Learning Goals of MSE Courses

MSE 200 Materials and Society

A. I can explain the role of materials in the advancement of society and to solve current, and predicted future, challenges.

B. I am able to describe the advantages and disadvantages of metals, ceramics, polymers, and composite materials for a particular application.

C. I can explain how material choices are constrained by application requirements.

D. I can propose reasons for alternative material or design choices.

MSE 250 Materials Science and Engineering

A. I am able to describe the basic concepts of atomic bonding, interatomic potentials, and atomic coordination in solids as they relate to metals, polymers, and ceramics. [1]

B. I can explain how atomic diffusion happens and calculate diffusivities and diffusion distances as function of temperature. [1]

C. I am able to explain how to obtain elastic modulus, yield strength, ultimate strength, modulus of resilience, modulus of toughness, and strain-to-fracture of a material from a measured load–displacement curve. [1]

D. I know how to identify and explain time-dependent deformation of materials. [1]

E. I understand effects of flaw size on fracture of materials. [1]

F. I am able to predict fatigue lifetime based upon S–N data. [1]

G. I can determine the amount and composition of phases present in a binary mixture of given composition and temperature based on its equilibrium phase diagram. [1]

H. I am able to explain how thermal treatments affect the distribution of equilibrium and non-equilibrium phases in steel. [1]

MSE 250lab

A. I can describe the basic concepts of crystallography including Miller Indices of planes and directions, relating density to crystallographic parameters, and stacking sequence of close packed crystal structures. [1]

B. I know how to experimentally identify elastic modulus, yield strength, ultimate strength, modulus of toughness, and strain-to-fracture from load–displacement curves. [6]

C. I am able to identify correlations between material hardness with other mechanical properties. [1]

D. I can identify a ductile-to-brittle transition using Charpy impact testing and fracture surface observations. [6]

E. I can identify mechanisms and approaches commonly used to strengthen different engineering materials. [1]

F. I can characterize microstructures of single and multi-phase engineering materials. [6]

G. I am able to characterize changes in properties of steel due to thermal treatments and relate them to changes in the microstructure. [6]

H. I can write laboratory reports that describe experimental work accurately and objectively. [3]

I. I can contribute to a team that conducts experiments, analysis, writing, and proof reading to generate an effective laboratory report. [5]

J. I can describe a contemporary issue that depends on materials composition, selection, and/or performance. [7]

MSE 260 Electronic, Magnetic, Thermal, and Optical Properties of Materials

A. I am able to predict basic electrical, thermal, magnetic, or superconductive (ETMSC) materials properties of an element or binary compound from its position in the periodic table. This includes an understanding of the relationship between different types of atomic bonding and ETMSC materials properties. [1]

B. I can describe the basic crystal structures of metals, semiconductors and insulators, as well as crystal structure notation and to be able to calculate bond lengths, atomic density, etc from mass density and crystal structure. [1]

C. I know how to draw a schematic energy diagram of the electronic structure of metals, semiconductors, and insulators and explain its relationship to electrical and optical properties. [1]

D. I can explain what ETMO properties are most relevant to particular materials applications such as analog electronic devices, capacitors, optoelectronics, and magnetic recording [7].

E. I can describe how metals, semiconductors, ceramics and polymers (materials) may be applied as sensor, electronic devices and products to serve societal needs and the well-being of society [4].

F. I comprehend the fundamentals of electrochemistry such as half-cell potential, corrosion, etc. [1]

MSE 310 Phase Equilibria in Materials

A. I can explain and determine thermodynamics parameters such as enthalpy, entropy, and free energy of a system at a giving condition. [1]

B. I am able to determine how much energy is absorbed or released in a system due to changes in temperature, phase, pressure, or chemical bonding state. [1]

C. I know how to predict changes in phase transition temperatures due to pressure changes. [1]

D. I am able to determine changes in free energy associated with mixing, and how they are related to phase diagrams, activity, and the equilibrium constant [1].

E. I can determine the changes in free energy, enthalpy, entropy, temperature, and pressure for equilibrium chemical reactions. [1]

F. I can determine the relative stability of a mixture of several compounds in contact with each other, as influenced by temperature, partial pressures, compositions, etc. [1]

G. I know how to read, interpret, and extract quantitative information from ternary phase diagrams [1,6].

H. I can qualitatively explain the statistical nature of thermodynamic quantities. [1]

MSE 320 Mechanical Properties of Materials

A. I understand the basic nature and role of dislocations and other crystal defects in plastic deformation. [1]

B. I can identify microstructural features of brittle and ductile fracture as well as microstructure-property relationships that affect ductility, toughness, fracture, fatigue, and creep of materials [1].

C. I understand brittle fracture and predict the fracture strength of brittle solids containing flaws of known size using Griffith Criteria. [1]

D. I am able to design an experiment to acquire data needed to characterize elastic constants, yield strength, ultimate strength, strain-to-failure, and work hardening of metals, ceramics, and polymers [1].

E. I can identify different testing methods associated with tension, compression, fatigue, fatigue crack growth, and creep of metals, ceramics, and polymers. [1]

F. I can predict the fracture strength of ductile materials using simple fracture mechanics concepts, and design tests to determine plane-strain fracture toughness. [1,6]

G. I can explain methods for toughening metals, ceramics, and composite materials and apply appropriate rules of mixtures to predict properties. [1]

H. I know how to predict fatigue life given load history, information on cracks, cyclic stress intensity and Paris law parameters [1].

I. I can identify different regions of fatigue crack growth based on ΔK and $\mathrm{d}a/\mathrm{d}N$. [1]

J. I can estimate total creep strains given times, temperatures, stresses and an Ashby deformation mechanism map; understand fundamentals of viscoelasticity; understand how to predict time-to-failure given creep temperature and load using the Larsen–Miller Parameter. [1]

K. I am able to calculate creep stress exponents and activation energies and identify the different regimes of creep strain–time periods as well as understand creep deformation mechanisms. [1,6]

MSE 331 Materials Characterization Methods I

A. I can quantify microstructures with advanced optical microscopy techniques. [6]

B. I know how to conduct, analyze, and interpret lab experiments using analytical thermal and mechanical testing analyses to obtain information useful for developing phase diagrams [6].

C. I can use indentation techniques to quantify mechanical properties. [6]

D. I am able to use optical microscopy to characterize slip phenomena in single crystals. [6]

E. I can conduct experiments that examine time-dependent deformation. [6]

F. I can conceptually understand, and quantitatively describe, the role of error and error analysis in experimental procedures and materials characterization. [6]

G. I learned how to effectively communicate the above experimental work in objective written laboratory reports [3].

H. I can describe how processing can affect the structure of a polymer, using time-dependent and vibrational spectroscopy. [1,6]

MSE 360 Fundamentals of Microstructural Design

A. I can use $\sqrt{Dt}$ properly to make estimates of diffusion phenomena. [1]

B. I am able to use solutions to Fick's 2nd law based upon the thin film, erf, and a series solution to predict composition gradients and apply these models to simple thermal and mass flow problems [1].

C. I can use Arrhenius plots to determine parameters needed for theoretical models of diffusivity to modify material properties at the atomic scale for metal, ceramic polymer, and electronic systems [6,7].

D. I understand non-equilibrium solidification phenomena to effect beneficial changes in microstructures in metals, ceramics and polymers. [1]

E. I am able to use understanding of non-equilibrium stored energy from plastic deformation processing and/or phase changes to design microstructures that improve properties in metals, ceramics, and polymers. [1]

F. I can predict times and temperatures needed to obtain desirable microstructural changes in a heat treatment process. [1]

G. I can solve problems with mixed units that require unit conversions. [1]

H. I can explain how a particular process or technique used in materials processing depends on diffusion, solidification, heat treatment, deformation, in an oral presentation [3].

I. I am able to explain how managing atomic behavior enables materials innovations that impact society [1].

MSE 370 Synthesis and Processing of Materials

A. I can identify basic methods of powder synthesis and fabrication. [1]

B. I can design simple risers for metals casting and predict solidification temperatures. [2]

C. I can identify a preferred method of fabrication for a component, given a specified geometry, production rate, and cost constraints [2].

D. I am able to explain how time, temperature, and particle size affect the densification of powders. [1]

E. I can describe the various strategies to tailor polymer chemistry for optimum processing, chemical and physical properties [1].

F. I am able to discuss the important parameters involved in surface treatment processes such as thin-film microdevice technology, carburization, and thick-film coating techniques. [1]

G. I can identify an ethical difficulty and suggest a potential solution consistent with a particular section of the NSPE code. [4]

H. I can describe methods for characterizing and suppressing corrosion in metals. [1,6]

MSE 381 Materials Characterization Methods II

A. I understand how X-rays are generated, convert from wavelength to frequency or photon energy, and calculate X-ray energies on the basis of the one electron atom model. [1]

B. I can analyze X-ray powder diffraction spectra to identify simple unknown phases/structures. [6]

C. I can use scanning electron microscopy and energy dispersive spectroscopy for analysis and phase identification on the surface of a heterogeneous material. [6]

D. I am able to use scanning electron microscopy to characterize fracture surfaces. [6]

E. I can characterize electrical properties and relate them to material structure. [6]

F. I can apply materials characterization techniques to design/select/diagnose material-related relationships between materials properties and materials processing [1].

G. I am able to communicate experimental findings using complex instrumentation and interpret results effectively for readers with a general knowledge in MSE [3].

H. I can identify and characterize corrosion and other electrochemical processes. [6]

I. I know how to use thermal analysis techniques to quantify heat of transition, dimensional stability, and chemical stability of materials. [1,6]

MSE 410 Materials Foundations for Energy Applications

A. I can describe the relationships between climate, energy availability and utilization, the development of technology, and the impact of these on societal development. [2]

B. I understand the advantages, disadvantages, and limitations of fossil fuels as energy resources. [4]

C. I am able to describe the benefits and limitations of carbon neutral energy sources such as solar, wind, nuclear, hydrogen, and bio-based materials. [4]

D. I can use fundamental principles of physics, chemistry, and materials science to design materials for solar cells, thermoelectric devices, light-emitting diodes, batteries, nuclear energy, and other materials relevant to alternative energy sources. [2]

E. I know how processing affects the performance and cost of materials used in photovoltaic devices, thermoelectric devices, batteries, light-emitting diodes, and other alternative energy devices. [1]

MSE 425 Biomaterials and Biocompatibility

A. I understand the dependence of material properties on the materials structure and processing history and how these influence biocompatibility. [1]

B. I understand the effect of surface morphology on function and biocompatibility. [1]

C. I understand the relationships between biological tissue properties and the material selection for an implant. [1]

D. I am able to appreciate the corrosiveness of the environment in which biomaterials must function and how this influences design of implant materials. [1]

E. I can use my understanding of science and engineering to compose a thorough written critique of any contemporary journal publication in the biomaterials literature [7].

F. I am able to effectively contribute understanding of biomaterials engineering from the perspective of my core engineering discipline in a project conducted by a multidisciplinary team [5].

MSE 460 Electronic Structure and Bonding in Materials and Devices

A. I can explain the basic concepts of quantum mechanics and use the Schrödinger equation to solve problems relating to basic quantum phenomena. [1]

B. I can use the free electron model of metals to predict their electrical and thermal properties [1].

C. I know how to use the band theory of metals to draw energy diagrams of the electronic structure of metals, semiconductors and insulators, and explain its relationship to electrical and optical properties. [1]

D. I can use an understanding of band engineering to design a simple electronic device [2].

E. I am able to explain the relationship between different types of atomic bonding and the resulting electronic, superconducting, or thermal properties. [1]

MSE 465 Design and Application of Engineering Materials

A. I can integrate the knowledge gained from the courses in the materials science curriculum. [1]

B. I can analyze and arrive at solutions to material-related issues in professional life. [2]

C. I am able to make recommendations based on socio-economic considerations for materials issues. [2]

D. I can provide written reports based on literature survey [3].

E. I am able to orally present reports to technical audiences and answer questions [3].

F. I can think critically.

MSE 466 Design and Failure Analysis

A. I can apply basic mechanical behavior materials concepts to failure in metallic, polymer, and ceramic materials. [1]

B. I know how to identify complex stress states arising from simple loading and boundary conditions, and apply modern fracture mechanics concepts to crack problems. [1]

C. I am able to identify the technical cause of failure by i) procuring failed parts, ii) collecting background information, iii) conducting laboratory experiments, iv) analyze and interpret experimental results, and v) can recommend design revisions. [6]

D. I am able to function on a team with multi-disciplinary strengths that makes effective use of subtasking. [5]

E. I can use nondestructive testing techniques and microscopy to identify the failure modes and origins of failure. [6]

F. I can recognize and assess the societal costs and potential impacts of engineering failures. [4]

G. I am able to communicate findings in oral and written reports. [3]

H. I can recognize and act on ethical issues in engineering problems. [4]

MSE 474 Ceramic and Refractory Materials

A. I can conceptualize that the binding energy curve is related to theoretical fracture strength, elastic moduli, and thermal expansion. [1]

B. I can discuss the crystal structures of silicates, clays, and other common ceramic materials in relation to properties. [1]

C. I know how to explain the connection between properties and processing techniques of glasses and glass ceramics. [1]

D. I can explain the microstructure/mechanical property relationships in ceramics, including the impact of grain size and porosity on fracture and creep. [1]

E. I can calculate the effective thermal and/or electrical conductivity of a porous or composite ceramic based on the conductivities of each phase, and discuss the assumptions involved in calculation. [1]

F. I am able to identify an ethical difficulty, conflicts of interest, and ethical problem solving strategies. [4]

G. I understand the operating principles of dielectric, ferro-electrics, paramagnetic, diamagnetic, ferri-magnetic, and anti-ferromagnetic ceramics. [1]

H. I can explain how defects affect the electrical, mechanical, and processing of ceramic materials. [1]

MSE 476 Physical Metallurgy of Ferrous and Aluminum Alloys

A. I know why and can predict how composition gradients develop during non-equilibrium solidification in ferrous and aluminum alloys. [1]

B. I can explain how solidification occurs in ingot, welding, and continuous casting of ferrous and aluminum alloys. [1]

C. I am able to explain how microstructure and composition can be controlled with microalloying additions to a melt prior to pouring, and with subsequent cooling rates. [1]

D. I can use empirical models based upon composition and microstructure parameters to predict mechanical properties in steels and aluminum alloys. [1,7]

E. I know the meaning of terminology relevant to heat treating, and the classes of steel and aluminum alloys. [1]

F. I can make economically motivated choices to identify a heat treating strategy that will minimize alloy and processing cost to obtain sufficient steel or aluminum alloy material performance for an application. [1] [2]

G. I am able to research literature to explain in oral and written form why heat treating and/or alloy modifications are able to provide particular economic and/or performance benefits. [3]

MSE 477 Manufacturing Processes

A. I can specify the experiments needed to determine the yield (flow) surface of a material for plane-strain deformation conditions.

B. I can identify the fundamental experimental work needed to determine plastic flow constants and formability limits needed in models for plastic deformation.

C. I am able to apply analytical solutions for plastic deformation by bi-axial sheet forming, drawing, extrusion, forging, pressing, and rolling, to predict limits of formability that precludes damage or fracture and the cost of doing these processes on ceramic, glassy, metal, and polymer materials based upon known material deformation data.

D. I can identify a process and process parameters needed to produce a composite material based upon particulate, fiber or lamellar reinforcement geometries for components made from polymers, metals, and ceramics, determine methods to evaluate the quality of the composite, and to estimate the cost of producing the material.

E. I can identify the plastic strain, strain rate, heat generation, and wear characteristics of a machining process, and the impact of material properties of tool and workpiece on the economics of the process.

F. I can demonstrate the ability to prescribe a process and cost analysis for making a particular part out of a particular material, and present it to the class as if it were a preliminary design review.

G. I can apply analytical solutions for plastic deformation by bi-axial sheet forming, drawing, extrusion, forging, pressing, and rolling, to predict limits of formability that precludes damage or fracture and the cost of doing these processes on ceramic, glassy, metal and polymer materials, based upon known material deformation data.

MSE 481 Spectroscopic and Diffraction Analysis of Materials

A. I can explain the relationships between atomic structure, x-ray production, X-ray scattering, and X-ray absorption. [1]

B. I can carry out crystal structure analysis of known and unknown materials based on Bragg's law and structure factor determination.[1]

C. I am able to relate changes in diffraction information in reciprocal space to materials changes due to composition, temperature, pressure, and defect content.[1]

D. I know how to design experiments to determine material composition, structure, and defect content [6].

E. I understand the underlying phenomena associated with different X-ray spectroscopic techniques and the capabilities and limitations of each.[1]

MSE 491 Amorphous Materials

A. I can identify and describe the structure of common amorphous systems in terms of short-, medium-, and long-rang order. [1]

B. I can conceptually and quantitatively describe common amorphous structure–property relationships including optical, electrical, and chemical. [7]

C. I understand the common processing methods used to make amorphous solids and identify key processing parameters for each including solidification of a melt, vapor deposition, and sol-gel deposition.[1]

D. I can identify the capabilities and limitations of common characterization techniques in the quantitative and semi-quantitative analysis of amorphous structure.[1]

E. I can describe the current state-of-the-art in the application of amorphous materials for energy harvesting, biomaterials, and the semiconductor industry.[1]