Materials Science & Engineering

Specialisations and Course Descriptions

Never Stand Still | Science | School of Materials Science and Engineering

Undergraduate Specialisations

Materials Science and Engineering

Materials engineering is a broad ranging discipline, which applies the principles of science and engineering to the development of metallic, ceramic and polymeric materials and to their manufacture into goods and their subsequent performance. It is founded on the relationship between structure and properties, an understanding of which permits materials to be engineered to specific end use requirements.

Ceramic Engineering

Ceramic Engineering teaches the science and technology involved in the production of ceramic products ranging from traditional ceramics such as bricks, tiles, plates, pottery, glass, refractories, and cement, through to new generation high-tech ceramics such as solid-state electronics, piezoelectrics, magnetic materials, engine parts and superconductors. Ceramic Engineering is concerned with the entire lifecycle of ceramic products from raw materials to the finished product.
Note MATS4002 is a compulsory elective for this stream.

Physical Metallurgy

Metallurgical engineering is a discipline concerned with extracting metals from their ores, and the development, production and use of metallic materials. Physical metallurgy involves the shaping, alloying, heat treatment, joining, corrosion protection and testing of metals.
Note MATS4001 is a compulsory elective for this stream.

Process Metallurgy

Metallurgical engineering is a discipline concerned with extracting metals from their ores, and the development, production and use of metallic materials. In particular process metallurgy is concerned with extracting metals from their ores to make *refined alloys.*
Note MATS3003 is a compulsory elective for this stream.

MSE Undergraduate Course Descriptions

Core Courses

MATS1192 Design and Application of Materials in Science and Engineering

The design of materials for applications in industry and society including, for example, metallurgical, electronic, medical, packaging and transport. Microstructure and structure-property relationships of the main types of engineering materials (metals, ceramics, polymers and composites); micromechanisms of elastic and plastic deformation; fracture mechanisms for ductile, brittle, creep and fatigue modes of failure in service; corrosion; metal forming by casting and wrought processes; phase equilibria of alloys; microstructural control and application to commercial engineering materials. Information retrieval. Communication skills. Plant visits. Introductory materials laboratories. Application of fundamental learning to problem solving.

MATS2001 Physical Properties of Materials

Modern atomic theory: shortfall of classical physics and an introduction to wave mechanics; many-electron atoms and the Pauli exclusion principle; zone and band theories. Electrical properties: classification of metals, semi-conductors and insulators; properties of amorphous, dielectric, piezoelectric, ferroelectric and pyroelectric materials. Thermal properties: heat capacity, thermal expansion, thermal conductivity and thermoelectricity. Magnetic properties: diamagnetism, paramagnetism, antiferromagnetism, ferrimagnetism and ferromagnetism; magnetic anisotropy and magnetostriction; magnetic materials and devices. Superconductivity and superconducting materials. Optical properties.

MATS2003 Materials Characterisation

Introduction to crystallography: crystal symmetry, Bravais lattices and crystal structures, Miller and Miller-Bravais Indices; Specimen preparation; optical and electron microscopy; image analysis and stereology; x-ray, electron, and neutron diffraction; x-ray fluorescence, infrared spectroscopy, Raman spectroscopy, x-ray photoelectron spectroscopy; differential scanning calorimetry, thermal gravimetric analysis, dynamic thermal analysis; non-destructive analysis - ultrasonics, radiography, computed tomography.

MATS2004 Mechanical Behaviour of Materials

Stress strain behaviour; atomic bonding and elastic modulus; basic introduction to plastic deformation and yielding; slip systems, dislocations, twinning; deformation behaviour of non-crystalline materials; principal stresses, transformation of stresses, complex stress and strain analysis; failure criteria, ductile failure, brittle fracture and Weibull modulus; deformation behaviour of polymers; deformation behaviour of composites.

MATS2005 Introduction to Fluid Flow and Heat Transfer

Fluid properties, Newtonian and non-Newtonian fluids; principles of fluid motion, mass and momentum balances; turbulent flow, dimensional analysis; mechanical energy balance, Bernoulli's equation; conduction and Fourier's law, steady-state conduction; forced and natural convection heat transfer; radiation, single body radiation, radiation exchange between objects.

MATS2006 Diffusion and Kinetics

Introduction to solid state diffusion, atomistics of diffusion, Fick's first and second laws; thin film solution and tracer diffusion measurements, semi-infinite and infinite diffusion couples - diffusion in a concentration gradient; temperature effects; surface, grain boundary and dislocation pipe diffusion; diffusion in ionic solids, interdiffusion and the Kirkendall effect, measurement of variable diffusion coefficients; thermodynamics vs. Kinetics, elementary and non-elementary reactions, reaction order, activation energy, Arrhenius law, irreversible and reversible reactions, degree of reaction; heterogeneous reactions, kinetics of solid state-gas (fluid) reactions, elementary steps, rate-controlling steps, intrinsic kinetics, chemisorptions, mass transfer in the gas phase and fluid, multicomponent system, Knudsen diffusion, shrinking core model.

MATS2007 Sustainable Materials Processing

This is a capstone course intended to develop problem-solving skills and integrate the concepts learned in Years 1 and 2 by applying them to sustainable materials and processing. Topics would include: Problem solving methodology; environmental footprint – production, maintenance and end-of-life disposal; embodied energy; pollution and carbon estimation and accounting; life cycle analysis; energy recovery; carbon sequestration; pollution minimisation; sustainable materials and processing technologies.

MATS2008 Thermodynamics and Phase Equilibria

Thermodynamic functions and properties of materials (chemical, mechanical and magnetic systems); thermodynamic laws and their application to materials: chemical equilibrium, gas-solid equilibria, Ellingham diagrams; electrochemistry: Porbaix diagrams; thermodynamics of solutions; construction and interpretation of 2 component phase diagrams.

MATS3001 Micromechanisms of Mechanical Behaviour of Metals

Theoretical strength; slip; twinning; deformation of single and polycrystals; dislocation multiplication; cross slip; climb; dislocation interactions. Strain hardening; solid solution hardening; age-hardening; dispersion hardening; grain size strengthening; other strengthening mechanisms. High temperature deformation; creep; stress relaxation; effect of strain rate and temperature; superplasticity. Common methods of forming metal products. Common classes of aluminium and nickel-based and titanium alloys to be taught illustrating some of the principles involved.

MATS3002 Fundamentals of Ceramic Processing

Ternary phase equilibria in ceramic systems. Processing of ceramics and its relationship to structure, properties and performance of ceramic materials. Starting materials, ceramic processing fundamentals, and processing technology taught in context of the main classes of ceramic materials (polycrystalline monolithic ceramics, glasses, and films/coatings) and the determination of structure, properties and performance.

MATS3004 Polymer Science & Engineering 1

Polymer Chemistry: Raw materials and synthesis of polymers: monomers, homo-polymers, copolymers, vinyl polymers; basic organic chemistry and applied polymer chemistry; free radical polymerization, reaction and termination rates using physical chemistry models; ionic, condensation and mixed mode polymerization.

Physical structure of polymers: primary and secondary bonds; amorphous, semi-crystalline, and rubbery states; molecular statistics of rubbery states; chain branching, networking; iso-free volume theory; properties affected by primary bonds; physical properties affected by secondary bonds.

Deformation behaviour of polymers: fundamental rheology; glassy and viscoelastic behaviour; effect of molecular weight, temperature and shear rate; structure-property correlation in glassy, semi-crystalline and oriented polymers; free volume and fractal theories; tensile, shear, compression and impact properties; effect of temperature and strain rates.

Commodity and specialty plastics: additives in plastics; commercial manufacture and application; single phase and multiphase conducting polymers,

Nano-polymers: concept, fabrication, characterization

MATS3006 Design and Application of Materials in Science and Engineering 3

This is a capstone course intended to provide students with the tools required for computational design and modelling for technological and professional materials engineering applications through application to the concepts learned in Years 1 to 3. The course starts with computer-aided drawing and design including dimensioning, tolerancing and standard drawing symbols, principles of detail design drawings and assembly drawings. Finite element, finite difference computational fluid dynamic modelling are then introduced based upon structural, heat transfer and fluid modelling respectively. The use of computational modelling as a part of materials engineering design is emphasised.

MATS3007 Materials Industry Management

Project Management: the stages of a project; planning; scheduling; personal dynamics; reporting; stakeholders; development of a project plan pertinent to the materials industry.

Accounting: financial accounting; development and analysis financial statements; ratio analysis; financial planning; finance; management accounting.

Career Development: self-promotion to gain employment; development of job applications and resumes; goal setting; performance appraisal; reward structures.

Marketing: market analysis; marketing concepts; product development; professional ethics.

Elective Courses

MATS3003 Engineering in Process Metallurgy

Basic mechanisms of heat, mass and fluid flow; fluid statics and fluid dynamics in metallurgy; macroscopic balance for isothermal systems; dimensional analysis and reactor design; heat and mass transfer through motionless media; heat and mass transfer in convective flow systems.

MATS3005 Phase Transformations

Classification of phase transformations. Nucleation in the gaseous, liquid and solid states. Solidification of pure and impure materials; thermal and constitutional supercooling and their influence on interface stability; solute redistribution and coring; eutectic and peritectic solidification; generation of as-cast structures during casting; grain refining; single crystal growth techniques; glass formation and glassy materials. Diffusional and non-diffusional solid-state transformations: nucleation and growth of phases; decomposition of solid solutions; ordering reactions; spinodal decomposition; the role of the eutectoid transformation in the formation of pearlite, bainite and martensite; hardenability; tempering. Theory of transformation kinetics and the origin of transformation diagrams. Aspects of ferrous and non-ferrous metallurgy and common classes of low carbon and alloy steels to be taught illustrating some of the principles involved.

MATS4001 Secondary Processing of Metals

Solidification, welding (emphasis on effect of welding on microstructure, HAZ's etc), fundamentals of metal-working (including hot working, Zener-Hollomon parameter, dynamic recovery and recrystallization and cold working including slip line field theory, slab and upper bound analyses, formability, residual stresses), powder metallurgy and sintering, machining, recrystallisation phenomena. Emphasis on the effect of processing conditions on microstructure and hence properties. Common classes of magnesium alloys, copper alloys and cast irons to be taught illustrating some of the principles involved.

MATS4002 Design with Advanced Ceramics

Design with advanced ceramics for structural, thermal, electrical, piezoelectric, chemical, catalytic, and wear applications. Fundamental structure-property relationships underlying thermal shock, mechanical strength and fracture toughness, Weibull modulus and reliability, piezo-, thermo and optoelectric behaviour, corrosion, wear/abrasion, photocatalysis. Case Studies in design and performance of ceramic materials and products.

MATS4003 Metallurgical Reaction Engineering and Processes

Introduction: Metal production - from raw materials to products.

Part 1: Elements of Metallurgical Reaction Engineering: Reaction rate and expressions for different reaction systems. Kinetics and thermodynamics of metallurgical reactions. Heat balance and mass balance of chemical reactors. Reactors for homogeneous reactions: batch and semi-batch reactors; plug flow reactors; mixed tank reactors. Reactors for heterogeneous reactions; fixed bed reactors; fluidised bed reactors; moving bed reactors.

Part 2: Key Metallurgical Processes: Roasting. Blast furnace iron making. Alternative ironmaking processes. Copper smelting. Aluminium smelting. Advances in innovative technologies for metal production.

MATS4004 Fracture Mechanics and Failure Analysis

Fracture mechanics, remnant life assessment, general practice in failure analysis, fractographic analysis, ductile and brittle fracture, fatigue, stress corrosion cracking, hydrogen embrittlement, fracture criteria in design, fracture toughness and fatigue testing.

MATS4005 Composites and Functional Materials

Polymer matrix, metal matrix and ceramic matrix composites. Nano-composites. Mechanical

behaviour of composites. Physico-chemical characteristion Fabrication techniques. Design with composites. Applications. Material processes used in the fabrication of electronic devices such as single crystal growth, implantation, lithography, etching and thin film growth. Methods of device packaging. Sources of failure and methods of fault diagnosis in devices. Specialty materials.

MATS4006 Polymer Science & Engineering 2

Mechanical properties of polymers: mechanisms of yield, deformation and fracture; factors contributing to strength and toughness; strategies to reduce stress and increase toughness; creep, recovery and stress relaxation; time-temperature superposition; fatigue; effect of polymer processing on mechanical behaviour.

Degradation mechanisms of polymers: crazing; environmental effects; degradation prevention.

Design and application of advanced polymers: toughened/strengthened polymers; fire-resistant plastics; testing methodologies for polymers; biomedical polymers; polymer matrix composites; Application of polymers in clean energy, electronics, sensors, and smart applications.

Nano-composites: with combination of high mechanical, electrical, and thermal properties

MATS4007 Engineered Surfaces to Resist Corrosion and Wear

Behaviour of surfaces, electrochemical series, corrosion, methods for prevention of corrosion, stress corrosion cracking, wear and friction phenomena, surface hardening - nitriding, carburisation, hard coatings, oxidation, oxidation resistant coatings, materials selection for corrosion and wear resistance. Common corrosion resistant alloys to be taught illustrating some of these principles involved.

Honours Thesis Courses

MATS4008 Materials Engineering Project (12 UOC)

An experimental or technical investigation or design related to some aspects of materials engineering in the specific discipline (metallurgical engineering, materials engineering or ceramic engineering). Students with an average mark above 70 will be allowed to do the 24 UOC Project MATS4010, with approval from the Head of School.
Note: this course is 12 UOC in total: 6 UOC per semester over two semesters.

MATS4009 Materials Engineering Project (18 UOC)

An experimental or technical investigation or design related to materials engineering in the specific discipline (metallurgical engineering, materials engineering or ceramic engineering). Students with an average mark above 70 will be allowed to do the 24 UOC Project MATS4010, with approval from the Head of School.
Note: this course is 18 UOC in total: 9 UOC per semester over two semesters.

MATS4010 Materials Engineering Project (24 UOC)

An experimental or technical investigation or design related to materials engineering in the specific discipline (metallurgical engineering, materials engineering or ceramic engineering). Only students with an average mark above 70 will be allowed to do this 24 UOC Project, with approval from the Head of School. Students with an average mark below 70 do the 18 UOC project MATS4009 ***and an additional*** 6 UOC Elective course in Materials Science and Engineering.
Note: this course is 24 UOC in total: 12 UOC per semester over two semesters.

MATS5001 Thesis A

An experimental or technical investigation or design related to some aspects of materials engineering in the specific discipline (ceramic engineering, metallurgical engineering or materials engineering).

MATS5002 Thesis B

An experimental or technical investigation or design related to some aspects of materials engineering in the specific discipline (ceramic engineering, metallurgical engineering or materials engineering). This may be taken as a stand-alone course in S2 or as a follow-on course to MATS5001 to provide a 12 UOC total thesis project.

MATS5003 Advanced Thesis

An experimental or technical investigation or design related to some aspects of materials engineering in the specific discipline (ceramic engineering, metallurgical engineering or materials engineering). This is a 6 UOC supplementary course for students who have taken or are taking both MATS5001 and MATS5002 and wish to undertake an 18 UOC total thesis project.
Note: for students who have not undertaken MATS5001 and MATS5002 please be aware that these courses may be taken as co-requisites with MATS5003.

MSE Masters by Coursework - 8717

Core Courses (24 UoC)

MATS6001 Fundamentals of Materials Processing

This course covers selected topics in materials processing including elements of both extractive metallurgy and secondary processing methods. Students will understand the basic elements of operations of processing used in primary metal refinement and assorted secondary processing and shaping methods such as casting, rolling, welding and powder metallurgy.

MATS6002 Fundamentals of Materials Design

This course covers a background on the relationship between materials structure and properties and hence the application of advanced engineering materials. Students will gain an understanding of how the structure of a material can be manipulated through variations in processing conditions and how manipulation of structure leads to variations in materials properties.

MATS6003 Presentation Skills

This course covers selected topics in presentation skills including public speaking, presentation techniques, visual aids, library skills, resume and cover letter writing skills, web design and the use of the persuasive media. This will provide students will skills that will assist in the development of their professional skills.

MATS6004 Materials Industry Management

This course covers selected topics in management skills for the materials industry. Students will understand the basic elements of management including project planning, financial tools, strategic analysis and professional ethics.

Research Project (12 UoC)

MATS6113 Research Project

This course is designed for students undertaking a Masters by Coursework program in Materials Science and Engineering. It will be based on the performance of an original research project. Students will need to demonstrate competency in the design and execution of a research investigation.

Elective Courses (48 UoC)

MATS6101 Thermodynamics and Phase Equilibria

This course covers the relationship between thermodynamics, phase equilibria and the prediction of materials microstructure. Students will understand the laws of thermodynamics and their application to the construction of binary phase diagrams. Analysis of phase diagrams will be used to predict materials structure and properties.

MATS6102 Kinetics and Phase Transformations

This course covers a background on the relationship between kinetics, diffusion, phase transformations and the prediction of materials microstructure. Students will understand how to predict materials structure based on the principles of phase transformations and apply this knowledge to commercial alloys.

MATS6104 Physical Properties of Materials

This course covers a background on the relationship between electronic and atomic structure of materials and their physical properties. Students will understand the electronic, magnetic, optical, thermal and superconducting behaviour of materials, including how these materials are processed and their behaviour optimised for specific applications.

MATS6105 Chemical Properties of Materials

This course covers the chemical properties of materials, especially corrosion and oxidation. Focus is placed on strategies to prevent the corrosion and oxidation of engineering materials. Students will understand the practical consequences of corrosion and oxidation and the role of materials selection and design in reducing these phenomena.

MATS6106 Mechanical Properties of Materials

This course covers the deformation mechanisms and strengthening of materials. Focus is placed on strategies to enhance the strength of engineering materials. Students will be able to apply the principles taught to materials selection problems.

MATS6107 Thermal Properties of Materials

This course covers the thermal properties of materials, especially high temperatures ceramic materials. Emphasis is placed on enhancing the thermal stability, toughness and strength of these materials. Processing methods used to manufacture these materials will also be studied.

MATS6108 Functional Properties of Materials

This course covers the fabrication, structure, properties and applications of composite and functional materials. Students will gain an understanding of the relationship between materials design, fabrication and behaviour of these materials.

MATS6109 Polymer Materials Science

This course will commence with a fundamental understanding of the principles of fabrication, structure and mechanical properties of polymeric materials. More advanced topics in the second half of the course will include more advanced engineering polymeric materials for advanced applications.

MATS6110 Computational Materials

This course covers the principles and application of solving materials science problems through computational approaches. Modelling packages such as ANSYS will be used to solve problems in areas of fluid dynamics and the structural properties of advanced materials.

MATS6111 Processes in Materials Engineering

This course covers the processing of mineral phases to generate metallic and ceramic materials. Emphasis will be on heat and mass flow in reactors such as blast furnaces used in primary steel making.

MATS6112 Characterisation of Materials

This course covers a range of methods in the analysis of materials including diffraction, microscopy and spectroscopy methods. Emphasis is placed on the applicability of each technique to appropriate analysis and the limitations of each method.

As part of the 48 UoC of electives in the Master of Materials Technology program, students may take up to two advanced Level 3 or 4 undergraduate courses in Materials Science and Engineering (maximum 12 UoC) from the following list:

MATS3003 Engineering in Process Metallurgy

MATS3005 Phase Transformations

MATS4003 Process Metallurgy Advanced

MATS4004 Fracture Mechanics and Failure

MATS4005 Polymer Science and Engineering 2