. Knoff G.K. and Bassi A.S., “Smart biosensor technology”, 2nd Ed.,Taylor & Francis, Florida, US, 2020.
3. Wu A. and Khan W.S., “Nanobiosensors: from design to applications”, Wiley-VCH; Weinheim, Germany, 2020.

4. Chandra P., “Nanobiosensors for personalized and onsite biomedical diagnosis”, IET, UK, 2016.
5. Malhotra B. and Ali M.A., “Nanomaterials for biosensors”, Elsevier, 2017.

CO-PO MAPPING:

CO	PSO					
	1	2	3	4	5	6
1	2	3	3	3	2	3
2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

NT3013 NANOELECTRONICS AND SENSORS **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To teach about nanoelectronics, two-terminal junction transistors, various gates, various characteristics of sensors and actuators and memory devices for nanoelectronics and sensors.

UNIT I OVERVIEW OF NANO-ELECTRONICS 9

Nanoscale electronics – basics and applications; low dimension electron transport – quantum confinement; quantum dots – coulomb blockade, ballistic transport, quantum interferences, landauer formula; quantum point contact – examples and applications.

UNIT II TWO-TERMINAL JUNCTION TRANSISTORS 9

CMOS – basics and process flow; MOS scaling theory – issues in scaling MOS transistors; PMOS versus NMOS – design and construction; integration issues of high K-MOS; MOS transistor and capacitor – characteristics, interface states, bulk charge, band offset, stability, reliability.

UNIT III GATE 9

Metal gate transistors – basics and requirements; quantum transport in MOSFET; ultrathin body silicon on insulator (SOI); double gate transistors – basics and applications; vertical transistors – finFET and surround gate FET; MOSFET types – compound semiconductor and hetero-structure MOSFET.

UNIT IV SENSORS AND ACTUATOR CHARACTERISTICS 9

Sensors and actuators – basics, types and working principles; characteristic features – range, resolution, sensitivity, error, repeatability, linearity, accuracy, impedance; nonlinearities – static and coulomb friction, eccentricity, backlash, saturation, deadband; system response – first order system response, under-damped second order system response, frequency response.

UNIT V MEMORY DEVICES AND SENSORS 9

Nano ferroelectrics – ferroelectric random-access memory; Fe-RAM circuit – design and fabrication; ferroelectric thin film – properties and integration; calorimetric sensors; electrochemical cells; gas-sensitive FETs; semiconductor gas sensors; electronic noses – identification of hazardous solvents and gases; semiconductor sensor array.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Explain the basics of nanoelectronics
CO2: Explain the working of two terminal junction transistors.
CO3: Comprehend the knowledge about the gates.
CO4: Perceive the various characteristics of sensors and actuators.
CO5: Comprehend about the memory devices in nanoelectronics.

REFERENCES:
1. Rainer W., "Nano electronics and information technology-advanced electronic materials and novel devices", 3rd Ed., Wiley-VCH, 2012.
2. Drexler K.E., "Nanosystems - molecular machinery, manufacturing & computation", 1st Ed., John Wiley and Sons, 1992.
3. Vladimir V.M., Viatcheslov A.K. and Michael A.S, "Introduction to nanoelectronics; science, nanotechnology, engineering and applications", 1st Ed., Cambridge University Press, 2008.
4. Khanna V.K., "Nanosensors: physical, chemical and biological", 2nd Ed., CRC Press, 2021.
5. Datta S., "Lessons from nanoelectronics: a new perspective on transport", 2nd Ed., World Scientific Publishers, 2018.

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CO	PSO					
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3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation

NT3014 **MEMS AND NEMS** **L T P C**

3 0 0 3

COURSE OBJECTIVE:
- To impart knowledge on MEMS and NEMS fabrication strategies.

UNIT I MEMS MICROFABRICATION 9

Historical development of microelectronics, evolution of microsensors, evolution of MEMS, emergence of micromachines; modeling – finite element analysis, CAD for MEMS; fabrication – ALD, lithography micromachining, LIGA, micromolding, SAW–IDT microsensor fabrication; packaging – challenges, types, materials, and processes.

UNIT II SCALING OF MEMS 9

Introduction to scaling issues; scaling effects on a cantilever beam; scaling of electrostatic actuators, scaling of thermal actuator, scaling of thermal sensors; mechanics and electrostatistics; influence of scaling on material properties.

UNIT III MICROSYSTEMS 9

Microsensors; microaccelerometer; microfluidics; mechanics for microsystems; design – thermomechanics, fracture mechanics, thin-film mechanics, microfluid mechanics.

UNIT IV MATERIALS FOR MEMS 9

Materials for MEMS and pro MEMS – silicon, metals, polymers; substrate materials for MEMS – silicon, quartz, ceramics, bulk metallic glasses; sharp memory alloys; carbon-based MEMS.

UNIT V COMMERCIAL AND TECHNOLOGICAL TRENDS 9

Commercial trends in miniaturization; high-density chip analysis; micro-accelerometers; micro-resonators; lab-in-chip for DNA and protein analysis; nano HPLC system; nanopatches.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Comprehend MEMS microfabrication strategies.
CO2: Explain the process for scaling of MEMS.
CO3: Discuss elaborately about microsystem.

CO4: Perceive the materials used in MEMS technology.
CO5: Perceive biological MEMS technology.

REFERENCES:

1. Madou M.J., "Fundamentals of microfabrication", 2^{nd} Ed., CRC Press, Boca Raton, 2017.
2. Hsu T.-R., "MEMS and microsystems: design, manufacture, and nanoscale engineering", 2^{nd} Ed., John Wiley & Sons, 2020.
3. Lyshevski S.E., "Nano- and micro- electromechanical systems", 2^{nd} Ed., CRC Press, Boca Raton, 2018.
4. Varadan V., Jiang X. and Varadan V.V., "Microstereolithography and other fabrication techniques for 3D MEMS", Wiley, 2001.
5. Gilleo K., "MEMS/MOEMS packaging: Concepts, designs, materials and processes", McGraw-Hill, 2005.

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2	2	3	3	3	2	3
3	2	3	3	3	2	3
4	2	3	3	3	2	3
5	2	3	3	3	2	3
Avg.	2	3	3	3	2	3

Note: 1-low, 2-medium, 3-high, '-"- no correlation