Program

M Sc - Nanoscience and Nanotechnology

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M.Sc. NANOSCIENCE AND NANOTECHNOLOGY

Educational Objective

This is a two-year course in *Nanoscience and Nanotechnology* with a focus on applications in energy science such as Photovoltaics, Batteries, Supercapacitors, Hydrogen Storage and Carbon Capture. Considerable research over the past decade has shown that nanomaterials can play a significant role in the above applications through use of nanoparticles, thin films and composites and materials with nano and mesoporous architectures. The course provides a fundamental understanding of the processing and properties of such materials and the physics and chemistry behind use of such materials in device applications, and the physics of the devices themselves. There are subject core courses dealing with design of nanosystems, nanomaterials and their processing, properties and characterization, as well as on the applications of nanomaterials to energy generation, storage, remediation and catalysis. Each student will have a thesis requirement involving one full year of hands-on independent research.

Programme Outcomes

- Will acquire diverse feel about energy consumption, conservation and progress in multiple aspects of energy in terms of cost, viability and feasibility.

- Will be educated on various energy related policies and their applications, practical difficulties, short comings in implementation and mass production.

- Will be able to integrate functional materials of various scientific interests into energy engineering for the development of energy conversion and storage technologies.
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- Will adopt research of different focuses in energy conversion and storage to develop novel techniques or methods to realize new functional materials and devices.

- Will be trained in various instrumentation techniques to produce materials of different nanostructures and device fabrication at lab and large scales.

- Will be practiced to assess various functional materials and their relationship with energy research and developmental process.

- Will be able to establish various characterization techniques which can relate materials and devices with their performance.

- Will be sensible on energy demands, energy policies and economics for the future developmental activities.

- Will be able to setting up own fabrication and material production business at the small scale as students with multi-disciplinary courses and research activities.

- Will be able to contribute to the society in terms of energy via reach out activities to make the process sustainable and more attractive.

Programme Educational Objectives

- To establish an energy-sensitive attitude among students and society on the energy crisis as it is going to limit our life in various aspects including standard, health, duration and economics.

- To construct an emerging new generation of life starting from student phase to integrate highly advanced energy handing methodologies, policies, regularities and activities through curriculum which involves introducing variety of energy conversion and storage methodologies along with emerging concepts in nanotechnology.

- To integrate multi-disciplinary research and teaching environments facilitating students-faculty alignment centered at various aspects of energy in the field of nanotechnology.

- To interface energy education with social functionality through various reach out activities creating awareness in setting up team works in energy demands, conservation methods and other requirements to realize energetically fulfilled society.

CURRICULUM

First Semester

Course Code	Type	Course	LTP	Credits
18MA613	FC	Statistical Data Analysis	101	2
18NT601	FC	Introduction to Classical &QuantumMechanics	300	3
18NS621	SC	Science andProperties of Nanomaterials	300	3
18NT621	SC	Physics of Semiconductor Nanostructures	300	3
18NS622	SC	Nanomaterials Synthesis	300	3
18NT629	SC	Introduction to Solid State Phenomena at Nanoscale	300	3
18HU604	HU	Amrita Values Programme	100	1
18HU602	HU	Career Competency-I		P/F
18NS624	SC	Lab: Nanomaterials Lab-I	102	3
18NT622	SC	Lab: Optoelectronis Lab	002	2
		Total Credits		**23**

Second Semester

Course Code	Type	Course	LTP	Credits
18NT630	FC	Chemical Thermodynamics	300	3
18NS625	SC	Characterization of Nanomaterials	300	3
18NT623	SC	EnergyConversion Scienceat Nanoscale	300	3
18NT624	SC	Thin Film Science and Technology	300	3
18NT631	SC	Nanophotonics	300	3
18NT625	SC	EnergyStorageScience at Nanoscale	300	3
18HU603	HU	Career Competency-II	100	1/F
18NS629	SC	Lab: Nanomaterials Lab-II	102	3
18NT626	SC	Lab: Energy Devices Lab	002	2
		Total Credits		**24**

Third Semester

Course Code	Type	Course	LTP	Credits
18RM601	FC	Ethics in Research and Research Methodology	101	2

18NT627	SC	Introduction to Nanodevice Fabrication	300	3
18NT628	SC	Nanomaterials for Hydrogen Storage and Carbon Capture	300	3
18NT796	P	Dissertation		5
		Total Credits		**13**

Fourth Semester

Course Code	Type	Course	LTP	Credits
18NT797	P	Dissertation		10
		Total Credits		**10**
		Overall Total Credits		**70**

FIRST SEMESTER

18MA613 STATISTICAL DATA ANALYSIS 1-0-1-2

LEARNING OUTCOMES:

Students who complete the course will understand the following:

- *The basic concepts of statistics and the need for statistical methods in research*
- *Data Analysis Methods*
- *The fundamental theory of probability and standard distributions*
- *Tests of Significance used in Statistical analysis*
- *The different types of multivariate analysis used in research*
- *Practical analysis of data using standard softwares like SPSS, SAS*
- *Practical understanding of Descriptive Data Analysis, Sampling Theory, Biostatistical Inference, Testing of Hypotheses, Nonparametric Methods and Multivariate Regression Analysis*
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SYLLABUS:

Introduction to Statistics-Need for Statistical Methods –Their uses and Misuses, Types of Variables, Data collection Methods, Population and Sample.

Descriptive Data Analysis Methods- Statistical Tables, Diagrams & Graphs, Measures of Averages, Measures of Dispersion, Correlation Analysis Methods, Regression Analysis Methods.

Theory of probability and Standard Distributions - Binomial, poisson& Negative Binomial, Standard univariate continuous distributions – Normal, Log normal & Exponential. Sampling distributions – Chi- square distribution and F & 't' distributions.

Tests of Significance of Statistical Hypotheses- Concept of Statistical Hypotheses –Null and Alternative hypotheses, Type I and Type II errors, Significance level, Critical region and Power of a test , P- value and its interpretation; Large and Small Sample Test – Normal test, Student's 't' test, Chi-square tests, Analysis of variance & Non parametric methods.

Nonparametric methods-Non-parametric methods for estimation, Methods for tests of significance for the independent and correlated samples, Nonparametric Methods for more than two populations.

Multivariate analysis Methods- Principles of Multivariate analysis, Multivariate regression analysis, Multivariate logistic regression analysis.

Practicals- (Statistical Software to be used: SPSS & SAS): (i) Practicals in Descriptive Data Analysis Methods, (ii) Practicals in Sampling Theory, (iii) Practicals in Biostatistical Inference, (iv) Practicals in Testing of Hypotheses, (v) Practicals in Nonparametric Methods, (vi) Practicals in Multivariate Regression Analysis.

TEXT BOOKS/REFERENCES:

1. *Statistical Techniques for data Analysis: J.K. Taylor & Cheryl C, 2004 Chapman & Hall (CRC).*
2. *Performing Data Analysis Using IBM SPSS: Lawrence S Meyers, 2015, John Wiley.*

18NT601 INTRODUCTION TO CLASSICAL & QUANTUM MECHANICS3-0-0-3

LEARNING OUTCOMES:

- Develop skills on modern developments in Physics at the nanoscale and their relationship with classical concepts.
- Understand various atomic models and their pros and cons in terms.
- Gain knowledge in fundamentals of operators for energy eigen values.
- Establish understanding the effect of nano-confinement in functional materials on various physical processes such as tunneling.

SYLLABUS:

Classical mechanics: review of Newtonian mechanics, introduction to Lagrangian and Hamiltonian formulations, failures of classical mechanics, Planck's quantum hypothesis, photo-electric effect, Compton effect, Bohr model of H-atom, particle in a box, correspondence principle, wave-particle duality, uncertainty principle, observables and operators, Schrodinger equation for free electron, particle in a box, linear harmonic oscillator, tunneling, applications of quantum mechanics in nanotechnology.

TEXT BOOKS/REFERENCES:

1. Classical Mechanics by Herbert Goldstein, John Safko, Charles P. Poole, Pearson Publishers, 3rd Edition (2011).
2. Introductory Quantum Mechanics for Applied Nanotechnology by D. M. Kim, Wiley-VCH; 2015.

18NS621 SCIENCE AND PROPERTIES OF NANOMATERIALS 3-0-0-3

LEARNING OUTCOMES:

Students who complete the course will have demonstrated the following:

- *Relate electronic bonding to material properties and materials classification*
- *Map crystal directions and planes in crystalline structure*
- *Relate crystalline structure to density and ease of deformation*
- *Quantify imperfections in crystalline structure and its role on properties*
- *Quantify diffusion within solids using Fick's First and Second Laws*
- *Quantify Mechanical properties of solids in terms of stress and strain and their relationship to each other*
- *Be able to predict failure from deformation behavior and geometry*
- *Relate composite properties to the individual materials combined and their architecture*

- *Define and quantify unique polymer properties and their relationship to polymer structure*
- *Predict phase composition from composition and temperature*
- *Quantify surface area and volume in nanosystems in comparison with microsystems*
- *To be able to develop and utilize equations for the thermodynamics of nanosystems*
- *Be able to quantitatively derive and relate particle size to physical properties, including, melting point and internal pressure*
- *Predict mechanical properties of nanoparticles and nanocomposites*
- *Quantify structural and mechanical parameters of classical nanomaterials classes.*

SYLLABUS:

Basic Materials Science:
Materials classification by bonding, amorphous and crystalline materials, crystal lattices, Miller indices, defects in crystal structure, principles of dislocations, theory of diffusion, mechanical properties, phase diagrams, polymeric materials, composite materials, electrical and optical properties
Nanomaterials science:
Types of Nanomaterials, definition of nanoscale, surfaces and particle size, surface energy and surface tension and relation to size, phase transformation in nanomaterials, specific heat and heat capacity of nanomaterials, mechanical properties of nanomaterials, optical properties of nanomaterials, electrical and magnetic properties of nanomaterials.

Inclusion and importance of surface energy, equations of thermodynamics with surface energy Equilibrium Particle size, internal pressure and stability, nucleation processes

Kinetics of reactions at nanoscale, Diffusion at nanoscale, ripening among nanoprecipitates.

TEXT BOOKS:

1. *Materials Science and Engineering – An Introduction, William D Callister, 12th Edition, John Wiley (Available in Amazon India, Rs. 287)*
2. *Nanomaterials – An introduction to synthesis, properties and applications, D. Vollath, Wiley-VCH, Second Edition 2013.*

18NT621 PHYSICS OF SEMICONDUCTOR NANOSTRUCTURES 3-0-0-3

LEARNING OUTCOMES:

- Able to categorize functional materials in terms of structural, optical and electrical.
- Gain ability to choose suitable functional materials for energy conversion applications.
- Able to explain the concept of charge transport and recombination in functional materials.
- Understand various loss mechanisms in electron and hole transport processes.

- Gain knowledge in recombination models.

SYLLABUS:

Semiconductors review; elemental and compound semiconductors; oxide semiconductors; electrical properties: electrons in semiconductors; band structures in semiconductors; intrinsic, extrinsic and compensated semiconductors; carrier concentration in semiconductors; carriers under thermal equilibrium and out of thermal equilibrium; current density in semiconductors; carrier drift and diffusion; conductivity and mobility; Hall effect, carrier transport and recombination; radiative, Auger and SRH recombination models, low dimensional semiconductors, emerging layered semiconductors, quantum size effects in semiconductor nanostructures.

TEXT BOOKS / REFERENCES

1. *Nanoscale Physics for Materials Science, By Takaaki Tsurumi, Hiroyuki Hirayama, Martin Vacha, Tomoyasu Taniyama, CRC Press, 2009*
2. *Leonid V. Azaroff, "Introduction to Solids", Second Edition, Tata McGraw- Hill Publishing Company Limited, 2006*

18NS622 NANOMATERIALS SYNTHESIS 3-0-0-3

LEARNING OUTCOMES:

Upon successful completion, students will have the knowledge and skills to:

- *Understand various chemical and physical methods for the synthesis of diverse types of nanomaterials (0D, 1D and 2D)*
- *Decipher information on the specific details of both bottom up and top-down synthesis*
- *Gather information on the different types of nanomaterials and their potential applications*

SYLLABUS:

Synthesis Methods of Nanomaterials: Top down : Milling; Bottom up approaches – Synthesis of zero dimensional metal, metal oxides, semiconductor nanoparticles by different routes – Colloidal method, Sol-gel, Electrodeposition; Kinetically Confined Synthesis of Nanoparticles - Aerosol synthesis, Micellar growth, Spray pyrolysis, Template-based synthesis; Synthesis of one dimensional nanosystems by different routes – VLS and SLS methods, Electrospinning; Synthesis of two dimensional nanosystems – Fundamentals of Film Growth; Vapor phase deposition methods - Physical and chemical methods; Superlattices; Self Assembly; Langmuir-Blodgett Films; Electrochemical Deposition; Special Nanomaterials – Core/shell structures, Carbon-based Nanomaterials, Micro and Mesoporous Materials, Organic-Inorganic Hybrids

TEXT BOOK/REFERENCES

1. G. Cao, Nanostructures and Nanomaterials – Synthesis, Properties and Applications, Imperial College Press 2006.
2. *Nanostructured materials: Processing, Properties and Potential Applications, Edited by Carl. C. Koch, Noyes Publications, 2002.*

18NT629 INTRODUCTION TO SOLID STATE PHENOMENA AT NANOSCALE 3-0-0-3

LEARNING OUTCOMES:

- Learn basics of crystal structures to classify materials based on structures.
- Gain knowledge on phonons, photons, plasmons and their influence in various physical aspects.
- Understand magnetic phenomena and relationship with electrical properties.
- Learn effect of nano on electrical and magnetic characteristics.

SYLLABUS:

Solid state phenomena - intro, phonons, heat capacity: thermal energy of a harmonic oscillator, specific heat capacity: Debye and Einstein models, anharmonicity and thermal expansion, heat conduction by phonons.Magnetism, dielectricsandsuperconductivity.Finite solids and nanostructures, Phonons in nanomaterials, surface plasmons in metal nanostructures, nanosized magnetic domains, magnetic tunnel junctions and magneto-resistance.

TEXT BOOKS/REFERENCES:

1. *P. Hofmann, Solid state Physics – An Introduction, Wiley VCH (2008).*
2. *David Pines, Elementary Excitations in Solids, CRC Press(1999).*

18HU604 AMRITA VALUES PROGRAMME 1-0-0-1

LEARNING OUTCOMES:

Students who complete the course will have demonstrated the following:

- *The basic concept of culture and values*
- *The relationship of culture with education, research, spirituality*
- *How culture is linked with gender, especially women*
- *The influence of media and politics in culture*

SYLLABUS:

Culture – definition and scope. Values and culture, cultural freedom

Culture and Education
Culture of Research – creativity and responsibility in research
Spirituality and Culture – spirituality as a way of life, spirituality and religion
Culture and women – gender oppression, motherhood
Culture and the Media
Culture and Politics – national values and political harmony
Philosophy and Culture, epistemology

18NS624 LAB: NANOMATERIALS LAB-I 1-0-2-3

LEARNING OUTCOMES:

After successful completion of the course, students will be able to:

- *Understand the preparation of standard solutions in different concentration units: Molarity, Molality and Normality*
- *Understand the synthesis of metal nanoparticles.*
- *Learn synthesis of plasmonic silver nanoparticles and observe its color change with varying size & shape of nanoparticles.*
- *Understand the principle and working of UV -Vis absorption spectroscopy technique and relation of absorption peak of silver nanoparticles with size and shape changes.*
- *Understand the synthesis of nanoparticles in non-aqueous route and observe its luminescence under UV lamp to understand quantum confinement effect.*
- *Understand the synthesis of nanoparticles in aqueous route and study the fluorescence properties of nanoparticles using spectrofluorometer*
- *Understand the UV-VIS absorption properties of nanoparticles and estimation of particle size using Brus equation*
- *Understand the principles of Atomic Force Microscope (AFM) and hands on experience in use of AFM in nanoparticle size characterization*
- *Understand the principles of Scanning Electron Microscope (SEM) and its use in characterizing nanoparticles*

SYLLABUS:

1. Metal Nanoparticles : Synthesis of plasmonic silver nanoparticles
2. Metal-oxide Nanoparticles: Synthesis of ZnO nanoparticles through non-aqueous route.
3. Absorption Spectroscopy of metal oxide (ZnO) nanoparticles and particle size calculation using Brus equation
4. Semiconductor Nanoparticles: Synthesis of doped ZnS nanoparticles through aqueous method; characterize fluorescence property using spectrofluorimeter
5. Silica Nanospheres: Synthesis and characterization by sol-gel chemistry
6. Surface Plasmon Resonance (SPR) analysis of differently shaped and sized gold

nanoparticles by absorption spectroscopy
7. Nanoparticle imaging by Atomic Force Microscope for size and shape analysis

18NT622 LAB: OPTOELECTRONICS LAB 0-0-2-2

LEARNING OUTCOMES:

- Learn synthesis of quantum dots by chemical methods.
- Study size-property correlation
- Coating thin-film metals andsemiconductors using sputtering and evaporation,
- Perform thickness measurement using profiler, ellipsometry, optical reflectance.
- Carryout Bandgap measurements using absorption and luminescence.
- Electrical transport measurements of bulkandthinfilmsin2and4probe configurations.

SYLLABUS:

Synthesis of quantum dots by chemical method and size-property correlation. Thin-film metals and semiconductors using sputtering and evaporation, Thickness measurement using profiler, ellipsometry, optical reflectance…etc.Band gap measurements using absorption and luminescence. Electrical transport measurements of bulk and thin films in 2 and 4 probe configurations.

TEXTBOOKS/ REFERENCES:

1. *S. M.Sze,"Physics of Semiconductor Devices",Wiley-Interscience, 1969.*
2. *D KSchroder,"SemiconductorMaterialandDeviceCharacterization",3rd Edition, WileyPublishers, 2006.*

18HU602 CAREER COMPETENCY I Credits: Pass/Fail

LEARNING OUTCOME:

- Effectively improve employability in the professional world. Gives training to assist the student to prepare for interviews

SYLLABUS:

Soft Skills

Introduction to 'campus to corporate transition':
Communication and listening skills: communication process, barriers to communication, verbal and non-verbal communications, elements of effective communication, listening skills, empathetic listening, role of perception in communication.
Assertiveness skills: the concept, assertiveness and self-esteem, advantages of being assertive, assertiveness and organizational effectiveness.
Self-perception and self-confidence: locus of control (internal v/s external), person perception, social perception, attribution theories-self presentation and impression management, the concept of self and self-confidence, how to develop self-confidence.

Goal setting: the concept, personal values and personal goals, goal setting theory, six areas of goal setting, process of goal setting: SMART goals, how to set personal goals
Time management: the value of time, setting goals/ planning and prioritizing, check the time killing habits, procrastination, tools for time management, rules for time management, strategies for effective time management
Presentation skills: the process of presentation, adult learning principles, preparation and planning, practice, delivery, effective use of voice and body language, effective use of audio visual aids, dos and don'ts of effective presentation
Public speaking-an art, language fluency, the domain expertise (Business GK, Current affairs), self-confidence, the audience, learning principles, body language, energy level and conviction, student presentations in teams of five with debriefing

Verbal

Vocabulary building: introduction to the methods and practices of learning vocabulary, learning through practice sets to face questions on antonyms, synonyms, spelling error, analogy, wrong form of words, frequently confused words, understanding the nuances of spelling changes and wrong use of words.

Grammar: Analyzing subject verb agreement, pronoun agreement, tense consistency, and misplaced or dangling modifiers, parallel construction, active and passive voices, faulty comparison

Students take a few online practice tests to understand the test taking strategy and work on their specific areas of improvement.

Aptitude

Introduction to numbers – number line, classification of numbers, prime and composite numbers, co-prime numbers, number of zeros in an expression, LCM, HCF, remainder theorem, rules of divisibility, base system

Basics of equations- introduction to simple and quadratic equations, roots of an equation, word problems, problems on ages, consistency of equations

Percentages, profit and loss: introduction to percentages, percentage change, value appreciation and depreciation, comparison observations, fundamentals concepts of business/commercial terminologies like cost price, selling price, profit, loss, marked price and discount

Ratio proportion and variation/partnership – fundamentals of ratios, duplicate ratio, triplicate ratio, sub duplicate ratio and sub triplicate ratio, direct and inverse proportion, joint variation, partnership and profit sharing

Averages and mixtures – mean, median and mode, measure of central tendency, concept of assumed average and weighted average, AM, GM and HM – relationship between AM, GM and HM, cheaper quantity and dearer quantity, rule of allegation, profit v/s quality of items getting mixed.

Simple interest and compound interest – time value of money, capital/principle, period of

investment, rate of return, period of compounding, SAGR and CAGR

Data interpretation – representation of data using tables, bar charts, pie charts, case study, line graph, scatter diagram – analyzing the data for decision making

Venn diagrams- set theory – concept of sets, types of set, forms of set representation, power set, sub set and super set, 2 and 3 variable venn-diagrams, familiarity with words like AND, OR, atleast, atmost, exactly 'n' elements

Cubes – importance of aligning cuts to minimize/maximize the number of pieces of small cubes, painting a cube and cutting the cube, disintegration and integration of cubes, diagonal cutting, volume/LSA/TSA of cubes

References

Communication and listening skills:

- Andrew J DuRbin , "Applied Psychology: Individual and organizational effectiveness", Pearson- Merril Prentice Hall, 2004
- Michael G Aamodt, "An Applied Approach, 6th edition", Wadsworth Cengage Learning, 2010

Assertiveness skills:

- Robert Bolton, Dorothy Grover Bolton, "People Style at Work..and Beyond: Making Bad Relationships Good and Good", Ridge Associates Inc., 2009
- John Hayes "Interpersonal skills at work", Routledge, 2003
- Nord, W. R., Brief, A. P., Atieh, J. M., & Doherty, E. M., "Meanings of occupational work: A collection of essays (pp. 21- 64)", Lexington, MA: Lexington Books, 1990

Self-perception and self-confidence:

- Mark J Martinko, "Attribution theory: an organizational perspective", St. Lucie, 1995
- Miles Hewstone,"Attribution Theory: Social and Functional Extensions", Blackwell, 1983

Time management:

- Stephen Covey, "The habits of highly effective people", Free press Revised edition, 2004
- Kenneth H Blanchard ,"The 25 Best Time Management Tools & Techniques: How to Get More Done Without Driving Yourself Crazy" , Peak Performance Press, 1st edition 2005
- Kenneth H. Blanchard and Spencer Johnson, "The One Minute Manager", William Morrow, 1984

Verbal

- Lewis Norman, “Word Power Made Easy”, Goyal Publishers, Reprint edition, 1 June 2011
- S. Upendran, “Know Your English”, Universities Press (India) Limited, 2015
- Green, Sharon, and Ira K. Wolf, “Barron's New GRE”, Barron's Educational Series, 2011
- Kaplan, “New GMAT Premier”, Kaplan Publishing, U.K., 2013
- www.merriam-webster.com
- www.bbc.co.uk/learningenglish
- www.cambridgeenglish.org

Aptitude

- Arun Sharma, “How to Prepare for Quantitative Aptitude for the CAT Common Admission Test”, Tata Mc Graw Hills, 5th Edition , 2012
- Arun Sharma, “How to Prepare for Logical Reasoning for the CAT Common Admission Test”, Tata Mc Graw Hills, 2nd Edition, 2014
- Arun Sharma, “How to Prepare for Data Interpretation for the CAT Common Admission Test”, Tata Mc Graw Hills, 3nd Edition, 2015
- R.S. Aggarwal, “Quantitative Aptitude For Competitive Examinations”, S. Chand Publishing, 2015
- R.S. Aggarwal, “A Modern Approach To Verbal & Non-Verbal Reasoning”, S. Chand Publishing, Revised -2015
- SarveshVerma, “Quantitative Aptitude-Quantum CAT” , Arihant Publications, 2016
- www.mbatious.com
- www.campusgate.co.in
- www.careerbless.com

SECOND SEMESTER

18NT630 CHEMICAL THERMODYNAMICS 3-0-0-3

LEARNING OUTCOMES:

- Develop basic knowledge in heat, energy and interaction with materials.
- Learn thermodynamic laws and their applications in various systems.
- Understand phase rule/phase diagrams
- Gain knowledge in the temperature assisted chemical reactions.

SYLLABUS:

Laws of thermodynamics, work, heat, internal energy, enthalpy, entropy, Gibbs and Helmholtz free energy, chemical potential, physical and chemical equilibrium, phase equilibria (one and two components), equilibria of chemical reaction, thermodynamics of mixtures. The phase rule and phase diagram.thermodynamics of osmosis and reverse osmosis.

TEXT BOOKS/REFERENCES:

1.*E.Keszei, Chemical thermodynamics: An Introduction, Springer,2012.*
2.J.M. Smith, Hendrick Van Ness, Michael Abbott and Mark Swihart, Introduction to Chemical engineering thermodynamics, McGraw hill, 8 Edition.2018
3.H. Devoe, Thermodynamics and Chemistry, Prentice hall, 2nd Edition, 2016.

18NS625 CHARACTERIZATION OF NANOMATERIALS 3-0-0-3

LEARNING OUTCOMES:

Upon successful completion, students will have the knowledge and skills to:

- *Diffraction data analysis (especially X-ray diffraction) for identification of crystal structure of nanomaterials and thin-films*
- *Understanding working principles and analysis of size, topography and morphology analysis of nanomaterials based on SEM/TEM and scanning probe microscopies (AFM and STM).*
- *Understand fundamentals of spectroscopy techniques and nanomaterials chemical analysis using Micro-wave, IR and X-ray photoelectron spectroscopies*

SYLLABUS:

X-ray diffraction and Reciprocal lattice, Bragg's law, Ewald'ssphere construction, XRD of nanolayers, effects of nanosize and shape anisotropyofnanostructures, texture and strain measurements, SEM: scattering of electrons, secondary and backscattered electrons, electron sources, imaging modes in SEM and its use for nanomaterials size and shape analysis, TEM: Interaction of high energy electrons with matter, elastic and inelastic scattering, TEM instrumentation, imaging and diffraction modes of operation, imaging and contrast in TEM, HRTEM, Energy dispersive analysis of x-rays, Nanomaterials size and size distribution analysis, shape and structural analysis, SPM: Principle of operation, contact and non-contact AFM, dynamic force microscopy, and various other modes of SPM including STM. Chemical Characterization – Optical Spectroscopy, IR spectroscopy: vibrational modes, theory of IR spectroscopy, infrared spectrometers, single and group frequencies, advantages of FTIR. Raman spectroscopy, surface enhanced Raman spectroscopy, X-ray photoelectron spectroscopy.Use of these techniques for nanomaterials and biomaterials analysis.

TEXT BOOKS / REFERENCES:

1. Harold P. Klug and Leroy E. Alexander, "X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials", Second Edition, Wiley-Interscience, 1974

2. C. N. Banwell and E. McCash, Fundamentals of Molecular Spectroscopy, McGraw Hill Education (2017).

3. N. Yao and Z. L. Wang, Handbook of Microscopy for Nanotechnology, Springer Science and Business Medi (2005).

18NT623 ENERGY CONVERSION SCIENCE AT NANOSCALE 3-0-0-3

LEARNING OUTCOMES:

- Able to determine band structure alignment at material interfaces
- Gain ability to assess quality of functional materials in terms of light-matter interaction.
- Acquire knowledge on various loss mechanisms in photovoltaic devices.
- Able to estimate photovoltaic performance and its limiting factors based on quality of materials.
- Assess physical properties of materials and make decision on their application in energy conversion devices.

SYLLABUS:

Basics of Energy Conversion Science:
Introduction: need for energy-types of energy-sources of energy-energy consumption, Functional materials: semiconductors-dielectrics-metals-transparent conductors, work function-bandgap-electron affinity-mobility-conductivity, absorption and their influence in device design, Photovoltaics: basic principles-Physics of electronic junctions: pn-pin-metal/semiconductor-Shockley–Queisser limit-band energy analysis-electrical and optical characteristics of solar cells: I-V, EQE, CV, and V_{OC} decay, wafer and thin film based solar cells: homojunction-heterojunction- Schottky barrier-tunnel junction-tandem structure-carrier transport and loss mechanisms, recombination models-anti-reflective coating-surface texturing,

excitonic solar cells.

Energy conversion in nanoscale structures: size effects in light-matter interactions, 0D, 1D and 2D quantum confined functional materials for energy conversion, size driven advantages and disadvantages of functional materials in devices, charge carrier dynamics at nanoscale in energy conversion devices.

TEXT BOOKS/REFERENCES:

1. *Jenny Nelson, "The Physics of Solar Cells", First Edition, Imperial College Press, 2003.*
2. *Stephen Fonash, Solar Cell Device Physics - 2nd Edition, Academic Press,2010*

18NT624 THIN FILM SCIENCE AND TECHNOLOGY 3-0-0-3

LEARNING OUTCOMES:

- Understand various thin film processing including wet-chemical, PVD and CVD methods.
- Gain knowledge in vacuum science and technology.
- Able to establish relationship between process and materials.
- Develop new applications in thin films science.

SYLLABUS:

Vacuum science and technology: kinetic theory of gasses, gas transport and pumping, vacuum systems, physical vapor deposition: process and systems, thermal evaporation, electron beam evaporation, sputtering (DC, RF magnetron) chemical vapor deposition, film formation and nanostructure, characterization of thin films, epitaxial quantum systems, applications of thin films in nanotechnology.

TEXT BOOKS / REFERENCES:

1. *Handbook of Thin Film Technology, H. Frey and H. R. Khan, Springer Science and Business Media (2015)*
2. *The Materials Science of Thin Films, Milton Ohring, Academic Press(2002).*

18NT631 NANOPHOTONICS 3-0-0-3

LEARNING OUTCOMES:

- Acquire knowledge light-matter interaction in functional nanoscale materials.
- Learn the effect of nano-confinement of light in materials.
- Get fundamental ideas of plasmonics and develop devices based on the surface plasmon effect.
- Learn metamaterials and their applications in nanoplasmonics.

Review of vector analysis, electrostatics, electric fields in matter, magnetostatics, magnetic field in matter, electrodynamics, light-matter interactions, concepts and devices in nanoscale

optics and photonics. Nano-scale and near-field optics, near-field optical probes, quantum confined materials, plasmonics, photonic crystals, silicon, graphene and diamond photonics, metamaterials, nanolasers, single-photon sources.

TEXT BOOKS / REFERENCES:

1. J. W. Haus, "Fundamentals and Applications of Nanophotonics", Woodhead Publishing, 2016.

2. S. V. Gaponenko, "Introduction to Nanophotonics", Cambridge University Press, 2010.

3. Introduction to Electrodynamics, David J Griffiths, 3rd edition, 1999.

18NT625 ENERGY STORAGE SCIENCEAT NANOSCALE 3-0-0-3

LEARNING OUTCOMES:

- Gain basic knowledge on electrochemical principles and kinetics of reactions.
- Learn non-Faradaic and Faradaic reaction.
- Develop knowledge in nanomaterials as anode and cathode for batteries and electrochemical capacitors.
- Get introduced to solid state batteries and fabrication procedure.

SYLLABUS:

Introduction to electrochemistry, potentials and thermodynamics of cells, galvanic and electrolytic cells, kinetics of electrochemical reactions, mass transfer by migration and diffusion, non-Faradaic and Faradaic reactions, nanomaterials as anode and cathode for batteries and electrochemical capacitors, advanced batteries with nanoscale materials and surface/interface modifications, liquid and solid electrolytes, cycle-life, capacity, energy and power density assessments, safety concerns and solutions. Electrochemical methods: potentiostatic and galvanostatic, cyclic voltammetry, chronoamperometry, chronopotentiometry and electrochemical impedance.

Textbooks/References:

1. L. R. Martinez and N. Omar, Emerging Nanotechnologies in Recahrgeable Energy Storage Systems, 1st Edition, Elsevier (2017).

2. G. A. Nazri and G. Pistoia, Lithium Batteries, Springer, 2009.

3. Allen Bard and Larry R. Faulkner, Electrochemical Methods, John Wiley & Sons Inc, 2001.

18NS629 LAB: NANOMATERIALS LAB-II 1-0-2-3

LEARNING OUTCOMES:

Students who complete the course will have demonstrated the following:

- *Understand the synthesis of polymeric nanoparticles and the role of reaction parameters that varies the particle size*

- *Understand the principles of Dynamic Light Scattering technique in estimating the particle size and zeta potential. How zeta potential is related to the particle stability*
- *Understand the basics of vibrational spectroscopy (FTIR & Raman) in characterizing samples and how the spectral data can be interpreted.*
- *Understand the electrospinning technique and parameters that influence the formation of micro and nano sized fibers.*
- *Understand the thermal and mechanical characterization of polymeric samples*
- *Understand the basics of XRD in characterizing crystalline and amorphous samples.*

SYLLABUS:

1. Polymeric Nanoparticles: Synthesis of alginate nano and micro particles; characterization of particle size by Dynamic Light Scattering (DLS) and Zeta analysis
2. Fourier Transform Infra-red Spectroscopy(FTIR): Preparation of Chitosan Nanoparticles and characterization using FTIR
3. Electrospinning: Fabrication of electrospun PVA nanofibres and microfibers; characterization of fibers morphology and diameter using SEM
4. Thermal characterization of polymers using Thermogravimetric – Differential thermal Analysis (TGA-DTA)
5. X-ray diffraction spectrometer (XRD): Structural characterization of crystalline and amorphous nanomaterials
6. Raman spectroscopy: Characterization of polymeric and inorganic samples using Raman Spectroscopy
7. Mechanical Testing and Rheology: Characterization of materials mechanical properties by studying stress-strain curve.

18NT626 LAB: ENERGY DEVICES LAB 0-0-2-2

LEARNING OUTCOMES:

- Acquire hands on experience in Dye sensitized solar cell fabrication and testing.
- Knowledge in thin film heterojunction photovoltaic device fabrication and testing.
- Fabricate and study Quantum dot solar cell fabrication and testing.
- Learn fabrication of Li ion battery anode and cathode half-cell fabrication and testing.
- Get expertise in Li ion battery full-cell fabrication and testing.
- Fabricate and study Supercapacitor/Pseudocapacistor.

SYLLABUS:

1. Dye sensitized solar cell fabrication and testing.
2. Thin film heterojunction photovoltaic device fabrication and testing.
3. Quantum dot solar cell fabrication and testing.
4. Li ion battery anode and cathode half-cell fabrication and testing.
5. Li ion battery full-cell fabrication and testing.

6. Supercapacitor/Pseudocapacistor fabrication and testing.

18HU603 CAREER COMPETENCY II Credits: 1-0-0-1

LEARNING OUTCOME:

- To provide skills and techniques to clear and interview to get employed.
- Gives training to assist the student to prepare resumes and attending of interviews

SYLLABUS:

Soft Skills

Interpersonal skill: ability to manage conflict, flexibility, empathetic listening, assertiveness, stress management, problem solving, understanding one's own interpersonal needs, role of effective team work in organizations

Group problem solving: the process, the challenges, the skills and knowledge required for the same.

Conflict management: the concept, its impact and importance in personal and professional lives, (activity to identify personal style of conflict management, developing insights that helps in future conflict management situations.)

Team building and working effectively in teams: the concept of groups (teams), different stages of group formation, process of team building, group dynamics, characteristics of effective team, role of leadership in team effectiveness. (Exercise to demonstrate the process of emergence of leadership in a group, debrief and reflection), group discussions.

Interview skills: what is the purpose of a job interview, types of job interviews, how to prepare for an interview, dos and don'ts of interview, One on one mock interview sessions with each student

Verbal

Reasoning: Introduction to higher order thinking skills and deductive reasoning through critical thinking and syllogisms exercises. Students are trained to think critically and analyze an argument critically. They practice these skills extensively.

Logical ordering of sentences: to improve logical thinking and ability to put ideas cohesively.

Reading comprehension: intermediate & advanced level reading passages are provided to the students for practice. Students are taught techniques to read a dense passage in a fast & accurate manner.

Punctuation and e-mail writing: students hone their e-mail writing skills and are taught the essentials of punctuation and e-mail etiquette.

Aptitude

Time and distance: speed, distance, displacement, relative speed, average speed, races, boats and streams-upstream and down-stream movement, problems on trains, concept of relative speed, motion in circular track – clockwise and anti-clockwise rotations

Time and work- unitary method, concept of man-days, efficiency in task completion, sharing of wages proportionately, questions on pipes and cisterns

Geometry, mensuration-line/ray/angles, length of segments, area and properties of geometrical figures, properties of angles, diagonals, LSA, TSA and volume of solids

Seating arrangements/ puzzles- linear arrangements, circular arrangements, selection, comparison and distribution of objects under given constraints, analysing given constraints and present definitive or probable solutions for a given problem.

Permutations and combinations- fundamental principle of counting-selection and arrangement of objects, factorial notations, permutations with/without repetition, rank of a word, sum of all permutations, team formation with certain constraints

Probability- chances, odds in favour and odds against favour, events-independent and mutually exclusive types, conditional probability
Nonverbal reasoning – picture based series, mirror image, water image, paper folding, paper cutting, grouping of figures, figure matrix

Quant Based Reasoning – case study, application oriented problems

References

Team Building

- Thomas L.Quick, "Successful team building", AMACOM Div American Mgmt Assn, 1992
- Brian Cole Miller, "Quick Team-Building Activities for Busy Managers: 50 Exercises That Get Results in Just 15 Minutes", AMACOM; 1 edition, 2003.
- Patrick Lencioni, "The Five Dysfunctions of a Team: A Leadership Fable", Jossey-Bass, 1st Edition, 2002

Verbal

- Kaplan GMAT 2012 & 13
- www.campusgate.co.in
- www.indiabix.com
- www.bristol.ac.uk/arts/skills/grammar/grammar_tutorial/page_55.htm

Aptitude

- Arun Sharma, "How to Prepare for Quantitative Aptitude for the CAT Common Admission Test", Tata Mc Graw Hills, 5th Edition, 2012
- Arun Sharma, "How to Prepare for Logical Reasoning for the CAT Common Admission Test", Tata Mc Graw Hills, 2nd Edition , 2014
- Arun Sharma, "How to Prepare for Data Interpretation for the CAT Common Admission Test", Tata Mc Graw Hills, 3nd Edition , 2015
- R.S. Aggarwal, "Quantitative Aptitude For Competitive Examinations", S. Chand Publishing , 2015
- R.S. Aggarwal, "A Modern Approach To Verbal & Non-Verbal Reasoning", S. Chand Publishing , Revised -2015
- SarveshVerma, "Quantitative Aptitude-Quantum CAT" , Arihant Publications , 2016
- www.mbatious.com
- www.campusgate.co.in
- www.careerbless.com

THIRD SEMESTER

18RM601 ETHICS IN RESEARCH AND RESEARCH METHODOLOGY 1-0-1-2

LEARNING OUTCOMES:

Students on completion of this course will –

- *Understand the basic concepts of ethics in proper conduct of research*
- *Understand about plagiarism in research and how it should be avoided*
- *Gain a clear idea about the importance of proper data documentation*
- *Students will have a clear idea about the research methodologies that need to be adopted during their research*

SYLLABUS:
Plagiarism, regulatory principles, safety in research, ethics in stem cell research, ethics in clinical research, ethics in nanomaterials based research

Principles of data documentation, protocol development, research questions and hypothesis driven research, technical writing fundamentals

TEXTBOOK:

1. Research Ethics for Scientists, C. Neal Stewart Jr., Wiley-Backwell Publishers, 2011
2. Ethics in Science, Ethical Misconduct in Scientific Research, John D'Angelo, CRC Press, 2012.

18NT627 INTRODUCTION TO NANODEVICE FABRICATION 3-0-0-3

LEARNING OUTCOMES:

- Learn energy band analysis of metal semiconductor junctions.
- Learn nanoscale device making process such as lithography.
- Understand the effects of nano into device operating principles.
- Able to estimate the device performance based in approbriat models.

SYLLABUS:

Introduction to nanodevices - methods and techniques; scaling effects; concepts of micro-/nano-physics for design and analysis; Lithography: optical and e-beam lithography, projection printing; soft lithography, replication, embossing/nanoimprint, focused ion beams,nano-electronics; nano-sensors; micro-/nano-electromechanical systems; fabrication and testing; key advances in the recent years especially about fabrication and testing of nanodevices.

TEXT BOOKS/REFERENCES:

1. *Z. Cui, Nanofabrications: Principles, capabilities and limits, Springer (2017).*

2. *T. Li and Z. Liu, Outlook and challenges in Nanodevices, Sensors and MEMS, Springer (2017).*

18NT628 NANOMATERIALS FOR HYDROGEN STORAGE AND CARBON CAPTURE3-0-0-3

LEARNING OUTCOMES:

- Realize the essential requirement of hydrogen.
- Learn labscale hydrogen storage systems.
- Lean metal oxides and hydrides for hydrogen storage
- Understand the essential requirement for carbon capture.
- Develop functional materials CO_2 capture using adsorption and absorption.

SYLLABUS:

Hydrogen energy - Hydrogen: Its merit as a fuel, Hydrogen storage methods - Metal hydrides, Intermetallic hydrides, complex hydrides, Physisorption of hydrogen on porous materials. thermodynamics and kinetics of metal hydrides, tailoring reaction enthalpy of hydrides, nanoparticles for hydrogen storage. nanoparticles in 3D support. Various methods of nanomaterial synthesis, Carbon based materials for hydrogen storage. Introduction to climate change and issues related to greenhouse gas emissions, CO_2 capture-post and pre combustion capture, oxy fuel combustion, CO_2 capture using adsorption and absorption materials, advantage of metal oxide based nanomaterials for CO_2 capture.

TEXT BOOKS / REFERENCES:

1. *Handbook of Hydrogen Storage: New Materials for Future Energy Storage edited by Michael Hirscher, Wiley-2010.*
2. *Nanomaterials for solid state hydrogen storage-Robert A. Varin, springer 2007.*
3. *Introduction to carbon capture and sequestration, The Berkeley lectures on energy-vol 1, Berendsmit, imperial college press, 2014.*