

Material Science and Engineering Program Course Descriptions

MSE 200 Advanced Engineering Mathematics (3-0-3) This course presents basic mathematical methods for engineers including: differentiation and integration, Taylor's expansion, linear systems resolution and matrix formalism, partial differential equations, Laplace, Fourier and Legendre transforms, statistics and probability

MSE 201. Fundamentals of Materials Science and Engineering (3-0-3) This course is intended for students who do not have a materials science & engineering background. The course will cover four major topics including: (1) fundamental concepts (2) microstructure development & phase equilibria (3) material properties and (3) fabrication methods and applications. The course will cover atomic structure, atomic bonding, crystal structures, defects, and diffusion in materials. It also will cover phase transformations and phase equilibria and how they impact microstructure development. The electrical, magnetic, optical, thermal, and mechanical properties of materials will also be reviewed. The course will also highlight modern fabrication technologies and applications of metals, ceramics, semiconductors, and polymers.

MSE 202. Mechanical Behavior of Engineering Materials (3-0-3) This course explores the phenomenology of mechanical behavior of materials at the macroscopic level and the relationship of mechanical behavior to material structure and mechanisms of deformation and failure. Topics covered include elasticity, viscoelasticity, plasticity, creep, fracture, and fatigue, elementary theory of statics and dynamics of dislocations, fundamentals of thermal behavior: heat capacity, thermal expansion and conductivity; effects of thermal stress.

MSE 203. Materials Characterization (3-0-3) This course will introduce the basic principles of materials characterization and the common characterization techniques available at KAUST. It will cover the following topics: Diffraction methods: basic principles, interaction of radiation and particle beams with matter, XRD, scattering techniques; Spectroscopic methods; Imaging: optical including confocal microscopy, scanning, transmission electron, scanning tunneling and field ion microscopy; Microanalysis and Tomography: energy dispersive, wavelength dispersive, Auger Processes, Electron, Ion and Atom Probe Tomography, SIMS, photoelectron spectroscopy; thermal analysis: DTA, DSC. Lab visits and demonstrations will be scheduled to the class to discuss some case studies.

MSE 204. Electrochemistry & Corrosion (3-0-3) This course offers, in a first part, an overview of the fundamentals of electrochemistry including thermodynamics, non-equilibrium systems and Electrode/Electrolyte interfaces followed by an Introduction to modern applications of electrochemistry such as synthesis of nanoparticles, nanowires and thin films; as well as electrochemical means of energy conversion and storage. The second part deals with Corrosion phenomena: types of corrosion cells and damages, thermodynamics and kinetics, uniform corrosion, passivity, localized corrosion, atmospheric and high temperature corrosion, environmentally induced cracking. Prevention of corrosion using electrochemical and surface engineering means. Corrosion mechanisms and protection of materials of practical interest.

MSE 205. Materials Modeling (3-0-3) *Prerequisites: Applied Quantum Mechanics MSE 232.*

Introduction to the theory and application of materials modeling techniques. Advantages of modeling to the engineer. Data requirements and structuring. Analytical and numerical methods. Basic numerical algorithms. Modeling for different length scales from atomistic to continuum. Band structure approaches for crystalline solids. Density functional theory. Classical and quantum molecular dynamics. Application and use of commercial and freeware computer packages.

MSE 206. Structural Ceramics (3-0-3) Powder preparation and characterization: production of powders, with emphasis on chemical routes for nano-grained oxide and non-oxide materials. Powder characterization: particle shape, particle size and size distribution, specific surface area.

Consolidation and forming: inter-particle forces and colloid stability. Binders and dispersants. Shaping methods: die pressing, isostatic pressing, extrusion, tape casting, screen printing, spin coating, deep coating, ink jet printing. Sintering: driving force and material transport mechanisms, role of grain boundaries and pores, grain growth and pore stability, liquid phase sintering. Nanosintering (grain growth control techniques): pressure-assisted sintering, spark plasma sintering, microwave sintering. Production of flat glass by the float process. Controlled crystallization of glass for glass ceramics.

MSE 207. Biomaterials (3-0-3) This course offers a basic understanding of the concepts underlying the design and selection of materials for use in biological applications. It focuses on both hard and soft tissue materials. The class addresses modern topics including biosensors, surface and interface functionalization. Further topics include: A brief introduction to relevant tissue types: anatomy, biochemistry and physiology; concepts of biocompatibility, host response, material degradation, testing and selection criteria; an overview of current research on biomechanics and its relevance to prosthesis design and tissue engineering; basic concepts of drug delivery and molecular biomechanics.

MSE 208. Nanomaterials (3-0-3) This course describes the most recent advances in the synthesis, fabrication and characterization of nanomaterials. Topics to be covered: Zero-dimensional nanomaterials, including nanoparticles, quantum dots and nanocrystals; one dimensional materials including nanowires and nanotubes; two-dimensional materials: including self-assembled monolayers, patterned surfaces and quantum well; three-dimensional nanomaterials: including nanoporosity, nanocomposites, block copolymers, and supra-crystals. Emphasis on the fundamental surface and size-related physical and chemical properties of nanomaterials; and their applications in biosensing, nanomedicine, catalysis, photonics, and nanoelectronics.

MSE 209. Polymeric Materials (3-0-3) This course describes polymerization processes; polymer solutions (Flory-Huggins model and application to polymer blends); polymer chain conformations; calculation of end-to-end distribution function $W(r)$ for short range interacting chains; rotational isomeric state scheme and temperature dependence; chain with long range interactions (excluded volume effect); radius of gyration; the crystalline and amorphous states of polymers; the glass transition (configurational entropy model); mechanical, electrical and optical properties and characterization of polymers.

MSE 210. Functional Ceramics (3-0-3) Fundamental concepts relevant to functional ceramics will be reviewed, including defect chemistry and reactions, Brouwer diagrams, Ellingham diagrams, Heckman diagrams, ionic and electronic transport, and tensor notation. The physics, materials, and applications for the following classes of functional ceramics will be covered: linear dielectrics, ferroelectrics & multiferroics, piezoelectrics, pyroelectrics, electrooptics, thermoelectrics, and semiconducting oxides. Selected technological applications will be reviewed including varistors, sensors, MEMs, capacitors, memories, transistors, night vision systems, positive temperature coefficient resistors, and electro-optic devices.

MSE 211. Engineering Alloys (3-0-3) This course offers a basic understanding of materials requirements of alloys for various applications. Topics covered include: the trade-off between properties (e.g., strength and toughness) and micro-structure; the impact of alloy composition on the micro-structure; property differences and design philosophy in steels, nickel-, titanium- and aluminum- based alloys, focusing on construction, aerospace and automotive applications; alloy evolution and Production routes.

MSE 212. Mechanical Behavior of Composite Materials (3-0-3) (Same as ME 343) Response of composite materials (fiber and particulate reinforced materials) to static, cyclic, creep and thermomechanical loading. Manufacturing process-induced variability and residual stresses. Fatigue behavior, fracture mechanics and damage development. Role of the reinforcement-matrix interface in mechanical behavior. Environmental effects. Dimensional stability and thermal fatigue. Application to polymer, metal, ceramic and carbon matrix composites.

MSE 213. Materials for Energy (3-0-3) Emphasizes materials engineering aspects and the role they play in important energy related technologies such as energy harvesting approaches, supercapacitors and energy storage media, batteries, fuel cells, bio-energy, nuclear energy, solar and wind based power generation, thermoelectricity, and Hydrogen generation.

MSE 216. Crystallography & Diffraction (3-0-3) The objective of this course is to present the basic concepts needed to understand the crystal structure of materials. Fundamental concepts including lattices, symmetries, point groups, and space groups will be discussed and the relationship between crystal symmetries and physical properties will be addressed. The theory of X-ray diffraction by crystalline matter along with the experimental x-ray methods used to determine the crystal structure of materials will be covered. Application of X-ray diffraction to proteins, electron diffraction and neutron diffraction will be briefly discussed.

MSE 217. Kinetics and Phase Transformations (3-0-3) *Prerequisites: MSE224.*

The course offers a modern and fundamental understanding to the main concepts and practical applications of Kinetics and Phase Transformations in materials science. The following major topics are discussed within the frame of this course: kinetics of homogenous chemical reactions, thermodynamics of irreversible processes including an introduction to the Onsager postulates, mathematical description of Diffusion in Materials (Fick's Laws and an atomistic description via random-walk process). Basic concepts of phase transformation theories, including homogeneous and heterogeneous nucleation and growth, spinodal decomposition and Landau theory of phase transformation

MSE 218. Thin Film Science & Engineering (3-0-3) Thin films and coatings are the material building blocks of many modern and pervasive technologies ranging from electronics to optics and photovoltaics, and from anticounterfeiting to glazings and hard coatings. The fundamentals and atomistics of thin film growth are discussed in detail. Deposition techniques for thin films and coatings are presented, including physical and chemical vapor depositions, molecular beam epitaxy, atomic layer deposition, and low-pressure plasma processes. Organic thin film deposition. Solution-processing and printing of inorganic, and hybrid organic-inorganic thin films. Artificially structured and chemically modulated layered and nanocomposite materials. Ex situ/in situ characterization of thin films and coatings.

MSE 219. Electronic, Optical, Magnetic, and Thermal Properties of Materials (3-0-3) This course offers an overview of the electronic, optical, magnetic and thermal properties of materials, not limited to solid state. It covers the fundamental concepts of band structure and bonding of materials, electrical and thermal conduction in metals, semiconductors and dielectric. The interaction between light and matter will be addressed and important concepts such as excitons will be introduced. Finally magnetism and superconductivity will be introduced. Although a significant part will be devoted to the study of solid state, the physical properties of non-crystalline and liquid materials will be mentioned.

MSE 221. Defects in Solids (3-0-3) The course will cover the various types of defects that occur in solids including point, linear, two-dimensional, and three-dimensional defects. Non-stoichiometry in materials, defect equilibria, reactions, Kroger-Vink formalism, Brouwer and Ellingham diagrams will be discussed. The physics and thermodynamic aspects of defect formation, mobility, and interaction will be discussed. Defects common in metals, ceramics, and polymers will be reviewed and differences highlighted. The impact of each defect type on the mechanical, electrical, optical, magnetic, and thermal properties of materials will be discussed.

MSE 222. Solar Cell Materials and Devices (3-0-3) This course will provide the students with an up-to-date basic knowledge of the physical and chemical principles of materials used in solar cells of various kinds including but not limited to technologies such as:

- 1) silicon based solar cells,
- 2) CIGS, CIS and other inorganic thin film solar cells,
- 3) multijunction solar cells,
- 4) nanoparticles and quantum dots solar cells,
- 5) organic and hybrid solar cells and

6) thermal and concentrator solar power generation.

MSE 223. Soft Materials (3-0-3) This course covers chemical and physical aspects of soft materials such as gels, polymers, lipids, surfactants and colloids; physical chemistry of soft materials; phase transformations and self-assembly; the role of intermolecular and surface forces in determining morphology and hierarchy. Membranes, catalysis, drug delivery, flexible and stretchable materials and devices

MSE 224. Statistical Thermodynamics & Equilibrium Processes (3-0-3) *Prerequisites: Advanced Engineering Mathematics MSE 200 (Students might attend this course as co-requisite).* The course offers a modern fundamental understanding to the main concepts and practical applications of thermodynamics in materials science. The following major topics are discussed within the frame of this course: review of basic laws of classical thermodynamics, an introduction to phase equilibria including the theory of solutions, chemical reaction and surface and interfacial phenomena. Additionally, an introduction to statistical thermodynamics of gases and condensed matter is provided.

MSE 232. Applied Quantum Mechanics (3-0-3) *Prerequisites: Advanced Engineering Mathematics MSE200.* Introduction to non-relativistic quantum mechanics. Summary of classical mechanics and electrodynamics. Postulates of quantum mechanics, wave functions, and operator formalism. Stationary state problems, including quantum wells. Harmonic oscillator. Angular momentum and spin. Atoms, molecules, and band theory of solids. Time evolution. Approximation methods for time-independent as well as time-dependent interactions, including electromagnetism. Scattering theory. Modern applications.

MSE 298. Graduate Seminar (variable credit) Master-level seminar focusing on special topics within the field

MSE 299. Directed Research (variable credit) Master-level supervised research.

MSE 392. Advanced Topics in Material Science I (variable credit) Lecture-based class.

MSE 393. Advanced Topics in Material Science II (variable credit) Lecture –based class.

MSE 397. Dissertation Advisement (variable credit)

MSE 398. Graduate Seminar (variable credit) Doctoral level seminar focusing on special topics within the field.

MSE 399. Directed Research (variable credit) Doctoral-level supervised research.

