M.TECH. - NANOTECHNOLOGY AND RENEWABLE ENERGY

This is a two year course in Nanotechnology & Renewable Energy Technologies with an application focus on product development in energy conversion and storage devices. The course is designed as per the guidelines of the Make in India and Skill Development programs of the Government of India. There are basic foundation courses in nanomaterials and properties, followed by subject core courses dealing with product development, energy conversion, storage, energy management and international policies.

CURRICULUM

Course Code	Type	Course	L T P	Credits
First Semester				
16NS601	FC	Research Methodology and Statistics	2 0 0	2
16NS602	SC	Science and Properties Of Nanomaterials	3 0 0	3
16NT601	FC	Introduction to Quantum Mechanics	3 0 0	3
16NT602	FC	Social Responsibility and Translation	2 0 0	2
16NT603	SC	Energy Conversion Devices	3 0 0	3
	E	Elective - I	3 0 0	3
16HU601		Cultural Education*		P/F
*Non-credit Course				
Second Semester				
16NT604	SC	Power Electronics for PV and Storage	3 0 0	3
16NT605	SC	Energy Storage Devices	3 0 0	3
16NT606	SC	Product Development 1	2 0 2	4
16NT797	P	Dissertation		3
	E	Elective – II	3 0 0	3
			Total in 1st & 2nd Semester	**32**

Course Code	Type	Course	L T P	Credits
Third Semester				
16NT607	SC	Nanodevice Fabrication	3 0 0	3
16NT608	SC	Product Development 2	2 0 2	4
16NT798	P	Dissertation		6
	E	Elective – III	3 0 0	3
16HU602	HU	Technical writing and Presentation*		P/F
*Non-credit Course				
Fourth Semester				
16NT609	SC	Advanced Thermodynamic Engines	3 0 0	3
16NT799	P	Dissertation		13
			Total in 3rd& 4th Semester	**32**

Total credits : 64

Electives

Course Code	Course	L T P	Credits
First Semester			
16NT701	Energy Economics and Public Policy	3 0 0	3
16NT702	User interface Design	3 0 0	3
16NT703	Leadership in Energy and Environmental Design	3 0 0	3
16NT705	Physics of Semiconductors	3 0 0	3
Second Semester			
16NT704	Energy Management and Energy Audit	3 0 0	3
16NS603	Nanomaterials - Chemistry and Design	3 0 0	3
16NS606	Characterization of Nanomaterials	3 0 0	3
Third Semester			
16NT707	Hydrogen Storage and Carbon Capture Technologies	3 0 0	3
16NT708	Test, Validation and Reliability Engineering	3 0 0	3
16NT709	Embedded Systems Design	3 0 0	3

16NS601 RESEARCH METHODOLOGY AND STATISTICS 2-0-0-2

Theory of probability and Standard Distributions- Probability: Random experiment, Sample space, Events, Mutually exclusive and exhaustive events, Frequency and classical definition of probability, Axiomatric definition of probability, Addition and multiplication theorems, Conditional probability and independence , Bye's theorem Random Variables and Probability Distributions :- Definition of discrete and continuous random variables, Probability density functions and distribution functions, Standard univariate discrete distributions – Binomial, poisson& Negative Binomial, Standard univariate continuous distributions – Normal, Log normal & Exponential. Sampling distributions – Chi- square distribution and F & 't' distributions. Logic of Statistical Inference- Concept of 'statistic' and 'parameter', Estimators and its properties, point and Interval estimation of parameters, Confidence intervals, concepts of standard error Principles of test of significance, Bayesian Inference Methods.

Methods of tests of Significance 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.

TEXT BOOKS/REFERENCES:

1. *Wayne C. Booth, Gregory G. Colomb and Joseph M. Williams, "The Craft of Research", Third Edition, University Of Chicago Press, 2008.*
2. *John W. Creswell, "Research Design: Qualitative, Quantitative, and Mixed Methods Approaches",Second Edition, SAGE Publications, 2002.*
3. *C.R. Kothari, "Research Methodology", NEW AGE, 2013*

16NS602 SCIENCE AND PROPERTIES OF NANOMATERIALS 3-0-0-3

Materials classification by bonding, amorphous and crystalline materials, crystal lattices, Miller indices, Bragg's Law, Defects in crystal structure, principles of dislocations, theory of diffusion, mechanical properties, phase diagrams, polymeric materials, composite materials, corrosion, electrical and optical properties, types of nanomaterials, 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, carbon-based nanomaterials.

TEXT BOOKS/REFERENCES:

1. *Nanomaterials – An introduction to synthesis, properties and applications, D. Vollath, Wile-VCH, Second Edition, 2013.*
2. *Charles Poole and Frank Owens, "Introduction to Nanotechnology", First Edition, John Wiley India, 2006.*
3. *Hari Singh Nalwa, "Encyclopedia of Nanotechnology", Second Edition, American Scientific Publishers, 2004.*

16NT601 INTRODUCTION TO QUANTUM MECHANICS 3-0-0-3

Introduction: Failures of classical mechanics, Postulates of quantum mechanics; particle and waves, Heisenberg uncertainty principle, Bohr model of atom, atomic orbital theory, density of states, Pauli exclusion principle, black body radiation, Photons: the quantization of light, wave particle duality, Double slit experiment and its significance, Stern Gerlach experiment and its significance, de Broglie's wavelength theory and derivation, The hydrogen atom: The Rutherford-Bohr atom, The quantum atom, Schrödinger's wave equation- Introduction to Schrodinger equation for free particle in one dimension, Barrier tunneling, linear harmonic oscillator, quantum confinement theory based on nanostructures, applications of quantum mechanics in nanostructures.

TEXT BOOKS/REFERENCES:

1. *Arthur Beiser, "Concepts of Modern Physics", Seventh Edition, McGraw Hill Education, 2015.*
2. *Ajoy K.Ghatak and S. Lokanathan,"Quantum Mechanics, Theory and Applications", Springer, 2004.*
3. *V. K. Thankappan,"Quantum Mechanics", New Age International, 2012.*

16NT602 SOCIAL RESPONSIBILITY AND TRANSLATION 2-0-0-2

This is a course where students need to identify a social need, design and develop a solution for the social need, deploy the solution and document the results. Ideally, a village should be chosen and a team of not more than four students should visit the village, study and analyze their need set. Then they have to debate about how to solve one of the issues faced by the villagers and provide a solution to the problem.

The primary purpose of the course is to engage the students with the real needs of rural India and to develop a mindset of servicing the poor and needy.

A field manual will be provided which will be updated on a regular basis and should be submitted at the end of the course. The evaluation will be based on the updated filed manual and a presentation by the team.

16NT603 ENERGY CONVERSION DEVICES 3-0-0-3

Fundamentals of solar cells: types of solar cells, semiconducting materials, band gap theory, absorption of photons, excitons and photoemission of electrons, band engineering; Single junction and triple-junction solar panels, metal-semiconductor heterojunctions, and semiconducting materials for solar cells.

Single crystal, thin film deposition, polycrystalline and amorphous silicon solar cells, CIGS, and CdTe thin-film cells, conversion efficiency; solar cell manufacturing processes: material resources, chemistry, and environmental impacts; low cost manufacturing processes

Current trends in photovoltaic research and applications; nanotechnology applications; Basic characterization techniques. Current-voltage measurements and Incident photon to current efficiency (IPCE).

Dye sensitized solar cells (DSSCs); QDs based solar cells; polymer solar cells; organic solar cells; perovskite solar cells; flexible solar cells;

Shockley–Queisser limit; Mechanisms; Key efficiency parameters; Substrates; Procedure for the preparation; Examples of dyes for photosensitization; Electrolytes for DSSC; Solid state DSSC. Hole transport material; Influence of additives on the solar cell performance; Influence of chemical doping on conductivity and hole mobility. State of the art in emerging energy conversion devices.

TEXT BOOKS/REFERENCES:

1. *SuneelDeambi, "Solar PV Power: A Global Perspective", The Energy and Resource Institute, 2011.*
2. *Aldo V. da Rosa , "Fundamentals of Renewable Energy Processes", Second Edition, Elsevier Academic Press, 2009.*
3. *Martin A. Green, "Solar Cells: Operating Principles, Technology, and System Approaches", First Edition, Prentice-Hall, 1998.*
4. *Jenny Nelson, "The Physics of Solar Cells", First Edition, Imperial College Press, 2003.*
5. *Chetan Singh Solanki,"Solar Photovoltaics: Fundamentals, Technologies and Applications", Third Revised Edition, Prentice Hall India Learning Private Limited, 2015.*
6. *Chetan Singh Solanki,"Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and Engineers", Prentice Hall India Learning Private Limited, 2013.*

7. *K.Kalyanasundaram,"Dye Sensitized Solar Cells", EPFL Press Distributed by CRC Press, 2010.*
8. *Antonio Luque, Steven Hegedus,"Handbook of Photovoltaic Science and Engineering", Second Edition, John Wiley & Sons, Ltd, 2011.*
9. *M.A. Green,"Third Generation Photovoltaics: Advanced Solar Energy Conversion", 2003 Edition, Springer, 2003.*
10. *C.J. Brabec,"Organic Photovoltaics: concepts and realization", 2003 Edition, Springer, 2003.*
11. *B. von Roedern, H.S. Ullal, and K. Zweibel,"Polycrystalline Thin-film Photovoltaics: from the laboratory to solar fields", 2006.*
12. *S.R. Wenham,"Applied Photovoltaics", Routledge, 2006.*

16NT604 POWER ELECTRONICS FOR PV AND STORAGE 3-0-0-3

PV cell interconnection, module structure and module fabrication, equivalent circuits, load matching, efficiency, fill factor and optimization for maximum power, design of stand-alone PV systems, system sizing, device structures, device construction, installation, measurements, DC to AC conversion, charge controllers, MPPT

Grid tie topologies, MPPT algorithms, converter topologies, ripple management, control schemes of converters, simulation techniques, high side driving, optical isolated drivers, converter protection, EMI & EMC management, common mode and differential mode inductor design

Modeling and Control of power converters, modeling and simulation of PV Inverter topologies, interleaved converters, its control and simulation, advanced double-carrier based SPWM Control

Wires: Basics, types, measurements of wire dimensions, wire sizing, junction box, inverters, on-site storage and grid connections, planning regulations and approval, installation, troubleshooting, safety, protection and switchgear for PV systems

LED lighting systems, linear drivers, HV LED systems, switch mode drivers for LED systems, control, thermal management and safety

TEXT BOOKS/REFERENCES:

1. *SanjayaManiktala, "Switching Power Supplies A to Z", Newnes, 2006.*
2. *Michael Boxwell,"Solar Electricity Handbook 2014: A Simple Practical Guide to Solar Energy - Designing and Installing Photovoltaic Solar Electric Systems", Eighth Edition, Greenstream Publishing, 2013.*
3. *Geoff Stapleton,"Grid-connected Solar Electric Systems: The Earthscan Expert Handbook for Planning, Design and Installation", Routledge, 2011.*

4. *Fang Lin Luo,"Advanced DC/AC Inverters: Applications in Renewable Energy (Power Electronics, Electrical Engineering, Energy, and Nanotechnology)", CRC Press, 2013.*
5. *Fang Lin Luo, "Power Electronics: Advanced Conversion Technologies", CRC Press, 2010.*

16NT605 ENERGY STORAGE DEVICES 3-0-0-3

Thermodynamics and kinetics of electrochemical reactions including phase transitions; electrochemical methods – constant current constant voltage charge/discharge; impedance spectroscopy and cyclic voltammetry. Principle of battery, power and energy characteristics; advanced and emerging battery systems (such as, Li-S & Li-air); Nanostructured materials for Li-ion batteries; Battery operation under extreme conditions; principles of supercapacitors technology; difference between batteries and supercapacitors. Scale-up Technologies; Safety and Hazard controls; Lab component: making batteries and supercapacitor making, teaching scale-up and safety issues.

TEXT BOOKS/REFERENCES:

1. *A J Bard and L R Faulkner, "Electrochemical methods: Fundamentals and Applications", Second Edition, John Wiley and Sons, 2002.*
2. *B Conway,"Electrochemical supercapacitors: Scientific Fundamentals and Technological Applications", 1999 Edition, Springer, 1999.*

16NT606 PRODUCT DEVELOPMENT 1 2-0-2-4

Concept selection: Structured method for concept selection, Overview of methodology, Concept screening, Concept scoring, Caveats.

Concept testing: defining the purpose of the concept test, survey population, survey format, communicating the concept, measuring customer response, interpreting the results.

Product architecture: Definition, Implication of the architecture, establishing the architecture, Delayed differentiation, Platform planning, Related system level design issues.

Sustainable life cycle model for products, stage gate product development methodology, new concepts for managing product development, TRIZ method

Hands on product development training in selected areas from the following. Solar PV, energy storage, power electronics, energy management, analog and digital electronics, embedded

systems, front end software, material processing, characterization, test and validation, data analysis and reporting.

TEXT BOOKS / REFERENCES:

1. *Gerhard Pahl, "Engineering Design: A Systematic Approach", Third Edition, Springer, 2009.*
2. *James G. Bralla, "Design for Excellence", McGraw-Hill, 1999.*
3. *Karl T Ulrich "Product Development Process", Fourth Edition, McGraw-Hill.*
4. *Victor Papanek, "Design for the real world: Human ecology and social change", Second Edition, Academy Chicago Publishers, 1985.*
5. *Kevin Henry, "Drawing for Product designers", Laurence King Publishing, 2012.*
6. *Edward Crawley, "Strategy and Product development for complex systems", Prentice Hall, 2015.*

16NT607 NANODEVICE FABRICATION 3-0-0-3

Introduction to nanofabrication methods and techniques; scaling effects; concepts of micro-/nano-physics needed for design and analysis; nano-electronics; nano-sensors; nano-electromechanical systems; fabrication, testing and metrology methods employed for micro-/nano-systems; key advances in the recent years especially about fabrication and testing of nanodevices; hands-on component for the students to design, fabricate and test nano-scale devices.

TEXT BOOKS/REFERENCES:

1. *Fahrner Wolfgang, "Nanotechnology and Nanoelectronics", First Edition, Springer, 2005.*
2. *Yugang Sun, "Semiconductor Nanomaterials for Flexible Technologies", First Edition, Elsevier, 2010.*
3. *Waqar Ahmed and Mark Jackson, "Emerging Nanotechnologies for Manufacturing" First Edition, Elsevier, 2009.*

16**NT608 PRODUCT DEVELOPMENT 2 2-0-2-4**

Industrial design: definition, Assessing the need & Impact of industrial design, Industrial design process, Management, Assessing the quality

Design for manufacture: Definition, Step I-Estimating the manufacturing cost, Step II-To reduce the cost of components, Step III-Reduce the cost of assembly, Step IV-reduce the cost of supporting, Step V-Consider the impact of DFM decisions on other factors

Prototyping: Understanding prototypes, Principles of prototyping, Prototyping technologies, planning for prototypes.

Patents and Intellectual property, Product development economics,

TEXT BOOKS / REFERENCES:

1. *Gerhard Pahl, "Engineering Design: A Systematic Approach", Third Edition, Springer, 2009.*
2. *James G. Bralla, "Design for Excellence", McGraw-Hill, 1999.*
3. *Karl T Ulrich "Product Development Process", Fourth Edition, McGraw-Hill.*
4. *Victor Papanek, "Design for the real world: Human ecology and social change", Second Edition, Academy Chicago Publishers, 1985.*
5. *Kevin Henry, "Drawing for Product designers", Laurence King Publishing, 2012.*
6. *Edward Crawley, "Strategy and Product development for complex systems", Prentice Hall, 2015.*

16NT609 ADVANCED THERMODYNAMIC ENGINES 3-0-0-3

Review of the fundamentals of thermodynamics including system, processes, Zeroth, First and Second laws with their application, application of the laws on steady and unsteady system. available Energy, entropy and Third law of thermodynamics, thermodynamic cycles and their analysis, thermodynamics of combustion, internal combustion engines including spark ignition engines, compression ignition engines and turbine engines, external combustion including steam engines

Stirling cycle and Stirling engines, history, development, applications, current status and future, Actively controlled Stirling engines.

TEXT BOOKS/REFERENCES:

1. *Michael A. Boles, "Thermodynamics An Engineering approach", Eighth Edition, McGraw-Hill, 2015.*
2. *V Ganesan, "Internal combustion engines"Fourth Edition, McGraw-Hill, 2012.*
3. *William R Martini, "Stirling engine design manual", Second Edition, CreateSpace Independent Publishing Platform, 2013.*
4. *Allan J Organ, "Stirling cycle engines: Inner workings and design", First Edition, Wiley, 2013.*
5. *Jim R Larsen, "Eleven Stirling engine projects you can build", CreateSpace Independent Publishing Platform, 2012.*
6. *Vinod Kumar Gopal, "Active Stirling Engine: Ph.D thesis", University of Canterbury.*

ELECTIVES

16NT701 ENERGY ECONOMICS AND PUBLIC POLICY 3-0-0-3

Energy economics: basic concepts, energy data energy balance, energy accounting framework, economic theory of demand, production and cost market structure, application of econometrics, input and output optimisation and simulation methods to energy planning and forecasting problems. Dynamic models of the economy and simple theory of business fluctuation

Costing: Time value of money - present worth and future worth; economic performance indices-simple and discounted payback, levelised cost - calculation of unit cost of power generation, cost-benefit ratio, E\D ratio, net present value, internal rate of return. Energy- GDP elasticity, national and regional energy policies-RE certificate, RE purchase obligation, subsidy and taxation, renewable recovery fund. Energy-environment interactions at different levels; energy security issues.

Energy policies of India- supply focus approach and its limitations- energy paradigms - DEFUNDUS approach - end use orientation - energy policies and development - case studies on the effect of central and state policies on the consumption and wastage of energy - critical analysis - need for renewable energy policies in India. Energy and environment- Greenhouse effect-Global warming-Global scenario-Indian environmental degradation-Environmental loss-The Environmental protection Act 1986-Energy conservation schemes-Statutory requirement of energy audit, Economic aspects of energy audit, Capital investment in energy saving equipment, Tax rebates-Advantages of 100% depreciation, India's plan for a domestic energy cap and trade scheme. Social cause benefit analysis-Computation of IRR and ERR-Advanced models in energy planning-Dynamic programming models in integrated energy planning-Energy planning case studies-Development of energy management systems-Decision support systems for energy planning and energy policy simulation.

TEXT BOOKS/REFERENCES:

1. *Robert S. Pindyck, "Microeconomics", Seventh Edition, Pearson Education, 2009.*
2. *Kenneth S. Deffeyes, "Hubbert's Peak: The Impending World Oil Shortage", Princeton University Press, 2001.*
3. *A.V. Kneese, "Handbook of Natural Resource and Energy", North Holland, 1993.*
4. *Chopra S.K, "Energy Policy for India", English Oxford and IBH Publishing.*

16NT702 USER INTERFACE DESIGN 3-0-0-3

Design: Psychology, Knowing what to do, the design challenge, user-centred design

Source: Jakob Nielsen

Usability engineering: Introduction, generations of user interfaces, the usability engineering lifecycle, usability heuristics, usability testing, usability assessment methods beyond testing, interface standards, international user interfaces, future developments.

Source: Kevin E. Mullet

Designing visual interface: Introduction, elegance and simplicity, scale contrast and proportion, organisation and visual structure, module and program, image and representation, style and techniques.

TEXT BOOKS / REFERENCES:

1. *Donald A. Norman, "The Design of Everyday Things", Basic Books, 2014.*
2. *Jakob Nielsen, "Usability Engineering", First Edition, Elsevier, 2015.*
3. *Kevin E. Mullet, "Designing Visual Interfaces: Communication Oriented Techniques", Prentice Hall, 1994.*
4. *Steve Krug, "Don't Make Me Think, Revisited: A Common Sense Approach to Web Usability", Third Edition, Pearson Education, 2015.*

16NT703 LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN 3-0-0-3

Introduction, history, rating systems: certification level, credit system and its goals, credit weighting process. LEED performance- energy performance research, water performance research, IEQ performance research, sustainable sites research, materials and resource research, innovation in design research, other related research notes.

LEED v4 criteria for 1. Building Design and Construction 2. Interior Design and Construction 3. Building Operations and Maintenance 4. Neighbourhood Development.

REFERENCES:

1. *LEED v4 for Building Design and Construction – USBC.*
2. *LEED v4 for Interior Design and Construction – USBC.*
3. *LEED v4 for Building Operations and Maintenance – USBC.*
4. *LEED v4 for Neighbourhood Development – USBC.*
5. *LEED Reference Guide for Building Design and Construction – USBC.*
6. *LEED Reference Guide for Homes Design and Construction – USBC.*
7. *LEED Reference Guide for Interior Design and Construction – USBC.*
8. *LEED Reference Guide for Building Operations and Maintenance – USBC.*
9. *LEED Reference Guide for Neighbourhood Development – USBC.*
10. *Ari Meisel, "LEED Materials: A Resource Guide to Green Building", First Edition, Princeton Architectural Press, 2010.*

16NT705 PHYSICS OF SEMICONDUCTORS 3-0-0-3

Crystal structures; Crystal planes, directions and indices; Common semiconductor crystal structures; Single, poly and multi crystalline semiconductors; Surface and interfaces; Structural imperfections and dangling bonds; Point, line, planar and volume defects; Semiconductors Review; elemental and compound semiconductors; oxide semiconductors; emerging layered semiconductors; technological applications and future prospects; semiconductor material processing; (bulk) single crystal growth; low dimensional systems; chemical vapor deposition and physical vapor deposition; 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; Carrier transport and recombination; Radiative, Auger and SRH recombination models; Fundamental transport equations in semiconductors; Optical Properties: Absorption, excitation, transmittance and reflectance; Optical transition and electron-phonon interaction; Excess carrier generation; Carrier capture and capture cross section; Excess carrier lifetime in crystalline and defective semiconductors; Photo-and electroluminescence; Magnetic Properties: Origin of magnetism in semiconductors; Concepts on dia, para and ferromagnetism; Hall effect and magnetoresistance; Magnetic domains, domain walls and hysteresis; Dilute magnetic semiconductors; Spintronics;

TEXT BOOKS / REFERENCES:

1. *C. Kittel, "Solid State Physics", Eighth Edition, Wiley Internations, 2006*
2. *Leonid V. Azaroff, "Introduction to Solids", Second Edition, Tata McGraw- Hill Publishing Company Limited, 2006*

16NT704 ENERGY MANAGEMENT AND ENERGY AUDIT 3-0-0-3

Energy management in electrical power systems: supply-demand gap on electric power grid: causes and remedial measures. Energy trading; demand response; micro grids and smart grid.

Energy conservation management: general principles of energy management and management planning, conducting energy, audit, energy audit instruments, energy audit report, monitoring, evaluating and following up energy saving measures projects, energy efficiency analysis, management of heating, ventilating and air conditioning, management of process energy, energy consumption, parameters affecting specific energy consumption, flexi targeting technique. Cogeneration: types and schemes, case study. Management of electrical load and lighting: management opportunities with electric drives, lighting heating and electrolytic systems, electrical load analysis and peak demand control. Economics of power factor improvement: reactive power management, capacitor sizing, degree of compensation, capacitor losses. Location, placement, maintenance, case study. Computer aided energy management, energy efficiency policy initiatives. Energy economic. financial evaluation of energy projects, evaluation of proposals, profitability index, life cycle costing approach, investment decision and uncertainty, consideration of income taxes, depreciation and inflation in investment analysis

Source: Terry Niehus

Energy audit: Basics, accounting and analysis, understanding utility bills, energy economics, survey instrumentation, the building envelope audit, the electrical system audit, the heating, ventilating and AC audit, the physical plant audit, central plant retrofit considerations, maintenance and energy audits, self-evaluation checklist, energy audit to industrial assessments, energy auditing software, retro-commissioning, investment grade energy audits

TEXT BOOKS/REFERENCES:

1. *Barney L .Capehart, "Guide to energy management", Eighth Edition, Fairmont Press, 2016.*
2. *Albert Thumann, "Handbook of Energy Audits", Ninth Edition, Fairmont Press, 2012.*

16NS603 NANOMATERIALS - CHEMISTRY AND DESIGN 3-0-0-3

Introduction to Molecular orbitals theory, Nanochemistry: Size and confinement effect in nanoparticles; Origin of surface energy; Stabilization mechanisms to minimize overall surface energy; Elementary Thermodynamics:- Introduction to Thermodynamics, First law of thermodynamics, Enthalpy of phase transition, Second law of thermodynamics:- Entropy, The Gibb's Free energy:- properties of the Gibb's Free energy and it's variation with pressure and temperature (thermodynamics of transition). Phase transition & Specific Features of Nanoscale Growth:- Crystalline Phase Transitions in Nanocrystals with respect to grain size dependence. Understanding the thermodynamics of the grain size dependence of Phase Transitions. Thermodynamics of spinodal decomposition and nucleation–growth. Triggering the Phase Transition, Controlling Nucleation, Controlling Growth, Controlling Aggregation. Stability of Colloidal Dispersions.

TEXT BOOKS/REFERENCES:

1. *B.S Bahl, ArunBahl and G.D Tuli, "Essentials of Physical chemistry", Twenty fourth revised edition, S chand Co. Ltd, 2000.*
2. *Masuo Hosokawa, Kiyoshi Nogi, Makio Naito and Toyokazu Yokoyama, "Nanoparticle Technology Handbook",First Edition, Elsevier, 2007.*
3. *C. Br´echignac P. and Houdy M. Lahmani, "Nanomaterials and Nanochemistry", First Edition, Springer Verlag, 2007.*
4. *Guozhong Cao, "Nanostructures and Nanomaterials- Synthesis, Properties and applications",First Edition, Imperial College Press, 2006.*
5. *Jonathan W. Steed, David R. Turner and Karl J. Wallace, "Core concept in Supramolecular Chemistry and Nanochemistry", First Edition, John Wiley & Sons Ltd, 2007.*

16NS606 CHARACTERISATION OF NANOMATERIALS 3-0-0-3

Characterization of Nanomaterials: Structural characterization – XRD, Reciprocal lattice, Bragg's law, Ewald's construction, XRD of nanolayers, Grazing incidence diffraction, texture and stress measurements with x-ray diffraction, SEM: scattering of electrons, secondary and backscattered electrons, electron gun, lenses and apertures, imaging modes in SEM, TEM: Interaction of electrons with matter, elastic and inelastic scattering, electron sources, lenses, apertures and resolution, TEM instrument, Forming diffraction patterns and images, selected area and convergent beam electron diffraction patterns, Imaging and contrast in TEM, HRTEM, Electron energy loss spectrometry, SPM: Principle of operation, instrumentation and probes, contact and non-contact AFM, various modes of operation of SPM, Chemical Characterization – Optical Spectroscopy, IR spectroscopy: theory of IR spectroscopy, single and group frequencies, advantages of FTIR, Raman Spectroscopy and X-ray photoelectron spectroscopy.

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. *David B. Williams and C. Barry Carter, "Transmission Electron Microscopy: A Textbook for Materials Science", Second Edition, Springer, 2009.*
3. *Ray F. Egerton, "Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM", Second printing edition, Springer, 2008.*
4. *Bharat Bhushan, "Springer handbook of Nanotechnology", Second Revised and Extended Edition, Springer, 2007.*

16NT707 HYDROGEN STORAGE AND CARBON CAPTURE TECHNOLOGIES 3-0-0-3

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. Introduction to climate change issues and issues related to greenhouse gas emissions, CO2 capture-post and pre combustion capture, oxy fuel combustion, CO2 capture using adsorption and absorption materials.

TEXT BOOKS/REFERENCES:

1. *Michael Hirscher, "Handbook of Hydrogen Storage: New Materials for Future Energy Storage edited", Wiley, 2010.*
2. *Robert A. Varin, "Nanomaterials for solid state hydrogen storage", Springer, 2007.*
3. *BerendSmit, "Introduction to carbon capture and sequestration, The Berkeley lectures on energy-vol 1", Imperial College Press, 2014.*

16**NT708 TEST, VALIDATION AND RELIABILITY ENGINEERING 3-0-0-3**

Reliability Engineering: Concept and definition of reliability-reliability mathematics-failure distributions, hazard rate function; bathtub curve, hazard models-exponential, Rayleigh, Weibull, Normal, Lognormal distributions-MTTF, MTBF, median time to failures-failure models-Reliability of systems-serial and parallel configurations-Reliability of complex configurations-Markov analysis-Design for reliability-Design for maintainability-Reliability testing.

Source: Avner Engel

Verification, validation and testing (VVT): Introduction

VVT activity and methods: System VVT activities-development, post development. System VVT methods; non testing, testing.

Modelling and optimising VVT process: modelling quality cost, time and risk. Obtaining quality data and optimising VVT strategy. Methodology validation and examples.

TEXT BOOKS / REFERENCES:

1. *Charles Ebeling, "An introduction to reliability and maintainability in engineering", Twelfth Edition, McGraw-Hill, 2000.*
2. *Lewis.E.E, "Introduction to reliability engineering", Second Edition, Wiley India, 2012.*
3. *Avner Engel, "Verification, Validation, and Testing of Engineered Systems", First Edition, Wiley, 2011.*

16NT709 EMBEDDED SYSTEMS DESIGN 3-0-0-3

Embedded system Introduction: Embedded systems overview, design challenges, processor technology, IC technology, design technology, embedded system design considerations and requirements, processor selection and trade-offs, embedded applications

Embedded programming in C: programming Style, programming process, preprocessing, compiling, linking, loading, downloading, debugging, C basics: Declarations and expressions, arrays, qualifiers, decision, control statements, variable scope, functions, C pre-processor, structures, pointers, in-line assembly, debugging and optimization, emulators and simulators processor

ARM processors and peripherals: Overview, architecture of Cortex-M , programming model, registers, operating modes, Instruction set, addressing modes, SysTick timer, NVIC on the ARM Cortex-M Processor, Peripherals: Introduction, IO ports, timers, counters, watchdog timers, UART, SPI, I2C, PWM, ADCs and DACs

Embedded hands on session: LEDs, switches and relays, keypad controllers, LCD controllers, motor controlling, DC motor-stepper motor-servo motor, real time clocks, analog sensor interfacing, EEPROM interfacing, UART communication with PC

RTOS: Introduction to basic concepts of RTOS: Need, task, process & threads, Round-Robin scheduler, semaphores, thread synchronization and communication, monitors, fixed scheduling, OS consideration for I/O devices, overview of available RTOS for Cortex M

System design Case study - Measurement and embedded control of electrical apparatus: Conduct case study of a well-established embedded project and discuss in detail about the Sensors used, types & characteristics, Data acquisition & Display system, signal conditioning circuit design, embedded processor interfacing circuit, actuator section

TEXT BOOKS / REFERENCES:

1. *Jonathan W. Valvano, "Embedded Systems: Introduction to Arm Cortex-M Microcontrollers", Second Edition, CreateSpace, 2012.*

2. *Jonathan W. Valvano, "Embedded Systems: Real-Time Interfacing to Arm(r) Cortex -M Microcontrollers", Second Edition, CreateSpace Learning, 2011.*
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