M.Tech. Programme in 'Materials Science & Engineering (MSE)'
School of Engineering, IIT Patna

1. Introduction to the programme

Materials Science and Engineering (MSE) is an interdisciplinary field of science and engineering which investigates the relationship between the structure, property and processing of materials useful for various influence its properties. It is a discipline that enables both the creation and application of materials in society. Materials scientists and engineers develop materials for new applications, improve existing materials to enhance performance and evaluate ways in which different materials can be used together. The M.Tech. degree is designed in a way to provide a holistic view on all the classes of materials including metals, ceramics and polymers. The program is intended to provide in-depth knowledge in the fundamentals, analysis and structure-property correlation of various materials system. The courses will be conducted by faculties from the Department of Materials Science & Engineering (MSE). There will be options also for taking elective courses from within and outside the department. Moreover, specialists from overseas and experts from industries will be invited to lecture for a few classes in selected modules.

2. Course structure and Syllabus

2.1 Name of the courses: Core Courses

1. M S 501: Nano-structured Materials (3-0-0-6)
2. MS 503: Advanced Materials Characterisation Techniques (3-0-0-6)
3. M S 502: Materials Processing Technology (3-0-0-6)
4. M S 504: Structural and Functional Properties of Materials (3-0-0-6)

2. 2 Elective Courses (Elective I –III)

1. MS505: Thermodynamics and Phase Diagrams (3-0-0-6)
2. MS509: Surface Engineering (3-0-0-6)
3. MS511: Rubber Science and Technology (3-0-0-6)
4. MS513: Coating Technology (3-0-0-6)
5. MS515: Advanced Building Materials (3-0-0-6)
6. CH501: Nanobiotechnology (3-0-0-6)
7. CH511: Theory and Modelling in Nanoscience (3-0-0-6)
8. PH502: Nanomaterials for Solar Energy and Photovoltaics (3-0-0-6)
9. MA539: Mathematical Modeling (3-0-0-6)

2.3 Elective Courses (Elective IV –VI)

1. MS508: Advanced Ceramics and Glass (3-0-0-6)
2. MS510: Composite Science and Technology 3-0-0-6
3. MS512: Alloy Development and Heat Treatment (3-0-0-6)
4. MS514: Joining of Materials (3-0-0-6)
5. PH515: MEMS and NEMS (3-0-0-6)

2.4 Lab Courses

1. M S 519: Microstructure and Phase Analysis Laboratory (0-0-3-3)
2. MS 520: Materials Characterisation Laboratory (0-0-3-3)

3. Course Curriculum

M.Tech. Programme in 'Materials Science and Engineering (MSE)'

School of Engineering, IIT Patna

Revised Course Curriculum:

1ST SEMESTER

Sl. No.	Course Number	Course Title	L	T	P	C
1.	MS501	Nano-structured Materials	3	0	0	6
2.	MS503	Advanced Materials Characterisation Techniques	3	0	0	6
3.		Elective I	3	0	0	6
4.		Elective II	3	0	0	6
5.		Elective III	3	0	0	6
6.	HS513	Technical communication	2	0	0	4
7.	MS519	Microstructure and Phase Analysis Laboratory	0	0	3	3
TOTAL			**17**	**0**	**3**	**37**

2ND SEMESTER

Sl. No.	Course Number	Course Title	L	T	P	C
1.	MS502	Materials Processing Technology	3	0	0	6
2.	MS504	Structural and Functional Properties of Materials	3	0	0	6
3.		Elective IV	3	0	0	6
4.		Elective V	3	0	0	6
5.		Elective VI	3	0	0	6
6.	MS520	Materials Characterisation Laboratory	0	0	3	3
7.	MS517	Seminar	0	0	4	4
TOTAL			**15**	**0**	**7**	**37**

3RD SEMESTER

Sl. No.	Course Number	Course Title	L	T	P	C
1.	MS603	Project-Phase I				24

4TH SEMESTER

Sl. No.	Course Number	Course Title	L	T	P	C
1.	MS604	Project-Phase II				24

TOTAL CREDITS: 37+37+24+24 = 122

Detailed syllabus: (Core courses)

MS501 **Nano-structured Materials** 3-0-0-6

Nanocrystals, thin films & coatings, definitions, Effect on properties and phase stability in lower dimension compared to the bulk state,

Materials at Reduced Dimensions, Two-dimensional nanostructures – surfaces and films, One-dimensional nanostructures – nanotubes and wires, Zero dimensional nanostructures – fullerenes, nanoparticles, nanoporous materials, Nanoclays, Graphene, polyhedral oligomeric silsesquioxane (POSS) nanoparticles, Colloidal Monodisperse Nanocrystals, nanocrystals of ferrite, oxide and chalcogenides, core-shell nanoparticles, micelle assisted nanoparticles, surfactant coated nanoparticles, microemulsion synthesis, self-assembly routes, Inorganic-organic hybrid materials, hydrophobic and hydrophilic nanoparticles, water-dispersable nanoparticles,

Synthesis routes, Sol-gel technique, Nonaqueous Sol–gel route for Metal Oxide nanoparticles, hydrothermal synthesis, co-precipitation, preparation of nanocomposites,

Properties and applications at the nanoscale, Electrical, Mechanical, Magnetic, (Electro)Chemical, Optical, Thermal and thermoelectric properties, Health and regulatory issues with Nanomaterials

Text Book:

1. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, 2nd ed., Guozhong Cao, Ying Wang; Imperial College Press, 2004.
2. Nanoparticles: From Theory to Application, Günter Schmid, Wiley, 2005.
3. Synthesis, Properties, and Applications of Oxide Nanomaterials, José A. Rodriguez, Marcos Fernández-García, Wiley, 2007
4. Monodispersed Particles, T. Sugimoto, Elsevier.
5. Characterization of Nanophase Materials, Zhong Lin Wang, Wiley
6. Nanomaterials, Nanotechnologies and design: an introduction for engineering and architects, Michael Ashby and Paulo J. Ferreira; Elsevier, 2009.

Reference Books:

1. Nanoscale Materials in Chemistry, Kenneth J. Klabunde, Ryan M. Richards, 2nd Edition, Wiley, 2009
2. Nanoparticulate Materials: Synthesis, Characterization, and Processing, Kathy Lu, Wiley.
3. Nanostructured Materials (Processing, Properties and Applications), Carl C. Koch, Elsevier, 2006
4. Nanoparticles and Nanostructured Films: Preparation, Characterization, and Applications, Janos H. Fendler, Wiley, 2008
5. Nanostructured Materials and Nanotechnology, Hari Singh Nalwa (ed.); Elsevier, 2001.

MS503 **Advanced Materials Characterisation Techniques** 3-0-0-6

Importance and the need for materials characterization, highlights of various characterization techniques, Crystal structure & polymorphism determination techniques, X-Ray Diffraction (XRD), Bragg's Law, phase identification and analysis by XRD, stress calculation, different approaches for crystal and grain size measurements XRD

Powder characterization techniques, Particle size analysis techniques based on light scattering, Powder characterisation by microscopy techniques (light, electron), light scattering, gas adsorption (BET), Gas pycnometer for density measurement, and compositional analysis of powders by XRF and ICP techniques

Metallography and microstructures, Principles of optical microscopy -resolution, magnification, depth of focus; electron diffraction, imaging (various contrasts), Cross-Sectional and fracture

surface analysis of materials/coatings using FESEM, Crystal Identification through Selected area diffraction pattern (SADP) etc.
Tribology, Wear type and its Characterization, wear surface analysis, Tribometer, Friction, Low friction materials/coating etc.
Instrumentation and principles of techniques used for thermal analysis (DSC, DTA, DMA, TG, DTG, EGD, RMA, DPC, DETA, TMA) and micro-thermal analysis, combined method of thermal analysis and their applications in materials characterization.
Rheological and viscoelastic properties of materials, importance of characterization for polymer systems, measurement techniques, melt flow index, capillary and slit die extrusion rheometry, oscillatory rheometry, rotational rheometry, extensional rheometry, extrudate die swell and draw down techniques.

Test Books:

1. An Introduction to Materials Characterization, P. R. Khangaonkar; Penram Publishers, 2010.
2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Yang Leng; 2nd ed., Wiley, 2013.
3. Scanning Electron Microscopy and X-Ray Microanalysis, Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy and Patrick Echlin; 3rd ed., Springer, 2003.
4. Physical Methods for Materials Characterisation, P.E.J.Flewitt, R.K.Wild ; Institute of Physics Publishing Ltd., 1994.
5. Thermal characterization of polymeric materials, Edith A. Turi (ed.), Academic Press, 1996.
6. Introduction to Polymer Rheology, Montgomery T. Shaw; Wiley, 2011.
7. Polymer Rheology and Processing, A.A. Collyer, Leszek A. Utracki; Springer, 1990.

Reference Books:

1. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry, Marc De Graef, Michael E. McHenry; 2nd (ed.), Cambridge University Press, 2012.
2. Crystal Structure Determination, Werner Massa; 2nd (ed.), Springer, 2010.
3. Crystal Structure Analysis: Principles and Practice, Peter Main, William Clegg (ed.), Alexander J. Blake, Robert O. Gould , Vol 6, Oxford Science Publication, 2001.

MS502 **Materials Processing Technology** 3-0-0-6

Introduction of Materials, Types, distinctions, properties and applications of Metals, Ceramics and Polymers. Different types of polymer processing operations and engineering aspects: Mixing and compounding (twin screw extruders, banbury and other mixing equipments in polymer processing), extrusion process, injection moulding, blow moulding, thermoforming, rotational moulding, compression moulding, transfer moulding, reaction injection moulding, calendering, roller and blade coating, film blowing, textile/fiber spinning technology

Technology for ceramic powder preparations, solid state reactions, Sintering operations, Types of sintering, sintering mechanisms, Colloidal processing of ceramics, DLVO theory, Porous ceramics and ceramic fibres, Co-precipitation method, Sol-Gel process, products for engineering applications

Metal Forming: Introduction to rolling, forging, extrusion, drawing and its engineering aspects, Development of microstructures with different processing technologies and its effects on forging, extrusion, rolling, and drawing on metallic alloy components. Effect of alloying additions. Casting: Pattern and Mould, Melting and Pouring, Solidification and Pouring, Fundamentals of Solidification, Joining: Welding and its types, Brazing and Soldering, Microstructural mechanisms associated with metals joining operations and it engineering applications, Powder Metallurgy

Text Books:

1. Principles of Polymer Processing, Tadmor; 2nd (ed.), Wiley, 2006.
2. Polymer processing fundamentals, Tim A. Osswald, Hanser (eds.); 1998
3. Polymer Processing, David H. Morton-Jones, Routledge (eds.); Chapman & Hall, 1989.
4. Rubber Products Manufacturing Technology, Anil K. Bhowmick, M. M. Hall and H Benary, (eds.); Marcel Dekker Inc., 1994.
5. Ceramic Materials: Science and Engineering, C. Barry Carter, M. Grant Norton; 2nd (ed.), Springer, 2013.
6. Ceramic Processing and Sintering, Mohamed N. Rahaman; 2nd (ed.), Marcel Dekker Inc., 2003.
7. Chemical Processing of Ceramics, Burtrand Lee, Sridhar Komarneni; 2nd (ed.), CRC Press, 2010.
8. Solidification and Crystallization Processing in Metals and Alloys, Hasse Fredriksson; Wiley, 2012.

MS504 **Structural and Functional Properties of Materials** 3-0-0-6

Elastic modulus – Stress-strain curves - Tensile test of ductile material – properties evaluation, Hardness measurement tests – Fracture of materials – Mechanisms of Ductile and Brittle fracture; recovery and recrystallization, fracture toughness, Fatigue – Endurance limit – Fatigue test; Creep, fracture toughness. High temperature deformation, Plasticity, yield strength, dislocation mechanisms, strengthening mechanisms in materials, Viscoelastic behavior with models, creep and stress relaxation, Boltzmann superposition principle and time-temperature superposition

Thermal properties, specific heat, thermal conductivity, Thermal expansion, thermal stress, thermal stability, Thermal radiation, emissivity, thermal diffusivity, Relationship between structure and thermal properties of materials, Experimental methods for thermal analysis of materials

Electrical and electronics, magnetic and optical properties of materials, Fermi level & Hall effect in semiconductors, Band theory, Ferroelectrics & piezoelectrics, Snell's law, Maxwell equations, luminescence, fluorescence, Microscopic origin of magnetic moments, Magnetic susceptibility, Exchange interaction, Types of Magnetism in materials, Hysteresis in ferromagnetic materials, Response of the functional materials to external parameters, e.g., pressure, temperature. Applications in Giant magneto-resistance effect, Spintronics, Material aspects and design rules of functional devices.

Text Books:

1. Mechanical Behaviour of Materials, Thomas H. Courtney; 2nd (ed.), Waveland press Inc.,2000.
2. Fatigue of Materials, S. Suresh; 2nd (ed.), Cambridge University Press, 2003.
3. Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg; Wiley, 2012.
4. Mechanical Metallurgy, George E. Dieter; MCGRAW-HILL Publications, 1998.
5. Electronic Materials Science, Eugene A. Irene; WILEY, 2005.
6. An Introduction to Electronic Materials for Engineers, Zhengwei Li, Nigel M. Sammes; World Scientific Publishing Co. Pte. Ltd., 2011

Reference Books:

1. Electronic Materials and Devices, David K. Ferry, Jonathan P Bird; Wiley,2001
2. Conducting Polymers and Plastics, J.M. Margolis (ed.); Chapman and Hall, 1989.
3. Conductive Polymers, R.B. Seymour (ed), Plenum Press, 1981.

4. Electroceramics: Materials, Properties, Applications, A. J. Moulson , J. M. Herbert; Wiley, 2003.
5. Solid State Chemistry and Its Applications, Anthony R. West; John Wiley & Sons, 1985.

(Elective Courses) (Elective I-III)

MS505 **Thermodynamics and Phase Diagrams** 3-0-0-6

Thermodynamics basic concepts (state variables, the first law, the enthalpy concept, heat capacity) The second law (reversible and irreversible processes, entropy, Gibbs energy, Hemholtz energy, Gibbs-Duhems equation, Maxwell's relationships) Equilibrium conditions (chemical potential, driving force, the third law, Clausius-Clapeyrons equations, Thermodynamic application to materials: Ellingham diagrams; Electrochemistry: Porbaix diagrams; thermodynamics of solutions, construction and interpretation of 2 component phase diagrams.

Phase Diagram– Gibbs's Phase rule – Interpretation of mass fractions using Lever's rule –Hume Rothery rules-Binary Iso-morphous system- Binary Eutectic alloy system (Lead-Tin System) – Binary Peritectic alloy system (Iron-Nickel System) – Invariant reactions – Iron-Iron carbide phase diagram- Slow cooling of Hypo and hyper eutectoid steels – Temperature-Time-Transformation (TTT) and Continuous Cooling Transformation (CCT) Diagrams, Phase equilbria in ceramics

Text Books:

1. Introduction to the Thermodynamics of Materials, David R. Gaskell, 5th ed., CRC Press, 2008.
2. Phase Transformations in Metals and Alloys, Porter, Easterling; 3ed ed, CRC Press, 1991.
3. Thermodynamics in Materials Science, Robert DeHoff; 2nd ed, 2006.
4. Ceramic Materials: Science and Engineering, C. Barry Carter, M. Grant Norton; Springer, 2007

MS509 **Surface Engineering** 3-0-0-6

Introduction to surface Engineering, Differences between surface and bulk, Properties of surfaces, surface energy concepts, degradation of surfaces, wear and its type, Adhesive, Abrasive, Fretting, Erosion wear, Surface fatigue, Different types of Corrosion and its prevention, Galvanic corrosion, Passivation, Pitting, Crevice, Mircobial, High-temperature corrosion, Corrosion in nonmetals, polymers and glasses, Protection from corrosion through surface modifications

Changing the surface metallurgy: Localized surface hardening (flame, induction, laser, electron-beam hardening, Laser melting, shot peening), Changing the surface chemistry: Phosphating, Chromating, Anodizing (electrochemical conversion coating), Carburizing, Nitriding, Ion implantation, Laser alloying, boriding, Organic coatings (paints and polymeric or elastomeric coatings and linings), Hot-dip galvanizing (zinc coatings), Ceramic coatings (glass linings, cement linings, and porcelain enamels), Advanced surface coating methods: Gaseous State (CVD, PVD etc), Solution State (Chemical solution deposition, Electrochemical deposition, Sol gel, electroplating), Molten or semimolten State (Laser cladding and Thermal spraying)

Characterization of surface and coatings, Surface Characterization (physical and chemical methods, XPS, AES, RAMAN, FTIR etc), Structural Characterization, Mechanical Characterization (Adhesion, Hardness, Elastic Properties, Toughness, Scratch and Indentation etc.), Tribological Characterization, Corrosion tests

Text Books:

1. Introduction to Surface Engineering and Functionally Engineered Materials, Peter Martin; Wiley, 2011.
2. Materials and Surface Engineering: Research and Development, J. Paulo Davim; Woodhead Publishing review, 2012.

Reference Books:

1. Surface Engineering: Processes and Applications, Chinnia Subramanian, K.N. Strafford, R. St. Smart, I.R. Sare; Technomic Publishing Company, 1995.
2. Surface Engineering for Corrosion and Wear Resistance, J. R. Davis; ASM International, 2001.

MS511 **Rubber Science and Technology** 3-0-0-6

Elastomers: Natural rubber, Synthetic rubbers:-Polybutadiene, Styrene-butadiene rubber, Acrylonitrile butadiene rubber-Nitrile rubber, Poly-2-chlorobutadiene, Chloroprene rubber, Polyisoprene rubber, Butyl rubber, Halogenated copolymers of butyl rubber, Ethylene propylene rubber (EPM and EPDM), Ethylene vinylacetate copolymers, Chlorinated polyethylene, Chlorosulfonated polyethylene, Acrylic rubbers and ethylene acrylate copolymers, Epichlorohydrin rubber, Polypropylene oxide rubber, Fluoroelastomer, Polynorbornene, Polysiloxane and silicone rubber, Polysulfide rubber, Polyester and polyether rubber, Polyurethane elastomer, New elastomers

Blends:-Thermoplastic elastomers and thermoplastic vulcanizates, Different rubber based blends, Rubber chemicals and additives:- Mastication and peptizers, Vulcanizing agents, Accelerators, Activators, Retarders, Aging, fatigue and ozone protective agents, Antioxidants, Reinforcing and non-reinforcing fillers, Other fillers and new fillers, Pigments, Plasticizers, processing aids and factice, Blowing agents, Adhesion promoters, Latex technology:-Natural rubber latex, styrene butadiene rubber latex, nitrile rubber latex, polychloroprene latex, latex compounding, latex processing, Processing of elastomers:- Compound preparation, Processing to sheets, Manufacture of extruded products, Manufacturing of molded goods, Elastomer testing and analysis:- Mechanical testing, Adhesion testing, Electrical testing, Chemical testing, Thermal testing, Morphology

Text books:

1. Rubber technology handbook, Werner Hofmann(ed); Hanser Publishers, 1989.
2. Rubber technology, third edition, Maurice Morton; Kluwer Academic Publishers, 1999.
3. Rubber chemistry, JA Brydson (ed), Applied Science Publishers Limited, 1978.
4. Handbook of elastomers, AK Bhowmick, Howard L. Stephens (ed); Marcel Dekker Inc, 2001.
5. Rubber Products Manufacturing Technology, Anil K. Bhowmick, M. M. Hall, H. Benary, (Ed); Marcel Dekker Inc,1994.
6. Rubber Compounding-Principles: Materials and Techniques, Fred W. Barlow (ed), Marcel Dekker Inc, 1996.
7. Physical testing of rubber, Roger Brown (ed); Chapman and Hall, 1996.
8. Current topics in elastomers research, A.K. Bhowmick (ed); CRC Press, 2010.
9. Developments in Rubber Technology, A. Whelan, K.S.Lee; Vol. 1 – 4, Applied Science Publishers, 1981.
10. Rubber Technology and Manufacture, C. M. Blow, C. Hepburn; 2nd Ed., Butterworths, London, 1982

MS513 **Coating Technology** 3-0-0-6

Introduction to coatings for different temperature applications, Properties of surfaces-wear, corrosion, optical, roughness, electrical and thermal properties, wetability

Concepts of coating, Thin film coating, Physical Vapour Deposition: Thermal Evaporation, E-Beam Deposition, Sputtering. Chemical Vapour Deposition: Thermal Assisted CVD, Plasma Enhanced CVD, Photo Assisted CVD, Metal Organic CVD, Sol-gel deposition, Thick Coating: Thermal spray Types of thermals spary and their advantages and disadvantages. Flame Spray, HVOF, Plasma spray- conventional vs. nanostructured coatings, Process parameters, thermal and kinetic history of inflight particle, microstructural features of plasma sprayed coatings, single splat studies, process-structure property relationship-challenges in prepartion, plasma spraying of nanopowders - its microsturcutre – properties –Liquid precurser plasma spray- Thermal barrier coatings and materials including yittria stabilized zirconia

Characterization of film and thick coatings, Coatings –thickness-porosity-hardness, fracture toughness, elastic modulus – adhesion-bending strength-fracture strength- tensile strength, coating tribology, corrosion measurement, phase analysis and microstructure, Surface characterization techniques. Applications of coatings: wear resistance, corrosion, thermal barrier, Anti scratch, Biomedical, near net shape, embedded sensors, Energy applications like Solid oxide fuel cell, Dye sensitized solar cell

Text Books:

1. Introduction to Surface Engineering and Functionally Engineered Materials, Peter Martin; Wiley, 2011.
2. Materials and Surface Engineering: Research and Development, J. Paulo Davim; Woodhead Publishing Ltd.,2012.
3. The Science and Engineering of Thermal Spray Coatings, Lech Pawlowski; Wiley, 2008.
4. The Cold Spray Materials Deposition Process: Fundamentals and Applications, Victor K. Champagne; Woodhead Publishing Ltd, Maney publishing Ltd., 2007

Reference books:

1. Quo Vadis Thermal Spraying? P. Fauchais, A. Vardelle, B. Dussoubs; Journal of Thermal Spray Technology, Vol. 10, 2001.
2. Thermal Spray Coatings, Kurt H Sien (ed); Chapman and Hall, 1996.

MS515 **Advanced Building Materials** 3-0-0-6

Introduction to building materials- classification and special features. Materials from Natural Rock and components-formation and classification of rocks, characteristics and application of various rocks. Ceramic Materials and components-Raw materials, classification of ceramic materials, clay brick, ceramic construction for walls and floors, roof tiles, acid-resistant items, sanitary ceramic items. Mineral binders-Air-setting binding materials, hydraulic binding materials. Concrete - General, classification of concrete, concrete mixes, Specific properties of concrete eg. Insulation, fire resistance, heaviness, lightweight, extreme climate etc., Mix design, concrete ad-mixtures, R.C.C.- curing & testing. Metal and metal components-Basic Metallurgy of Iron & Steel, composite & grades of steel, heat treatment of steel, steel reinforcement of concrete, corrosion of metals and protection, non-ferrous metals and its application. Heat insulating and acoustic materials and components. Organic binders and bitumen-&-tar-based materials-Bitumen, tars, emulsions, mastics, waterproofing items, steam-proofing and sealing materials. Polymers and polymer-based materials and components- polymers and plastics, polymer based building materials for walls, pipes, sanitary-ware, glues, mastics. polymer impregnated concrete (PIC), Polymer Cement Concrete (PCC), Cement based smoothing and screeding compounds. The use of water dispersed polymers in cement mixes for floor topping and concrete repair.

Text Books:

1. Building Materials, Duggal.S.K.;New Age International, 2009.
2. Buliding Materials, P. C. Varghese Phi; Learning Pvt. Ltd., 2005.
3. Fundamental Building Materials, K. Ward-Harvey; Universal Publishers, 2009.

CH501 **Nanobiotechnology** 3-0-0-6

Module 1: Generic Methodologies for Nanobiotechnology Introduction to Nanobiotechnology; challenges and opportunities associated with biology on the Nanoscale; nanobiotechnology systems; introduction to bioelectronics; Biologically relevant molecular nanostructures-Carbon nanotubes, quantum dots, metal based nanostructures, naowires, polymer based nanostructures, protein and DNA based nanostructures; Characterisation techniques for biological molecular nanostructures.

Module 2: Biosensors Introduction to biosensors; the biological component; the sensor surface; Immobilisation of the sensor molecule; Transduction of the sensor signal -Optical sensors; Electrochemical sensors; Suppression or substraction of non-specific background interaction at sensor surfaces; Sensor stabilisation; Data analysis.

Module 3: Imaging of Bionanostructures Practical and theoretical aspects of imaging biological systems, from the cellular level through to whole-body medical imaging, basic physical concepts in imaging. Major techniques using ionising and non-ionising radiation including fluorescence and multi-photon microscopy, spectroscopy, OCT, MRI, X-ray CT, PET, Confocal and SPECT imaging.

Module 4: Bionanomaterials Biomolecules for designing nano-structures; nanoprinting of DNA, RNA and Proteins, use of these nano-structures in biological and medical applications. Principles of self-assembly, self-organisation and its application to biology. DNA nanostructures, DNA robot, DNA microarrays, Bio-MEMS: biological and biomedical analysis and measurements and micro total analysis systems.

Module 5: Toxicological and Medical Applications of Nanobiotechnology Environmental behaviour and speciation of nanoparticles; Introduction to Nanomaterials for toxicology; bioaccumulation of Nanomaterials, Nanoparticles cytotoxiciy, Applications of Nanostructures in Drug discovery, Delivery, and Controlled Release.

Text Books:

1. Nanodevices for the Life Sciences, Challa S. S. R. Kumar (Editor), John Wiley & Sons, Inc.
2. Bionanotechnology, by Elisabeth Papazoglou, Publisher: Morgan & Claypool

Reference Books:

1. Bionanotechnology: Global Prospects
2. David E. Reisner (Editor), CRC Press (Taylor and Francis)

CH511 **Theory and Modelling in Nanoscience** 3-0-0-6

1. Molecular Dynamics;
2. Monte Carlo Methods;
3. Computations of Phase Transition under Confinement;
4. General Basis for predicting physical properties of nanocrystals and large clusters;
5. Quantum Confined Systems & computational techniques
6. Computational Electrodynamics Methods;
7. Large Scale Electronic Transport Calculations;
8. Density Functional Calculations in Carbon Nanotubes;
9. Time Dependent Density Functional Theory;

10. Computational Study of Nanotubes;
11. Excited State Properties (GW, BSE);
12. Computing Mechanical Properties and Modeling Growth;
13. How Well does Computation do with respect to Experiment
14. Present Day Scenario: regarding computation in the field.

Text Books:

1. Computational Nanoscience (RSC Theoretical and Computational Chemistry) yr. 2011.
2. Nano Structures: Theory & Modeling, yr 2004

PH502 **Nanomaterials for Solar Energy and Photovoltaics** 3-0-0-6

Solar radiations as a source of energy and mechanism for its entrapment; Measurements and limits of solar energy entrapment; Flat plate collectors and solar concentrators; Solar energy for industrial process heat (IHP) and design of solar green house; Solar refrigeration and conditioning; Solar thermo-mechanical power.

Introduction of energy storage/conversion devices, State-of-the art status of portable power sources, Solar/photovoltaic (PV) cells as a source of green energy; Fundamentals, Materials, Design and Implementation aspects of PV energy generation and consumption; Solar cell technologies (Si-wafer based, Thin film, GaAs based, dye-sensitized, PESC and organic solar cells), Efficiency of solar cells and PV array analysis, Photovoltaic system design (stand alone and grid connected) and applications; Balance of system (BOS) with emphasis on role of storage batteries; Cost analysis, Case study for performance evaluation and problem identification in wide-spread commercialization of the technology.

Text Books:

1. Solar Energy: Fundamentals & Applications; H. P. Garg and J. Prakash; Tata McGraw Hill, 1997.
2. Fundamentals of Photovoltaic Modules and their Applications, G. N. Tiwari, S. Dubey & Julian C. R. Hunt, RSC Energy Series, 2009.
3. Solar Photovoltaics: Fundamentals, Technologies and Applications (2nd ed.), C. S. Solanki, Prentice Hall of India, 2011 (ISBN: 978-81-203-4386-6)
4. Solar Cell Device Physics, Stephen Fonash (2nd ed.), Academic Press, 2010 (ISBN: 978-0-12-374774-7).

Reference Books:

1. Energy Storage, R. A. Huggins, Springer, 2010.
2. Handbook of Advanced Electronic and Photonic Materials and Devices: Ferroelectrics & Dielectrics, Vol. 10, H. S. Nalwa (ed.), Academic Press, 2001.
3. Electrochemical Nanotechnology, T. Osaka, M. Dutta, Y. S. Diamand (eds.), Springer, 2010, (ISBN: 978-1-4419-1423-1).
4. Encyclopedia of Nanoscience & Nanotechnology, Vol. 10, H. S. Nalwa (ed.), American Scientific Publishers, 2004.

MA539 **Mathematical Modeling** 3-0-0-6

System of differential equations; Linear and nonlinear stability; Basic idea of bifurcation; some illustrations with help of computer programming

Introduction to modeling; Elementary mathematical models and General modeling ideas; General utility of Mathematical models, Role of mathematics in problem solving; Concepts of mathematical modeling; System approach; formulation, Analyses of models; Pitfalls in modeling;

Illustrations models such as Population dynamics, Traffic Flow, Social interactions, Viral infections, Epidemics, Finance, Economics, Management, etc. (*The choice and nature of models selected may be changed with mutual interest of lecturer and students.*)

Introduction to probabilistic models.

Text & References:

1. D. N. P. Murthy, N. W. Page, Ervin Y. Rodin, Mathematical modelling: a tool for problem solving in engineering, physical, biological, and social sciences, Pergamon Press, 1990.
2. W. E. Boyce and R.C. DiPrima, Elementary Equations and Boundary Value Problems, 7th Edition, Wiley, 2001.
3. J. D. Murray, Mathematical Biology, Vol I, 3rd Ed, Springer, 2003.
4. Wei-Bin Zhang, Differential equations, bifurcations, and chaos in economics, Series on Advances in Mathematics for Applied Sciences, Vol 68, World Scientific, 2005.

(Elective Courses) (Elective IV-VI)

MS508 **Advanced Ceramics and Glass** 3-0-0-6

Processing and evaluation of engineering ceramics. Fracture behaviour of ceramic materials, The Weibull distribution, Toughening mechanism. Formation, mechanical properties and uses of fused alumina, sintered alumina products, borides, carbides, nitrites, silicides, zirconia and partially stabilized, zirconia, sialons.

Abrasives, abrasive operations, natural abrasives, abrasives like aluminium oxides, silicon carbide, diamond and boron nitride, miscellaneous synthetic abrasives, raw materials for abrasives, their proportioning, processing, manufacture of abrasives, grinding wheels, their drying, firing and testing.

Glassy State; Kinetic and thermodynamic criteria for glass formation, use of Na_2O-SiO_2 and Na_2O-CaO- SiO_2 phase diagrams in glass manufacture, types of glasses and their chemical compositions, Physical properties of glasses, density, refractive index, thermal expansion and thermal stresses, thermal endurance of glass, toughening of glasses, strength and fracture behaviour of glass and its articles, surface tension, viscosity and its measurement, effect of temperature and composition on the physical properties of glasses

Glass making raw materials, addition of cullet to the batch, reactions amongst the constituents of glass, thermal currents and flow pattern in the glass tank furnace, Defects in glass, bubbles and seeds, cords, stresses and colour inhomogeneity and their remedies, annealing of glasses

Glass ceramics; Nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics

Text Books:

1. Ceramic Materials: Science and Engineering, C. Barry Carter, M. Grant Norton; Springer, 2nd ed. 2013.
2. Glass Science and Technology, D.R. Uhlmann, N. J. Kredl (ed); Vol. 1&2, Academic Press, 1990
3. Chemistry of Glasses, Amal Paul; Chapman Hall, 1990.

Reference Books:

1. Fundamentals of Ceramics, M.W Barsoum; McGraw Hill, 1997.
2. Introduction to Ceramics, 2nd Ed, W. David Kingery, H. K. Bowen, Donald R. Uhlmann, Wiley,1976.
3. Hank book of Glass Manufacture, F.V.Tooley; Vol 1&2, Ashlee Pub. Co, 1984.

MS510 **Composite Science and Technology** 3-0-0-6

Introduction and Overview of Metal based composites, overviews key technologies and issues in the area, Fabrication of Metal Matrix Composites: Commonly used Matrices, Basic Requirements in Selection of constituents, solidification processing of composites - XD process, Spray processes - Osprey Process, Rapid solidification processing, Dispersion Processes - Stir-casting & Compo casting, Screw extrusion, Liquid-metal impregnation technique - Squeeze casting, Pressure infiltration, Lanxide process), Principle of molten alloy infiltration, rheological behaviour of melt-particle slurry, Synthesis of In situ Composites.

Resins- Resins used in polymer composites, Fillers- Fibers, conventional fillers and nanofillers used in polymer composites. Fabrication- Different processing techniques for polymer composites. Testing and characterization, Structure property relationship in conventional polymer composites and polymer nanocomposites, Applications.

Ceramic matrix composites, mechanical properties of ceramic matrix composites, different processing techniques for ceramic matrix composites, process capability and applications of various techniques.

Text Books:

1. Composite materials, K.K. Chawala; 2nd ed.,Springer-Verlag, 1987.
2. Nanocomposite Science and Technology, P. M. Ajayan, L. S. Schadler, P. V. Braun; Wiley-VCH Verlag GmbH Co, 2013.
3. Mechanics and Analysis of Composite Materials, V.V. Vasiliev, E.V. Morozov; Elsevier Science Ltd, 2001.
4. Ceramic matrix composites, K.K. Chawala; 1st ed., Chapman & Hall,1993.
5. Advances in composite materials, G. Piatti; Applied Science Publishers Ltd., 1978.
6. Composite Materials, Mel. M. Schwartz; Vol 1 & 2, Prentice - Hall PTR, 1997.
7. Advanced Polymer composites, Bor Z.Jang; ASM International,1994
8. Experimental Characterization of advanced composite materials, L.A. Carlsson and R.B. Pipes, 2nd ed., CRC Press, 1996.
9. Handbook of Composites, George Lubin, Stanley T. Peters , Springer, 1998.
10. Mechanics of composite materials, Richard M. Christensen, Dover Publications, 2005.

MS512 **Alloy Development and Heat Treatment** 3-0-0-6

Selection of engineering alloys, including steels (carbon, alloy, stainless, dual phase, TRIP/TWIP), cast irons, aluminium, magnesium, titanium, nickel and cobalt-based superalloys and zirconium alloys. In depth understanding of the microstructures and their development for the most common classes of engineering alloys, overview of microstructures, processing and properties in engineering alloys State-of-the-art approaches to the design and development of new alloys for the 21st century

Principles of heat treatment, the heat treatment of steels, and the heat treatment of aluminium alloys respectively, Use of heat treatment to produce required metallurgical properties. Cooling curves and equilibrium diagrams Heat treatment of steels, Hardenability, Strength, and Toughness Case hardening, Carburising, and Nitriding, De-carburising Re-heat treatment, Re-tempering, Annealing, and Normalising Heat treatment of Aluminium alloys, Annealing, Solution

treatment Natural ageing, Artificial ageing, Over ageing Explanation of the heat treatment of Aluminium alloys Control testing
Introduction, Theory of Heat Treatment, Heat Treatment Environment, Different Heat Treatment Techniques, Fundamentals and Properties; Annealing, Tempering, Hardening, Thermomechanical treatment, Fundamentals of Surface Hardening Treatment, Carburizing, Carbonitriding, Nitriding, Modern surface hardening techniques; Economy of Heat Treatment Processes

Text Books:

1. Principles of Heat Treatment of Steels, R.C. Sharma; New Age International (P) Ltd, 2003.
2. The Heat Treating Source Book, ASM International, 1986.
3. Heat Treatment of Metals;W.S. Owen, Institute for Metallurgists, 1963.
4. Engineering Physical Metallurgy and Heat Treatment; Y. Lakhtein, Mir Publisher, 1979.
5. Phase Transformations in Metals and Alloys; D.A. Porter, K.E. Easterling; Taylor and Francis, 2009.
6. Materials Selection in Mechanical Design, M.F. Ashby; 3rd ed., Butterworth-Heinemann Ltd.,2005.
7. Materials and Design, M.F. Ashby and Kara Johnson; Butterworth-Heinemann Ltd, 2002.

MS514 **Joining of Materials** 3-0-0-6

Welding, theory and classification of welding, submerged arc welding, gas metal arc welding or MIG/MAG welding, TIG welding, resistance welding. Other joining processes, soldering, brazing, diffusion bonding, and adhesive bonding of metallic materials; adhesive bonding, solvent bonding, and welding of polymer materials; brazing, frit sealing, diffusion bonding, and welding of ceramic materials and composite materials; soldering, wire bonding, flip-chip bonding, and wafer bonding of semiconductor materials; welding, soldering, adhesive bonding and bone in growth of biomaterials; welding, soldering and adhesive bonding of nanomaterials.

Text Books:

1. Metallurgy of Welding, Lancaster, Allen, Unwin; Springer, 1980.
2. Welding and Welding Technology, Little R.L; McGraw-Hill Companies, 1973.
3. Advanced Welding processes, Norrish, J., Woodhead, Woodhead Publishing, 2006.

PH515 **MEMS and NEMS** 3-0-0-6

Micro and nano mechanics – principles, methods and strain analysis, an introduction to microsensors and MEMS, Evolution of Microsensors & MEMS, Microsensors & MEMS applications, Microelectronic technologies for MEMS, Micromachining Technology – Surface and Bulk Micromachining, Micromachined Microsensors, Mechanical, Inertial, Biological, Chemical,Acoustic, Microsystems Technology, Integrated Smart Sensors and MEMS, Interface Electronics for MEMS, MEMS Simulators, MEMS for RF Applications, Bonding & Packaging of MEMS, Conclusions & Future Trends.
Nanoelectromechanical systems (NEMS) – a journey from MEMS to NEMS, MEMS vs. NEMS, MEMS based nanotechnology – fabrication, film formation and micromachining, NEMS physics – manifestation of charge discreteness, quantum electrodynamical (QED) forces, quantum entanglement and teleportation, quantum interference, quantum resonant tunneling and quantum transport, Wave phenomena in periodic and aperiodic media – electronic and photonic band gap crystals and their applications, NEMS architecture, Surface Plasmon effects and NEMS fabrication for nanophotonics and nanoelectronics, Surface Plasmon detection – NSOM/SNOM

Text Books:

1. Electromechanical Sensors and Actuators, Ilene J. Busch-Vishniac, Springer, 2008.
2. Introduction to Microelectronics Fabrication, Vol. V, G. W. Neudeck and R. F. Pierret (eds.), Addison – Wesley, 1988.
3. Introduction to Microelectromechanical Microwave Systems, H. J. De Loss Santos, 2nd edition, Norwood, MA: Artech, 2004.
4. Microsystems Design, S. D. Senturia, Kluwer – Academic Publishers, Boston MA, 2001.
5. Principles and Applications of Nano-MEMS Physics, H. J. Delos Santos, Springer, 2008.
6. Materials and Process Integration for MEMS Microsystems, Vol. 9, Francis E. H. Tay, Springer, 2002.

Reference Books:

1. Quantum Mechanical Tunneling and its Applications, D. K. Roy, World Scientific, Singapore, 1986
2. Encyclopedia of Nanoscience and Technology, Vol. 5, H. S. Nalwa (ed.), American scientific Publishers, 2004
3. Carbon Nanotubes and Related Structures, P. J. F. Harris, Cambridge University Press, UK, 1986.
4. Carbon Nanoforms and Applications, M Sharon and M. Sharon, Mc Graw Hill, 2010
5. VLSI Technology, S. M. Sze (eds.), Mc-Graw Hill, NY, 1983
6. Quantum Phenomena, S. Datta, Addison – Wesley, 1989.

Lab Courses

MS519: Microstructure and Phase Analysis Laboratory

(0-0-3-3) Prerequisite NIL

Practical aspects of X-ray diffraction analysis will be emphasized; hands-on experience in qualitative and quantitative analysis techniques, use of electronic databases, and phase analysis using XRD data

hands-on experience on the applications of metallography and optical microscopy, phase analysis using microscopic information, hands-on experience in the area of microstructures of metal, ceramic and polymer materials using optical microscopy and SEM

Standard laboratory practice including safety, report writing, and error analysis are also emphasized.

MS520: Materials Characterisation Laboratory

(0-0-3-3) Prerequisite NIL

Powder characterization using XRD, SEM and BET, gas pycnometer

Thermal properties of materials, identification of materials based on their TG, DSC, DMA characteristic responses

Laboratory testing practice related to tests based on the mechanical properties of materials, e.g., hardness, elastic modulus, tensile strength etc.

Standard laboratory practice including safety, report writing, and error analysis are also emphasized.