

## 2. MSc Surface Science and Engineering

### Core Courses

#### **SSE-501 Principles of Surface Science (3+0)**

Structure of surface, surface reactivity, crystallography of the surface, surface equilibrium, restructuring and relaxation, Surface electronic structure and Experimental methods, Different types of bonding, adsorption on the surface, Kinematics and dynamics of surface processes, surface activity and reactions, Heterogeneous catalysis, Layer-by-layer growth and island formation, Epitaxial growth, interfaces and their properties, surface Segregation.

#### **Recommended Books:**

1. Bracco, Gianangelo, Holst, Bodil, "Surface Science Techniques", Springer, 2013
2. Oura, K., Lifshits, V.G., Saranin, A., Zotov, A.V., Katayama, M. Brandon, D. and Kaplan, W. D., "Surface Science: An Introduction", Springer, 2nd Edition. 2008.

#### **SSE-502 Surface analysis and characterization (3+0)**

Advanced methods of surface and coating characterization:

X-ray diffraction and electron microscopy: X-ray diffraction, scanning and transmission electron microscopy, main principles, electron diffraction, possibilities and restrictions  
Spectroscopy: X-ray photoelectron spectroscopy. Auger-electron spectroscopy, Energy-dispersive spectroscopy, Glow-Discharge Optical Emission Spectroscopy, Raman and FTIR spectroscopy

Methods of contact and non-contact characterization of surface topography: Roughness: parameters and methods of measurements, Optical profilometry, Atomic force microscopy, Scanning probe microscopy

#### **Recommended Books**

1. Donald Mattox, Handbook of Physical Vapour Deposition (PVD) Processing, 2nd Edition, William Andrew 2010
2. John B Hudson, "Surface Engineering: An Introduction", Butterworth Heinemann, 2000.
3. Bose "High Temperature Coatings" Butterworth Heinemann 2007
4. Lang E., "Coatings for High Temperature Applications", Applied Science, 2000

### **SSE-503 Mechanical Behaviour of Thin Films and Coatings (3+0)**

Introduction to thin films, microstructure, Thin film technology, Problems associated with mechanical behaviour (Tolerance, Failure, Wafer cracking, Thin film peeling, Metal cracking problem, Electro-migration problem), Origins of stresses in thin films, Mechanics of thin films and substrates, Mechanics of residual stresses, Stress diagram, Misfit Strain, Thin film growth mechanism and stresses associated with growth, Analysis of stresses in thin film/coatings (Diffraction Techniques, Raman Spectroscopy, Curvature measurement, Cantilever beam bending, FIB-DIC technique)

Adhesion of thin films, In-situ micro-tensile testing (SEM, XRD, AFM, Raman spectroscope etc.), Stress-strain response of coating/substrate system, Raman spectroscopy in thin film stress evaluation during tensile testing, Coated-uncoated tensile test, Cracking and delamination of thin hard films under uniaxial deformation, Methods based on Agrawal and Raj shear lag model, Observations on Shear lag model, Interfacial strength and von Mises' yield criterion, Modifications in Agrawal and Raj model and Normal and shear stress distribution in thin films under uniaxial loading, Edge effects/segment size effects/Bending effects (theory) and shear lag model (Role of FEM and Raman spectroscopy)

Role of FEM in establishing mechanical behaviour of thin films and coatings, Cohesive zone FEM, Effect of Material Properties and Geometric parameters on the cracking behaviour,

Other mechanical testing methods: Nano-indentation, Scratch testing, Rockwell adhesion Testing, Bulge test, Micro-pillar compression Test, Peel Test, Three/Four point bend test, Wear Test.

#### **Recommended Books**

1. Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, Wiley 2012.
2. Joachim Roesler, Harald Harders, Martin Baeker, Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites, Springer 2010
3. Magonov, S. N. and Myung-Hwan Whangbo, "Surface Analysis with STM and AFM. Experimental and Theoretical Aspects of Image Analysis", VCH, 1996

### **MME-504 Corrosion and Corrosion control (3+0)**

Overview of Corrosion Science and Corrosion Engineering, The function and role of a Corrosion Engineer, Strategic impact and cost of Corrosion damage, Corrosion Kinetics and Applications of Electrochemistry to Corrosion, Activation polarization, concentration polarization and combined polarization. Reference electrodes. Passivity and passivity of alloys, Mechanisms of growth and breakdown of passive films, Corrosion failure, factors and Cells, Corrosion in soils and microbiologically influenced corrosion,

Prediction Corrosion Behavior, Corrosion Rate Measurements,

Corrosion Testing, Exposure Techniques, Evaluation of Different Types of Corrosion Corrosion Prevention Methods, Proper Materials Selection, Alteration of Environment, Design Considerations, Cathodic and Anodic Protection, Cathodic protection in Soils, Cathodic protection in Concrete, Sacrificial Cathodic Protection, Impressed Current Cathodic Protection, Inhibitors and Passivators, Protective Coatings, Coating Inspection and Testing,

High Temperature Corrosion, Pilling-Bedworth Ratio, Electrochemical and Morphological Aspects of Oxidation, Oxidation Kinetics, Effect of Alloying, Catastrophic Oxidation, Corrosion of Metals by Sulfur Compounds at High Temperatures, Practical High Temperature Corrosion Problems

#### **Recommended Books**

1. Pierre Roberge, Handbook of Corrosion Engineering 2/E, McGraw-Hill Professional 2012
2. Revie and Uhlig “Corrosion and Corrosion Control” Wiley 4th Ed. 2008
3. Fontana, M. G., “Corrosion Engineering”, McGraw-Hill, 2005
4. I. H. Khan, Corrosion Technology, Vol. 1 & 2, Institute of Chemical Engineering, Uni. of The Punjab, Lahore, Pakistan.

#### **Elective Courses:**

### **SSE-504 Conventional Surface Engineering Methods (3+0)**

Surface cleaning: Mechanical cleaning, Chemical cleaning, Cleaning fluids. Grinding, Polishing, Etching, Pickling, Buffing.

Electro and electroless plating, Electroforming, Conversion Coatings, Painting, Enamelling, Glazing, Hot dipping (aluminizing, galvanizing, tinning, terne coating etc.).

Case Hardening and Hard facing: Carburizing (pack, liquid, gas, vacuum), Cyaniding, Carbonitriding, Nitriding, Plasma (ion) Nitriding, Nitrocarburizing, Boronizing, Chromizing (hard and soft), Toyota Diffusion (TD) Process, Flame hardening, Induction hardening, Hard facing.

Diffusion Mechanisms, Steady State Diffusion, Non-Steady State Diffusion, Factors influencing Diffusion.

Mechanical surface treatments: Shot Peening, Water-jet Peening, Roller Burnishing, Explosive Hardening, Cladding, Mechanical Plating

### **Recommended Books:**

1. Elton N. Kaufmann, Characterization of Materials, Wiley 2012
2. Brandon, D. and Kaplan, W. D., "Microstructural Characterisation of Materials", Wiley, 2nd Edition. 2008.
3. Wachtman, J. B., "Characterization of Materials, Butterworths-Heinemann, 2000  
Loretto, M. H., "Electron Beam Analysis of Materials", 2<sup>nd</sup> Edition, Chapman and Hall, 1984
4. Flewitt P.E.J., Physical Methods for Material characterization, 2<sup>nd</sup> Edition, IOP, 2003

### **SSE-505      Advance Surface Engineering Practices      (3+0)**

Introduction to Surface Engineering and Coating Processes (PVD, CVD, Ion-Beam and Other Techniques), Vacuum Science and Technology (Plasma Physics and Chemistry, Surface Interactions), Sputter Deposition, Nucleation and Growth, Recent Advances in Surface Cleaning and Preparation Techniques, Hybrid Coatings and Deposition Processes

Electrical gas discharges, as a key process in the modern coating deposition technologies:

Plasma, Electron emission, Ionization, Dark discharge, Normal and abnormal glow discharges

Advance Deposition and surface modification methods: Physical vapor deposition: Magnetron sputtering, Ion implantation assisted magnetron sputtering, Cathode-arc evaporation, Filtered CAE, HIPIMS

Chemical vapor deposition: CVD with thermal activation, PACVD, ALD

Methods of surface modifications: Ion implantation, Ion etching, Laser treatment, Selective laser sintering

### **Recommended Books:**

1. Donald Mattox, Handbook of Physical Vapour Deposition (PVD) Processing, 2nd Edition, William Andrew 2010
2. John B Hudson, "Surface Engineering: An Introduction", Butterworth Heinemann, 2000
3. Bose "High Temperature Coatings" Butterworth Heinemann 2007
4. Lang E., "Coatings for High Temperature Applications", Applied Science, 2000
5. Heinz Dimigen, "Surface Engineering", Wiley-VCH, 2000, ISBN 3527301968

### **SSE-506 Tribology of Surfaces (3+0)**

Introduction to Tribology, Contact mechanics and Surface topography

Fundamentals of friction, Friction in metals, Friction in ceramics and plastics, Temperature at contacts, methods to reduce friction, Friction measurement methods

Wear and its types, Wear of plastics and ceramics, Wear measurement methods like: Visual, Tactile, Profilometry, Weighing, Abrasive wear testing, Rolling sliding wear testing, Pin-on-disc wear testing.

Lubrication, Types of lubrication (Hydrodynamic, Boundary lubrication, Hydrostatic lubrication, Elastohydrodynamic lubrication, Extreme Pressure lubrication, Mixed lubrication), Wear in lubricated contacts, Different Metalworking fluids, Solid lubricants (Graphite, Molybdenum Disulphide, Metallic and Polymeric Films, Glasses), Conversion Coatings, Selection of Metalworking fluids

Relationship between nano / micro / macro tribology, Tribology of machinery components, Tribology of magnetic storage devices, Different Case studies

### **Recommended Books:**

1. Donald Mattox, Handbook of Physical Vapour Deposition (PVD) Processing, 2nd Edition, William Andrew 2010
2. Kenneth Holmberg, Allan Matthew, Coatings Tribology, properties, Mechanism, Techniques and Applications in Surface Engineering, Elsevier, 2nd Edition, 2009.
3. Smith, D. L. "Thin Film Deposition, Principles and Practice", McGraw-Hill, 2000.
4. Grainger, S. and Blunt, J., "Engineering Coatings", Woodhead, 1998.
5. Lang E., "Coatings for High Temperature Applications", Applied Science, 2000
6. J. Mazumder Kluwer, "Laser Processing Surface Treatment and Film Deposition" Academic Publishers, 1996, ISBN 0792339010

### **MME-502 Composite Materials (3+0)**

History of composite materials, Classification of composite materials, Properties of composites compared to other materials, Introduction to different types of reinforcement, Manufacturing processes of fibers, Characteristic features of fibers, Introduction to different types of matrices, Interfaces and their characterization, Chemical structure and characteristic features of matrices, Curing system and formulations, Macro and Micro Mechanics of Composites, Principles and features of different mechanical test methods, Processing of thermoplastic matrix composites, Processing of thermosetting matrix composites, Processing of Metal matrix composite, Properties of MMCs, Application of MMCs, Multi-filamentary Superconducting Composites, Processing of ceramic matrix composites, Carbon-carbon composites, Secondary Processing and Joining of Composite. Industrial Application of Composite Materials, Fatigue and Creep Properties of Composites.

### **Recommended Books**

1. Ronald F. Gibson, "Principles of Composite Material Mechanics", 3rd ed, September 2011

2. Ever J. Barero, "Introduction to Composite Materials Design", 2nd ed, July 2010
3. Deborah D L Chung, "Composite Materials", Springer, 2003

### **MME-518                      High Temperature Materials                      (3+0)**

Introduction, applications and requirements of materials to be used in high temperature. Corrosion at elevated temperatures. Design of Alloys for High Temperature Services, Strengthening Mechanisms, Creep and Stress Rupture, Fatigue and Thermal Fatigue.

Super-alloys: their processing, high temperature mechanical properties, corrosion behaviour, micro-structural degradation behaviour of super alloy, Ni, Ti, Co and Fe base super alloys, refractory metals and alloys, oxidation resistant coatings and thermal barrier coatings

High temperature polymers, carbon-carbon composites, carbon-matrix composites for refractory applications.

Application of High Temperature Materials in automotive and aerospace industry.

### **Recommended Books**

1. Yoseph Bar-cohen, High Temperature materials and mechanisms, Taylor & Francis Group, 2014
2. Meetham, G.W., Van de Voorde, M.H. Materials for High Temperature Engineering Applications, Springer, 2000.
3. John B Hudson, "Surface Engineering: An Introduction", Butterworth Heinemann, 2000
4. Bose "High Temperature Coatings" Butterworth Heinemann 2007
5. Lang E., "Coatings for High Temperature Applications", Applied Science, 2000

### **SSE-507                      Functional Materials and Coatings                      (3+0)**

Crystal structures and defects in functional materials, Heat conduction mechanisms and thermal expansion. Electrical conduction, insulation, dielectric, optical and magnetic properties of various materials.

Application fields of porous functional materials, Functional surface properties. Self-cleaning, easy-to-clean surfaces, photo catalysis, antibacterial surfaces. Biologically inert or active materials, bio ceramics.

Functional materials coatings: Functional coatings for metals, polymers and glasses: hydrophobic and hydrophilic surfaces, anti-ice coating, anti-microbial coatings, air curable coatings

Coatings for large area application: transparent conductive coating, barrier coatings, integrated functional coatings.

Bio functional coatings: biocompatible and bioactive coatings.

### **Recommended Books**

1. Shi, Donglu, Functional Thin Films and Functional Materials, Springer, 2003
2. Seeber, Renato, Terzi, Functional Materials in Amperometric Sensing, Springer, 2014
3. Tiwari, L. Uzun, Advanced Functional Materials, Wiley, 2015
4. Martin Scholz, Biofunctional Surface Engineering, Pan Stanford Publishing, 2014
5. Wolfgang Knoll, Handbook of Biofunctional Surfaces, Pan Stanford, 2013

### **SSE-508 Vacuum Technology (3+0)**

Vacuum ranges, flow types, Adsorption, desorption, Different types of Vacuum pumps, Vacuum systems and pumping stations, Design and operation, measurements, equipment for measurements, Leak detection and methods, different calculations, detachable and non-detachable connections, flanges, valves and materials

### **Recommended Books**

1. Roth A. "Vacuum Technology", North-Holland, 2007.
2. Mattox, D. M. "The Foundations of Vacuum Coating Technology", Noyes Data Corporation/Noyes Publications, 2003
3. Jorisch W. "Vacuum Technology in the Chemical Industry", John Wiley & Sons Inc., 2010.



**SSE-509      Biomaterials and Bioactive Coating      (3+0)**

Introduction and applications of biomaterials, Biocompatibility, biomimetic materials and tissue engineering, Body reaction and response to material implantation, Tissue response to material implantation, Blood response and hemocompatibility.

Metallic Biomaterials (Stainless steels, Co-Cr, Titanium alloys, gold and noble metal alloys, NiTi, and Shape Memory Alloys), Bio-corrosion, Bioceramics (Hydroxyapatites), Bioinert, biodegradable and bioactive ceramics, Hard and soft tissues, Collagen and elastin, Tissue-derived biomaterials, Synthetic polymers, Composite biomaterials, Prostheses, Biocompatibility tests.

Biocoatings: Types of biocoatings and substrate materials, Biocompatible and bioactive coatings, Antibacterial coatings, Types of biological tests for bioactive coatings.

**Recommended Books**

1. M. Niinomi, T. Narushima, M. Nakai, Advances in Metallic Biomaterials, Springer, 2014
2. Cuie Wen, Surface Coating and Modification of Metallic Biomaterials, Woodhead Publishing, 2015.
3. Wolfgang Knoll, Handbook of Biofunctional Surfaces, Pan Stanford, 2013

**MME-512      Polymeric Materials      (3+0)**

Introduction and applications of polymeric materials, Mechanisms/methods of polymer formation Viscoelasticity of polymer melts. Viscosity dependence on temperature, pressure, structural parameters and test conditions. Recycling of polymers.

Advanced synthesis methods, hybrid polymers and inorganic nanomaterials, stimuli responsive polymers, biopolymers in materials synthesis, interfacial properties of polymer brushes, polyelectrolytes, polymer nanocomposites, and nanofabrication of

biopolymers. Living polymerizations; controlled radical polymerizations, dendrimers and hyperbranched polymers; copolymers, degradation of polymers, chemical transformations of synthetic and natural polymers, polymers from renewable resources; self-healing polymeric materials.

Polymer Coatings: Design and formulation of waterborne, high-solids and powder coatings. Stimuli-responsive polymeric films and coatings, smart coatings and nano-coatings, design requirements and considerations, evaluation of polymer coatings

### **Recommended Books**

1. Rose A. Ryntz, Philip V. Yaneff, Coatings of Polymers and Plastics, CRC Press, 2003.
2. Arthur A. Tracton, Coatings Materials and Surface Coatings, CRC Press, 2006.
3. Mark, James E, Physical Properties of Polymers Handbook, Springer 2007.

### **General Elective Courses**

#### **MME-526    Production Management and Quality Control                    (3+0)**

Principles of Organization charts based on line-staff-committee aspects. Social psychology. Personnel and legal aspects of labour relations. Unions. Factory Laws. Health and safety in industry. Costs, depreciation, yields and Scrap.

Financial controls. Investment assessment. Accounting. Interpretation of balance sheets. Stocks. Limited liability companies. Financial direction. Bank. Money market. Stock Exchange. Current economic problems. Introduction to principles of operational research and work study.

Selection and assessment of materials. Management statistics.

Introduction to Management Information Systems, People, Organizations, Systems and Management, Systems and Models, Management and Decision Making.

Information Technology Concepts: Hardware Fundamentals. Software Fundamentals. Database Management. Telecommunications. Transaction Processing and Management. Decision support system. Knowledge based system. Office Information systems.

Building Management Information Systems: Requirement Analysis, system design, system acquisition. Information and Maintenance. End user computing and development. M/s Management.

Information Resource Management. Selected issues in M/s Management.

### **Recommended Books**

1. Lockyer, K. G., "Production Control in Practice", Pitman, 2007
2. Norman Gaither, "Production and Operation Management", Dryden Press, 2007
3. William Gavett Harcourt, "Production and Operation Management", Brace & World, 2006

### **MME-527 Industrial Safety and occupational hazards (3+0)**

Introduction to occupational health and safety, definition and classification of accidents, job safety analysis, accident investigation, definitions of slip, trip and falls, walking and working surfaces, fall prevention and protection, Exposures to chemical, biological, and radiological hazards, Manual materials handling and lifting, Equipment-aided handling, Powered industrial trucks, Cranes, Materials storage, OSHA recordkeeping and reporting General requirements of PPE, Eye, head, hand, foot protection, First Aid, Fire and process safety (cause, prevention, response to fire, training for fire protection, emergency plans, emergency marking, plan for emergency), respiratory hazards, air monitoring, ventilation (control of airborne hazard), confined space standard, occupational noise exposure, temperature stress, electrical wiring methods, polarity, grounding, extension cords, plug-and cord connected equipment, combustion and explosion, controlling ignition hazards, Hazardous agents (metals, gasses, corrosives, solvents, biocides, etc.), Toxicology – exposure and entry (Exposure routes, Local effects, Gastrointestinal absorption, Respiratory absorption, Skin absorption etc.), Ergonomic ailments and their causes (Anatomy basics, Cumulative

trauma disorders, Hand-arm vibration syndrome, human factor problems), Identification and control of ergonomic stresses (Injuries and other indicators of ergonomic problems, Major risk factors: repetition, force, position, Other factors: vibration, cold, sharp edges, production pressure, environment), Ergonomically neutral positions, Ergonomic task analysis, Control of ergonomic stresses: administrative, engineering, personal protection, Tool and task design, Risk assessment and management, OSHA four point program, training and motivation, inspection programs.

### **Recommended Books**

1. Thomas J. Anton, "Occupational Safety & Health Management", 2nd ed, McGraw Hill, 2006
2. Daniel E. Della-Giustina, "Safety and Environmental Management", 2001
3. Ronald Packman, "A Guide to Industrial Safety and Health" Longmans, 2007