CURRICULUM

OF

MS/PhD in Materials and Surface Engineering

School of Chemical and Materials Engineering National University of Sciences and Technology, Islamabad

Courses- MS in Materials and Surface Engineering

Framework
MS in Materials and Surface Engineering

Program Structure

Course Structure	Course No.	Course Title	Credit Hours
Core Courses			
	MS 811	Materials Thermodynamics	3
	MS 812	Phase Transformation & Microstructures	3
	MS 821	Mechanical Behavior of Materials	3
	MS 851	Surface Engineering & Characterization	3
Elective Courses			
	MS 861	Engineering Ceramics and Glasses	3
	MS 871	Polymer Engineering	3
	MS 852	Advanced Surface Coatings	3
	MS 880	Corrosion and Protection	3
	MS 862	Electronic and Magnetic Materials	3
	MS 831	Modeling of Material Processes	3
	MS 881	Manufacturing Processes	3
	MS 854	Characterization of Materials	3
	MS 872	Composite Materials	3
	MS 855	Nano Materials and Nano Processing	3
	MS 822	Fractography and Fracture Analysis	3
Thesis	MS 899	Master's Thesis Research	6

2. Programme Details. Detailed course contents are as under:-

MS 811 Material Thermodynamics (3 CH)

Concepts of Helmholtz Free Energy and Gibbs Free Energy, Energy-Property relationships, Thermal Equilibria, Chemical Equilibria, Ellingham Diagrams, 1st order and 2nd order Transformations, Gibbs Helmholtz Relationships, Fugacity and Chemical activity, Equilibrium constant and its variation with temperature, Vant Hoff's equation, Effect of temperature and pressure on phase transformations, Clapeyron equation, Thermodynamics of solutions, Gibbs-Duhem relationship, Thermodynamic properties and equilibrium phase diagrams, Mixing functions, Excess functions, Phase Rule, Gibbs free Energy and Entropy Calculations of Phase transformation, Typical Equilibrium Phase Diagrams, Statistical Methods in thermodynamics.

Suggested Reading:

- Thermodynamics of Materials (David V. Ragone)
- Introduction to Thermodynamics of Materials (D. R. Gaskell)
- Thermodynamics, an Advanced Text for Material Scientists (J. Hudson)

MS812 Phase Transformation & Microstructures (3 CH)

Ideal and Regular Solution Models, Homogeneous and heterogeneous nucleation, Evolution and Development of Microstructures, Binary and Ternary Systems, Solidification, Annealing, Precipitation, Diffusion and Non-Diffusion Phase Transformation, Nano-Phases and Nano-Structured Materials, Nature of interfaces, Nucleation on grain boundaries and dislocations, Spinodal decomposition, Discontinuous transformations, Inter-lamellar spacing and growth rate.

Suggested Reading:

- Physical Metallurgy Principles (Reed-Hill)
- Phase Transformations in Metals and Alloys (D.A. Porter, K. E.Easterling)

MS 821 Mechanical Behavior of Materials (3 CH)

Shear Forces and Bending Moments, Torsion, Analysis of Stress and Strain, Shear stress and plastic deformation, Critical resolved shear stress for slip, Slip systems, Generation and mutual interactions of dislocations, Tension test, compression and hardness testing, Types of fracture, Fracture Mechanics, Rate and Temperature dependant deformation, Visco-elastic Behavior, Impact testing, Creep deformation, Creep rupture, Fatigue failure, Stress cycles and S-N curve, Stages of fatigue.

Suggested Reading:

- Mechanical Metallurgy (G. E. Dieter)
- Deformation and Fracture Mechanics of Engineering Materials (R. W. Hertzberg)

MS851 Surface Engineering and Characterization (3CH)

Elements of material surface interactions, surface tension, Young's sessile drop model, particle surface interactions, surface analysis by ions, electrons and photons, Physical vapor deposition, Chemical vapor deposition, Application of laser and Plasma for surface modification, Characterization of coatings for surface hardness, wear resistance, adhesion and microstructure, Coatings for corrosion resistance, aesthetic appearance, optical and electronic applications, Electroplating, Electro-less Deposition.

Suggested Reading:

- Surface Science: An Introduction (J. B. Hudson)
- Advanced Surface Engineering (W. D. Sproul, K. O. Legg)

MS861 Engineering Ceramics and Glasses (3CH)

Physical, Thermal, Electrical and Mechanical Properties of Ceramics, Ceramic Crystal Structures, Processing of Ceramic Powders, Sintering Kinetics, Hot pressing, Hot Isostatic Pressing, Over pressure sintering, Phase Transformation in Ceramics, Engineering Ceramics in Chemical Processes, Filters, Machining of Ceramics and Near Net Shape Manufacture, Kinetics of Glass Transition, Fictive Temperature, Factors influencing glass transition, Viscous and Visco-elastic behavior, Phase Transformation in Glasses, Glass production Techniques and Heat reatment of Glasses.

Suggested Reading:

- Fundamentals of Ceramics (Michel Barsoum)
- Modern Ceramic Engineering (David Richerson)
- Introduction to Ceramic Materials (W. D. Kingery)
- Principles of Ceramic Processing (James Reed)
- Fundamentals of Inorganic Glasses (A. K. Varshneya)

MS 871 Polymer Engineering (3 CH)

Polymeric Materials Classification, Structure and synthesis, Polymerization, co-polymerization, polymerization conditions and polymers processes, solutions and blends, stabilization of high polymers Mechanical Properties, Rheological properties, Structure-property relationship, Engineering applications of polymeric materials, Processing and forming of polymers.

Suggested Reading:

- Introduction to Polymers (R.J. Young and P.A. Lovell)
- Synthetic Polymers: Technology, Properties, Applications (Feldman and Barbalata)

MS 852 Advanced Surface Coatings (3 CH)

Coating deposition and Surface treatment techniques, Classification of Coatings, Hard facing, Thermal spraying, Vapor deposition, Microstructural modifications, Diffusion treatment, Implantation techniques, Surface Cleaning Methods, Surface roughening, Grit Blasting, Evaporation, Activated Evaporation, Activated Reactive Evaporation, Ion Implantation, Sputtering, Chemical Vapor Deposition, Physically Enhanced Chemical Vapor Deposition, Characterization of the coatings.

Suggested Reading:

- Advanced surface coatings : a handbook of surface engineering **(**D S Rickerby, A Matthews)
- Handbook of Tribology: Materials, coatings, and surface treatments (Bhushan, B.; Gupta, B.K.)

MS 880 Corrosion and Protection (3 CH)

Electrochemical aspects of corrosion, EMF series and various corrosion cells, electrochemical polarization, passivation, types of corrosion, pitting and crevice corrosion, galvanic corrosion, stress corrosion cracking, cavitation and fretting, corrosion and fatigue, corrosion evaluation techniques, protection methods, inhibitors, cathodic and anodic protection techniques, high temperature oxidation and corrosion.

Suggested Reading:

- Handbook of corrosion engineering (Pierre R. Roberge)
- Principles and Prevention of corrosion (Denny A. Jones)
- Corrosion and Corrosion control (Herbert H. Uhlig)

MS 862 Electronic and Magnetic Materials (3 CH)

Classification of materials according to magnetic properties, origin of magnetic moment of atoms, magnetization curves, magnetic domains, soft magnetic materials, hard magnetic materials, magnetic materials processing, cast and sintered magnets, magnetostriction, metallic and ceramic magnets, extra high field strength magnets for special applications, semiconductors, binary and tertiary semiconductor materials, growth of single crystal, doping techniques, characterization of doped layers, VLSI technology, semiconductor devices.

Suggested Reading:

- Introduction to the Electronic Properties of Materials (David Jiles)
- Electronic properties of Materials (Rolf E Hummel)
- VLSI Technology (S M Sze)
- Solid State Electronic Devices (Ben G. Streetman)
- Introduction to Solid State Physics (Charles Kittel)
- Magnetic Materials: Fundamentals and Device Applications (Nicola A. Spaldin)
- Introduction to Magnetic Materials (B D Cullity, C D Graham)

MS 831 Modeling of Material Processes (3 CH)

Theory and application of atomistic computer simulations to model, understand, and predict the properties of real materials. Energy models: from classical potentials to first-principles approaches. Density-functional theory and the total-energy pseudopotential method. Errors and accuracy of quantitative predictions. Thermodynamic ensembles: Monte Carlo sampling and molecular dynamics simulations. Free energies and phase transitions. Fluctations and transport properties. Coarse-graining approaches and mesoscale models.

Suggested Reading:

- Molecular Modeling Techniques in Material Science (Jorg Rudiger)
- Topics in Computational Materials Science (C Y Fong)
- Computational Studies of New Materials (Daniel A Jelski, Thomas F George)

MS 881 Manufacturing Processes (3 CH)

Material Properties and product attributes, Solidification Processes, Metal Casting, Glass working, Shaping processes for plastics, Rubber processing, Shaping processes for composites, Particulate processing of metals and ceramics, Powder metallurgy, Metal forming and Sheet metal working, Bulk Deformation Processes, Metal Machining and Cutting, Grinding and other abrasive processes, Non traditional machining, Surface processing, Coating and deposition processes, Joining and assembly, Rapid Prototyping, Micro fabrication, Manufacturing systems, Numerical control and industrial robotics.

Suggested Reading

- Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, 2nd Edition by Mikell P. Groover
- Fundamental Principles of Manufacturing Processes by Robert H. Todd, Dell K. Allen, and Leo Alting

- Manufacturing Processes for Technology, Second Edition by William O. Fellers and William W. Hunt

MS-854 Characterization of Materials (3 CH)

Structural Characterization, X Ray diffraction patterns, Quantitative and Qualitative analysis, Energy dispersive and wavelength dispersive analysis, thermal analysis, Differential Calorimetry, Thermal Gravimetric analysis, Molecular spectroscopy techniques, IR Spectroscopy, Gamma Ray Spectroscopy, Raman Spectroscopy, Nuclear Magnetic Resonance, Auger Spectroscopy, Atomic Force Microscopy.

Suggested Reading:

- Fundamentals of Molecular Spectroscopy (Banwell & McCash)
- Characterization in Silicon Processing (Yale E Strausser)
- Characterization of Organic Thin Films (Abraham Ulman)
- Applied Laser Spectroscopy (David L Andrews)

MS-872 Composite Materials (3 CH)

Role of interfaces, processes and production of Polymer Matrix Composites, Metal Matrix Composites, Ceramic Matrix Composites, Design Aspects of Composite based structures, Application and properties of Composite Materials, Production of glass fiber and carbon fiber composites, Titanium based Composite Materials.

Suggested Reading:

- Composite Materials Design and Applications (Daniel Gay)
- Composite Materials: Engineering and Science (Frank L Mathew

MS 855 Nano Materials and Nano Processing (3CH)

Nano Fabricated Computation Devices, Bio Molecular Devices and Molecular Electronics, Integrated Micro Systems and MEMS, Molecular Manufacturing and Nano Robots, Material Engineering processes applied to Electro-active Polymers, Micro-Nano scale instrumentation and Measuring.

Suggested Reading:

- Nano Technology (Mark A Ratner)
- Engines of Creation, The coming era of Nano Technology (Eric Drexler)

MS 822 Fractography and Fracture Analysis (3CH)

Engineering Aspects of Failure and Failure Analysis, Failure Modes, Characterization of fractured surface, Chemical Analysis, Microscopic Analysis, Failure prevention and case histories, Mechanical and Metallurgical causes of Failure. Fatigue failure, Creep Failure, Brittle fracture, Corrosion induced failure, Pitting as stress concentration.

Suggested Reading

- Failure Analysis of Engineering Materials, (Charlie K Brooks)
- Metal Failures, (Arthur J McEvily)
- Mechanical Failure Avoidance, (Charles E Witherell)
- Handbook of Case Histories in Failure Analysis, Volume 1 & 2, ASM

Courses- PhD in Materials and Surface Engineering

DETAILED COURSE CONTENTS

MS 901 - Advanced Engineering Mathematics (3 CH)

Mathematical and numerical investigation of direct, iterative & semi-iterative methods of solution of linear systems. Ordinary differential equations, Applied Differential Equations, Laplace and Fourier Transformations and their application, Problems related to boundary flow of heat and mass. Perturbation theory and asymptotic approximations: Perturbation theory for algebraic equations; Regular perturbation theory, Asymptotic and uniformity; stretched time; Boundary-layer problems.

Reading list

- Advanced Engineering Mathematics, Kreyszig, E. 7th. edn., Wiley 1993
- Perturbation Methods, E. J. Hinch
- Perturbation Methods in Applied Mathematics, J. D. Cole,
- Computational and Applied Mathematics for Engineering Analysis, A. S. Cakmak
- Fourier Series, G. P. Tolstov
- Basic Partial Differential Equations, D. Bleecker and G. Csordas

MS 954 Advanced Characterization Techniques, 3CH

Electron Microscopy: Principles of electron optics and Design of important components of electron optical instruments, Beam-Matter interaction, Scanning Electron Microscopy (SEM), Environmental Scanning Electron Microscopy (ESEM), Transmission Electron Microscopy (TEM): Electron Diffraction, Convergent Beam Electron Diffraction (CBED), Analytical methods using X-ray microanalysis (EDX) and Electron Energy Loss Spectroscopy (EELS). Specific X-ray analysis techniques, Single crystal diffraction, Surface Mass Spectroscopy- SIMS: Mass detection, ToF Mass Spectroscopy. Molecular

Absorption and Atomic Absorption Spectroscopy, Induction Coupled Plasma (ICP) Absorption and Emission Spectroscopy.

Suggested Reading

- Transmission electron microscopy, D B Williams and C B Carter, Plenum Press.
- Electron Beam Analysis of Materials, M H Loretto
- Encyclopaedia of Materials Characterization, Surfaces, Interfaces, Thin Films, C. R. Brundle, C.A. Evans, S. Wilson, eds, Butterworth-Heinemannn.
- Elements of X-ray Diffraction, B. D. Cullity and S. R. Stock
- Molecular Spectroscopy, Banwell and McCash
- Characterization of Materials, 2 Volumes, Elton N. Kauffman

MS 952 Materials for Biomedical Applications, 3CH

Surface chemistry and physics of selected metals, polymers, and ceramics; surface characterization methodology; modification of biomaterials surfaces; quantitative assays of cell behavior in culture; biosensors and micro-arrays; bulk properties of implants; and acute and chronic response to implanted biomaterials. Synthetic Materials for Orthopeadic and Dental applications, Bio compatibility of Metallic, Polymeric and Ceramic implants. Special Implants and Materials for Stents.

Suggested Reading

- Biomaterials Science: An Introduction to Materials in Medicine, Ratner, Buddy D.
- Engineering Materials for Biomedical Applications, Hin, Teoh Swee.

- Bio-Implant Interface: Improving Biomaterials and Tissue Reactions by J.E. Ellingsen and S.P. Lyngstadaas
- Bio-Based Polymers and Composites by Richard Wool and X. Susan
- Bio-Materials & Prototyping Applications in Medicine by Bopaya Bidanda and Paulo Bartolo
- Bio-Implant Interface: Improving Biomaterials and Tissue Reactions by J.E. Ellingsen and S.P. Lyngstadaas
- Bio-MEMS: Technologies and Applications by Wanjun Wang and Steven A. Soper

MS 963 Semiconductor and Optical Materials 3CH

Review of Atomic Structure and Statistical Mechanics, Semiconductor Materials and their Properties, Energy Bands in single crystals, Fermi energy and Fermi Surface, Compound Semi Conductors, Metal-Semiconductor contacts, Rectifying contacts, Ohmic Contacts, Zener Diodes, Photo-Diodes, Carrier transport in Semiconductors, Optical Constants, Damping Constant, Quantum Mechanical treatment of Optical Properties, Optical Spectra of pure metal, ceramics and glasses. Crystal Growth and Wafer Preparation, Epitaxial Growth, Lithography, Dielectric and Polysilicon Film Deposition, Metallization, Ion Implantation,

Suggested Reading

- Introduction to Semiconductor Materials and Devices, M. S. Tyagi
- Electronic Properties of Materials, Rolf E. Hummel (Springer)
- Semiconductor Optoelectronic Devices, Pallab Bhattacharya (Prentice Hall)
- Solid State Electronics, Ben G. Streetman (Prentice Hall)
- Introduction to Solid State Physics, Charles Kittel

- Fundamentals of Semiconductor Manufacturing and Process Control, Gary S. May, Costas J. Spanos
- Semiconductor Material and Device Characterization, Dieter K. Schroder
- VLSI Technology by S M Sze

MS 941 Materials for High Temperature Applications, 3CH

Elevated-temperature characteristics of Engineering Materials, Mechanical properties at elevated temperatures, Corrosion at elevated temperatures Super alloys: Properties, Metallurgy and Processing of Superalloys, Directionally solidified and single-crystal Superalloys, Powder Metallurgy of Super alloys, Heat Treatment of Superalloys, Elevated-Temperature corrosion of Superalloys, Microstructural instabilities, Thermal Barrier Coatings, Nonferrous Heat-Resistant Materials, Titanium Alloys, Refractory Metals and Alloys, Structural Intermetallic.

Suggested Reading

- Creep of metals and alloys, R W Evans, B Wilshire
- Nickel-base alloys, in Superalloys II, E W Ross, C Sims,
- Materials response to thermal-mechanical strain cycling in High temperature fatigue, D A Miller, R H Priest
- Materials for High Temperature Engineering Applications (Engineering Materials) by G.W. Meetham and M.H. Van de Voorde
- Titanium Alloys at Elevated Temperature: Structural Development and Service Behaviour (Microstructure of High Temperature Materials) by Michael Winstone

MS 951 Interface Engineering

Energetic material bonding to intermediate layers, Surface energetics and fracture mechanics, Morphology and Viscoelastic Behavior, Mophology of micro-phase segregation, compatibility of precursor materials and hard/soft segments; segmented and cross-linked polymers, viscoelasticity, networks and structure-property relations; analysis and application of viscoelastic models to practical systems; stress-strain, stress relaxation, and creep compliance; linear and non linear response in fabricated energetic materials; understanding of dynamic mechanical response. Fracture Mechanics, The various test geometries used in the evaluation of adhesion are rigorously analyzed in terms of strain energy release rate at the material-substrate junction. Advanced techniques e.g. lateral modulus gradient on the delamination of material combinations.

Reading List

- Fundamentals of Interface Engineering, R.J. Stokes and D.F. Evans, Wiley (1997)
- Energetic Composites, Handbook of Engineering Polymeric Materials, M.B. Khan, Marcel Decker, N.Y. (1997)
- Fracture Mechanics: Fundamentals and Applications, 3rd Edition, T.L. Anderson, CRC Press (2004)
- Preparation and testing of Adhesive Joints: B. Broughton and M. Gower, National Physical Lab (NPL) U.K. (2004).