Annexure-II

M.TECH – NANOTECHNOLOGY SYLLABUS FOR IstSEMESTER

NST 101 (AUG) 3:0

Applied Solid State Physics

With the development of advanced fabrication techniquesmaterials and structures that exhibit reduced dimensionality can besynthesized. It is now possible to observe and control quantum size effectsin a variety of materials. Examples include semiconductor quantum wells,quantum dots and heterojunctions. Topics to be covered in this courseinclude electrical, optical and magnetic properties of reduced-dimensionalmaterials and nanostructures.This course is also intended to build a basic understanding of solid state science, on which much ofmodern nanotechnology is built, and therefore includes elementary quantum mechanics.

Lecture Notes & Reference books

Neil W. Ashcroft, and David Mermin N., *Solid State Physics*, Brooks/Cole
Stephen Elliott, *Physics and Chemistry of Solids,* John Wiley, 1998
S. M Lindsay, *Introduction to Nanoscience*, Oxford (2010)
Charles Kittel., *Introduction to Solid State Physics*, John Wiley and Sons
Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe. *Quantum Mechanics (2 vol. set)*, John Wiley & Sons

NST 102 (AUG) 3:0

Applied Chemistry: Bio and Materials Chemistry

Thiscoursewillintroducestudentstothefundamentalsofmaterialsscience and materials chemistry.Topicsthatwillbecoveredinclude:bonding,crystalstructure,defects,diffusion,phases,aswellastheelectric al,thermal,optical,magnetic,andchemicalpropertiesofmetals,ceramics,andnanomaterials.Inadditiontocoveringho watomicbondingandcrystalstructureimpactthepropertiesofbulksolids,considerationwillalsobegiventotheimpactof quantizationeffectsonnanomaterialproperties.Structure of solids, symmetry concepts, crystal structure. Preparative methods andcharacterization of inorganic solids. Crystal defects and non-stoichiometry.Interpretation of phase diagrams, phase transitions. Kinetics of phase transformations,structure property correlations in ceramics, glasses, polymers. Composites and nanomaterials.
Basic concepts in biomaterials science, concept and assessment of biocompatibility of biomaterials, examples of some important metallic biomaterials, bio- ceramics and bio-composites

Lecture Notes & Reference books

Anthony R. West., *Solid State Chemistry and its Applications*, Wiley, 1998
Stephen Elliott, *The Physics and Chemistry of Solids*, John Wiley, 1998
William D. Callister, *Materials Science and Engineering: An Introduction*, (9th Ed), Wiley (2013)
Hull, D and Bacon, *D.J., Introduction to Dislocations,* Butterworth-Heinemann, 2001
David A. Porter, *Phase Transformations in Metals and Alloys*, (3rd Ed) (Revised Reprint), CRC Press
Basu B, Katti D and Kumar A,*Advanced Biomaterials: Fundamentals, Processing and Applications*, Wiley,2009.
Ratner, Hoffman, Schoet and Lemons, *An introduction to Materials in Medicine, Biomaterials Science*, Third Edition, Elsevier Academic Press, 2012.

NST 103 (AUG) 3:0

Introduction to Nanotechnology

This course introduces students to the field of Nano Science and Technology. This includes nanofabrication technology (how one achieves the nanometre length scale, from "bottom up" to "top down"technologies), the interdisciplinary nature of nanotechnology and nanoscience (including areas of chemistry,material science, physics, and molecular biology), examples of nanoscience phenomena (the crossover frombulk to quantum mechanical properties), and applications (from integrated circuits, quantum computing,MEMS, Nano-magnetics and bioengineering). Introduction to advanced optics such as LASERS, plasmonics, biophotonics, nanophotonics, non-linear optics etc.Students willbe asked to read and present a variety of current journalpapers to the class and lead a discussion on the various works.

Lecture Notes & Reference books

S. M Lindsay, *Introduction to Nanoscience*, Oxford (2010)
Charles P. Poole Jr. & Frank J. Owens, *Introduction to Nanotechnology*, Wiley (2003)
M.S. Ramachandra Rao, *Nanoscience and Nanotechnology: Fundamentals of Frontiers*, Wiley
M.A. Shah, *Nanotechnology: The Science of Small*, Wiley (2013)
Cao G., *Nanostructures and Nanomaterials, Synthesis Properties and Applications,* Imperial College Press, 2004

NST 104 (AUG) 3:0

Mathematical Methods for Data Analysis

The course will cover mathematical techniques necessary for understanding of materials science and engineering topics which form the basis of understanding Nano-science and technology such as energetics, materials structure and symmetry, materials response to applied fields, mechanics and physics of solids and soft materials. The course will use uses examples from courses NST – 101, 102 103 to introduce mathematical concepts and materials-related problem-solving skills. Topics include linear algebra and orthonormal basis, eigenvalues and eigenvectors, quadratic forms, tensor operations, symmetry operations, calculus of several variables, introduction to complex analysis, ordinary and partial differential equations, theory of distributions, Fourier analysis and random walks.Basic programming in PYTHON and/or MATLAB using simple examples. Numerical methods:interpolation, numerical integration and differentiation, Gaussian quadrature, basiclinear algebra, eigen solutions, linear and non-linear data fitting, solutions of ODEs.

Lecture Notes & Reference books

Louis Theodore, *Nanotechnology: Basic Calculations for Engineers and Scientists*, Wiley (2005)
Amos Gilat, *MATLAB: An Introduction with Applications (4th Ed)*, Wiley
Rudra Pratap, *Getting Started With MATLAB: A Quick Introduction for Scientists and Engineers*, OUP (2016)
Ikeda, Susumu, Kotani, Motoko, *A New Direction in Mathematics for Materials Science*, Springer (2015)

NST 105 (AUG)0:3

Micro- and Nano- Materials Synthesis and Analysis: Tutorial & Laboratory

The aim of this course is to introduce students to different phases (and phase diagrams) of materials focussing on their structure-property relationship. The student will also be familiarised with surfaces, interfaces and basic materials characterizationprinciples and techniques in addition to Practical aspects of chemical and physical methods of synthesizing nanomaterials (0D, 1D & 2D),Hands-on exposure to chemical and physical routes for

synthesis of nanomaterials, both top-down and bottom-up approach, e.g., solution-based techniques of synthesis (sol-gel, colloidal dispersion, self-assembly etc.), microwave irradiation assisted synthesis, combustion synthesis, chemical etching, ion milling, lithography etc.Also,chemical and physical method of thin film and quantum dot deposition/formation–chemical vapor deposition/etching, atomic layer deposition/etching, MBE, plasma assisted synthesis etc. will also be introduced.

Lecture Notes &Reference books

William D. Callister, *Materials Science and Engineering: An Introduction, (9^{th} Ed)*, Wiley (2013)
Goldstein J.I, Romig A.D. Newbury D.E, Lyman C.E., Echlin P., Fiori C. Joy D.C. and Lifshin E.., *Scanning Electron Microscopy and X-Ray Microanalysis: A Textbook for Biologists, Materials Scientists and Geologists*
Davis R. Gaskell, *Introduction to Thermodynamics of Materials (5^{th} Ed)*, CRC Press
Marc De Graef, Michel McHenry, *Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry (2^{nd} Ed)*, Cambridge University Press
Rolf E. Hummel, *Electronic Properties of Materials (4^{th} Ed)*, Springer (2013)
Robert M. Silverstein,*Spectrometric Identification of Organic Compounds*, Wiley (2014)
Markov Ivan V., *Crystal growth for Beginners, Fundamentals of Nucleation, Crystal Growth and Epitaxy*, World Scientific, 1998;
Milton Ohring, *Materials Science of Thin Films*, Academic Press, 2002
Cao G., *Nanostructures and Nanomaterials, Synthesis Properties and Applications*, Imperial College Press, 2004
Marc J. Madou, *Fundamentals of Microfabrication and Nanotechnology*, CRC press
Stephen A. Campbell, *Fabrication Engineering at the Micro- and Nanoscale (4^{th} Ed)*, Oxford University Press
Bhushan, Bharat (Ed.), *Springer Handbook of Nanotechnology*, Springer (2017)
Ivo Utke, *Nanofabrication Using Focused Ion and Electron Beams: Principles and Applications*, Oxford University Press (2012)

NST 106 (AUG) 0:0 (Compulsory)

Technical English Language Training (Writing/Presentation/)

This course is designed to help students learn to write their manuscripts,reports, anddissertations in a competent manner. **The do's and dont's of the English language will be dealt with primarily as a part of the course**. Assignments will include writing on topics to a student's research interest,so that the course may benefit each student directly.

Lecture Notes &Handouts

M.TECH – NANOTECHNOLOGY SYLLABUS FOR IIndSEMESTER

NST 201 (JAN) 2:1

Overview of Advanced Micro & Nano-material Characterization Techniques

Prerequisite: All the first semester courses

Principles, instrumentation, design and application of UV, visible and IR spectroscopy, massspectrometry, Mossbauer and NMR spectroscopy, X-ray methods of analysis including powderdiffraction, wavelength and energy dispersive x-ray fluorescence. Electron microscopy andmicroprobe. ESCA and Auger techniques, photo electron spectroscopic methods, scanningtunnelling and atomic force microscopy. Chromatography, thermal analysis including DTA, DSCand TGA.Hands ontraining on preparation of fine particles, growth of single crystals and thin films and their thermal analysis, magneticmeasurement, X-ray diffraction, SEM and TEM analyses, electrical and dielectric measurements.

Lecture Notes & Reference books

George M. Crankovic (Ed.), *ASM Handbook: Volume 10: Materials Characterization*, ASM International, 1986
Robert Cahn (Ed.), *Concise Encyclopaedia of Materials Characterization,2nd Edition*, Elsevier, 2004
Charles Evans, Richard Brundle and Shaun Wilson, *Encyclopaedia of Materials Characterization: Surfaces,Interfaces, Thin Films*, Elsevier, 1992
Tantra, Ratna, *Nanomaterial Characterization: An Introduction*, Wiley (2016)

NST 202 (JAN) 3:0

Semiconductor devices & Nano-electronics

Prerequisite: All the first semester courses

Non idealities in MOS structure, High-k dielectrics, Metal gate electrodes and work functionengineering, C-V and I-V characteristics Nano MOSFET performance metrics, non-classicaltransistor structure: Transport in Nano MOSFET, velocity saturation and overshoot, ballistictransport, Silicon on Insulator (SOI) –PDSOI and FDSOI, Multigate FET, metal-semiconductorsource/drain junctions, Germanium Nano MOSFETs, Effect of strain and quantization ontransistorperformance Compound semiconductor MESFETs and MOSFETs, Hetero structureMOSFETs,Emerging Research Devices and architectures, Characteristics of nanomaterials;scaling ofproperties with particle size; quantum confinement; device concepts based onnanomaterials andnanostructures; some methods for the preparation and characterization ofnanomaterials andstructures.

Lecture Notes && Reference books

Taur and Ning, *Fundamentals of Modern VLSI Devices*, Cambridge University Press
Streetman and Banerjee, *Solid State Electronic Devices*, Prentice Hall
Achutan and Bhat, *Fundamentals of Electronic Devices*, McGraw Hill
E.H. Nicollian and J.R.Brews, *MOS (Metal Oxide Semiconductor) Physics and Technology*, Wiley Publishers

NST 203 (JAN) 3:0

MEMS, NEMS theory & devices (Micro/Nano-mechanical aspects)

Prerequisite: All the first semester courses

This is a foundation level course in mechanics with which will prepare students to pursue advancedstudies related to mechanical phenomena at the micro and nano scales. Basics of continuumtheory, continuum hypothesis, elasticity, thermoelasticity, fluid mechanics, heat conduction,electromagnetism, coupled thermal-elastic and electrostatic-elastic systems, MEMS and NEMSstructures -- beams, plates, and membranes, scaling of mechanical properties and continuumlimits, numerical methods for mechanical modelling, mechanics beyond continuum theory. Micro- and Nano Fluidics.

Lecture Notes && Reference books

John A. Palesko and David H. Bernstein, *Modeling MEMS and NEMS*, Chapman and Hall/CRC
Leondes, Cornelius T. (Ed.), *Mems/Nems: (1) Handbook Techniques and Applications Design Methods, (2) Fabrication Techniques, (3) Manufacturing Methods, (4) Sensors and Actuators, (5) Medical Applications and MOEMS*, Springer (2006)
Tai-Ran Hsu, *MEMS & MICRO SYSTEMS Design and Manufacture*, Tata McGraw Hill, New Delhi,2002
Vijay K. Varadan, K. J. Vinoy, S. Gopalakrishnan, *Smart Material Systems and MEMS: Design and Development Methodologies*, Wiley (2006)

NSTE2 204 (JAN) 3:0*(Elective)*

Nano Medicine and Agricultural Technology

Prerequisite: TBD

Nanomedicine is a combination of nanotechnology and medicine. It provides new direction in medical diagnosis, monitoring and treatment at the level of single molecules or molecular assemblies at the “nano” scale. This course will focus on the basic applications of nanotechnology in health sciences, in clinical and research level and how nanotechnology has expanded its role in agriculture and food products.Following the applications of nanotechnology in human medicine, the course will alsoconcentrate on the potential of applying nanotechnology in veterinary medicine regarding animal health, animal breeding and animal food safety.The course will also summerize the applications of nanoparticles to the agro-food section, food packaging and supply chain andmoreover, relevant environmental, health and toxicological issues will be highlighted.

Lecture Notes && Reference books

Tuan Vo-Dinh, *Nanotechnology in Biology and Medicine: Methods, Devices, and Applications*, CRC Press (2018)
Gothandam, K.M., Ranjan, S., Dasgupta, N., Ramalingam, C., Lichtfouse, E. (Eds.), *Nanotechnology, Food Security and Water Treatment*, Springer (2018)
V Ravishankar Rai, Jamuna A Bai, *Nanotechnology Applications in the Food Industry*, CRC Press (2017)
Mariusz Skwarczynski, Istvan Toth (Ed.), *Micro- and Nanotechnology in Vaccine Development (1st Ed.)*, Elsevier (2017)
Shampa Sen, Yashwant Pathak, *Nanotechnology in Nutraceuticals: Production to Consumption*, CRC Press (2016)
Eugene Meyer, *Chemistry of Hazardous Materials (6th Ed.)*, Pearson (2013)
AlexandruGrumezescu, *Nutrient Delivery* (1st Ed), Elsevier (2016)

NSTE2 205 (JAN) 2:1 *(Elective)*

Computational Materials Science (with thrust on Nano Scale Modelling and Simulation)

Prerequisite: TBD

Introduction to computational modeling of materials, description of atomic interaction, the many-body problem, molecular dynamics, tight-binding approximation, first-principles (ab-initio) methods, Hartree-Fock, molecular orbital method, density functional theory and monte carlo simulation. Applications ofthese techniques in modeling of mechanical, electronic, magnetic, optical, and dielectric properties ofmaterials at nano scale, design principles of novel nanomaterials, nanoscale simulation software and applications.In addition, this course through examples will discuss recent modeling and simulation applications from current research for understanding material interactions, interfaces, deformation and failure; property predictions of relevance to polymeric composites; cementitious materials, nanoscale layered metallic composites, bio systems and biosensor applications to stimulate research motivation

Lecture Notes && Reference books

June Gunn Lee, *Computational Materials Science: An Introduction*, CRC Press (2011)
Richard Martin, *Electronic Structure: Basic Theory and Practical Methods,* Cambridge.
Delerue, Christophe Jean, Lannoo, Michel*., Nanostructures: Theory and Modeling,* Springer (2004)
Massobrio, Carlo, Bulou, Herve, Goyhenex, Christine (Eds.), *Atomic-Scale Modeling of Nanosystems and Nanostructured Materials,* Springer (2010)
Vinod K. Tewary and Yong Zhang, *Modeling, Characterization and Production of Nanomaterials: Electronics, Photonics and Energy Applications*, Elsevier (2015)

NSTE2 206 (JAN) 2:1 *(Elective)*

Nanotechnology for Environmental applications

Prerequisite: TBD

The course is aimed to provide general knowledge on the properties and composition of nanomaterials and characteristics of nanotechnologies and their effects towards industrial applications. The principles of nanocatalysis, membranes, nanofiltration and other methods in the processes of water treatment processes will be introduced and studied. The basics of nanoparticle aerosol formation in industrial processes will be assimilated. Nanofiltration and nanocatalysiswill be discussed for the application of air pollution abatement. The applications of nanotechnologies in waste treatment and polluted site remediation will be reviewed. The impact of nanomaterials to the environment and human health will beexamined.

Lecture Notes && Reference books

Sridharan, Karthiyayini (Ed.), *Emerging Trends of Nanotechnology in Environment and Sustainability: A Review-Based Approach*, Springer (2018)
ChaudheryMustansar Hussain, Ajay Kumar Mishra, *Nanotechnology in Environmental Science, 2 Volumes*, Wiley (2018)
Rai, Mahendra, da Silva, Silvio Silvério (Eds.), *Nanotechnology for Bioenergy and Biofuel Production*, Springer (2017)
M. H. Fulekar, Bhawana Pathak, *Environmental Nanotechnology*, CRC Press (2018)
Kaufui V. Wong, *Nanotechnology and Energy*, CRC Press (2018)

NSTE2 207 (JAN) 0:3*(Elective)*

Nano-Manufacturing Technology

Prerequisite: TBD

This course is designed to give training in basic processing/manufacturing for four specific modules that will be covered to realize four different devicesi) p-n junction diode, ii) MOS capacitor iii) MEMS Cantilever iv)

Microfluidic channel, thus encompassing nearly all the relevant “bottoms-up” and “top-down” techniques for manufacturing at nanoscale.

Lecture Notes && Reference books

S.M. Sze & G.S. May, *Fundamentals of Semiconductor Fabrication*, Wiley (2011)
Stephen A. Campbell, *Fabrication Engineering at the Micro- and Nanoscale (4th Ed)*, Oxford University Press
Ivo Utke, *Nanofabrication Using Focused Ion and Electron Beams: Principles and Applications*, Oxford University Press (2012)
Waqar Ahmed, M. J. Jackson, *Emerging Nanotechnologies for Manufacturing (Micro and Nano Technologies)*, Springer (2009)
Nicola Pinna (Ed), Mato Knez (Ed), *Atomic Layer Deposition of Nanostructured Materials*, Wiley (2011)
Mohamed Gad-el-Hak, *The MEMS Handbook, Second Edition - 3 Volume Set*, CRC Press (2005)

NSTE2 208 (JAN) 2:1 *(Elective)*

Nano Emulsions/Suspensions and Polymeric Nanoparticles

Prerequisite: TBD

This course is designed to study the both the theoretical and practical aspects of Nano-emulsion’s useful properties pertaining to robust stability, optically transparent appearance, and tunable rheology. Study of Nano emulsions in areas such as drug delivery, food, cosmetics, pharmaceuticals, and material synthesis. Additionally, Nano emulsion use as model systems to understand nanoscale colloidal dispersions. Study of theoretical and practical aspects of self-assembled and non-self-assembled Nano polymers and polymer nanocomposites structures, their study as 1D, 2D, 3D form and their combination and usage in Nano manufacturing via soft lithography

Lecture Notes && Reference books

Seid Jafari D. Julian McClements, *Nanoemulsions: Formulation, Applications, and Characterization, (1st Ed)*, Elsevier (2018)
Fakirov, Stoyko (Ed.), Nano-size Polymers: Preparation, Properties, Applications, Springer (2016)
Suprakas Sinha Ray and MostoBousmina, *Polymer Nanocomposites and Their Applications*, American Scientific Publishers (2006)

NSTE2 209 (JAN) 2:1 *(Elective)*

Nonlinear and Ultrafast Photonics

Prerequisite: TBD

Owing to the extensive use of nonlinearoptical phenomena and Ultrafast lasers in various fields, we believe a good understanding of theseprinciples is essential for students in all science and engineering disciplines, studentsinvolved in the area of Photonics, RF and Microwave systems, Optical Instrumentation andLightwave (Fiber-optic) Communications. In addition, this course intends to prepare students topursue advanced topics in more specialized areas of optics such as Biomedical Imaging, Quantumoptics, Intense field phenomena etc.

Lecture Notes && Reference books

Bahaa Saleh and MalvinTeich, *Fundamentals of Photonics*, Wiley (2007)
Hecht E, *Optics*, 5th Edition,Pearson (2016)
Robert W. Boyd, *Nonlinear Optics*, 3rd Edition, Elsevier (2008)
Govind P. Agrawal, *Nonlinear Fiber Optics*, 5th Edition, Elsevier (2012)
Andrew M Weiner, *Ultrafast Optics*, Wiley (2008)

M.TECH – NANOTECHNOLOGY SYLLABUS FOR IIIrd SEMESTER

MMTR 301 (AUG) 2:0

Research Methodology& Technical Writing

Prerequisite: Course Code NST-106 (Technical English Language Training (Writing/ Presentation/)

Research Methodology:
Research process, types of research, problem identification and hypothesis formulation, Research design, methods of data collection, reliability and validity, data presentation, and report preparation.
Introduction to Research Communication:
Grammar and Rhetoric: Sentential and supra sentential structure, Narrative and structuring argument, common error in composition. Reading skills for literature review: Previewing techniques, understanding the gist of an argument, identifying the topic sentence.
Writing skills (Part-I)
Sentence formation, Use of appropriate diction, paragraph and essay writing, coherence and cohesion. Summarizing, paraphrasing, outlining, Non-linear description, Narrative, Instruction and reporting. Descriptive and explanatory, analytical and argumentative writing, enhancing editing skills, punctuation.
Writing skills (Part-II)
Introduction to terminology, concept of research. Preparing research proposal/ Synopsis. Formulating thesis statement. Referencing (all style sheet). Writing Introduction, Footnotes/ Endnotes, Conclusion. Preparing Appendix, Bibliography (all style sheets), and Abstract. Writing acknowledgement. Concept of Keywords, preparing content page/ list of Tables and Figures. Use of classified materials, Plagiarism and copyright materials.

Lecture Notes && Reference books

Ranjit Kumar, *Research methodology: a step-by-step guide for beginners*, SAGE Publications India Pvt Ltd.
C.R. Kothari, *Research Methodology: Methods and Techniques*, New Age International, 2004.
Michael H. Markel,*Handbook of Technical writing,* Bedford/St Martins, 2012
Thomas N. Huckin, *Technical Writing and Professional Communication: For Non-native Speakers of English*, McGraw Hill, 1991.
Michael H. Markel,*Technical Writing Essentials*. St. Martin's Press, 1988.
Sharon J Gerson, Steven M Gerson,*Technical writing: Process and product*, Fifth edition, Pearson Education, 2006.

NST 302 (AUG) 2:0

Entrepreneurship, Ethics and Societal Impact

Prerequisite: None

This course is intended to give an exposure to issues involved in translating the technologies fromlab to the field. Various steps and issues involved in productization and business development willbe clarified, drawing from experiences of successful entrepreneurs in high technology areas. Theintricate relationship betweentechnology, society and ethics will also be addressed withillustrations from people involved in working with the grass root levels of the society.

Lecture Notes && Reference books

Gehrke, Pat J., *Nano-Publics: Communicating Nanotechnology Applications, Risks, and Regulations*, Palgrave Macmillan (2018)
Harald Throne-Holst, Eivind Soto, Pal Strandbakken, Gerd Scholl, *Consumers and Nanotechnology: Deliberative Processes and Methodologies*, CRC Press (2018)

NST 303 (AUG) 1:0Minor Project related towards subsequent Final Thesis/Project

This course comprises of introducing the student to the ways of literature survey and a term project related to their topic of interest. The aim is to get the student trained and prepared for the subsequent master's project/thesis

NST 304 (AUG) 10:0

Pre-requisite: NST 303

Final M.Tech Thesis/Project

M.TECH – NANOTECHNOLOGY SYLLABUS FOR IVth SEMESTER

NST 401 (JAN) 15:0

Pre-requisite: NST-304

Final M.Tech Thesis/Project