

Doctoral Degree Programme

AREA OF STUDY

- Applied Physics and Materials Engineering

Doctoral Degree Programme

Doctor of Philosophy

- **Applied Physics and Materials Engineering**

		Credits
Compulsory Courses:		
APME8003	Advanced Instrumentation for Materials Characterization	3
APME8025	Advanced Quantum Mechanics	3
APME8027	Research Ethics	--
APME8037	Research Writing	--
Required Electives:		
1 Required Elective from the list of Required Electives		3
APME8999	Doctoral Thesis	18
Grand Total:		27

List of Required Electives

APME8001	Solid State Physics	3
APME8007	Thin Film Physics	3
APME8014	Advanced Electrochemical Energy Conversion and Storage	3
APME8020	Advanced Optoelectronics	3
APME8021	Advanced Laser Spectroscopy Technology	3
APME8022	Transmission Electron Microscopy	3
APME8024	Special Topics in Applied Physics and Materials Engineering	3
APME8029	Advanced Inorganic Chemical Synthesis	3
APME8030	Advanced Mechanics of Materials	3
APME8031	Advanced Micro and Nano-systems: From Fundamentals to Applications	3
APME8032	Advanced Organic-Inorganic Engineering Materials	3
APME8033	Nanomaterials and Nanochemistry	3
APME8034	Semiconductor Physics	3
APME8035	Advanced Materials Science and Engineering	3
APME8036	Advanced Electromagnetism and Modern Scattering Techniques	3

Master's Degree Programme

Master of Science

- **Innovative Materials**

		Credits
Compulsory Courses:		
APME7001	Development on Innovative Materials	3
APME7002	Eco-friendly Materials for Sustainability	3
APME7003	Sustainable Energy Harvesting Technologies	3
APME7004	Technologies for Materials Characterization	3
Required Electives:		
4 Required Electives from the list of Required Electives		12
APME7098	Project Report	6
Total Credits:		30

List of Required Electives

APME7005	Advanced Energy Storage Technologies	3
APME7006	Special Topics in Emerging Materials	3
APME7007	Energy, Environment and Sustainable Development	3
APME7008	Functional Materials	3
APME7009	Introduction of Solid State Materials	3
APME7010	Materials Design	3
APME7011	Micro and Nano Systems	3
APME7012	Principles of Quantum Mechanics	3
APME7013	Semiconductor Materials and Physics	3

Course Description

DOCTORAL DEGREE PROGRAMME

APME8001 SOLID STATE PHYSICS

In this course, the behavior of atoms and shared electrons in solids will be described by classical physics and quantum mechanics. The discussion of solid with crystalline structure will be one of the emphases. Some properties of crystal such as defects, disorder and thermal vibration will be studied. Then, band theory will be investigated. The physics of p-n junction semiconductor will also be introduced. Materials will be classified by models of magnetism as well as electric properties.

Pre-requisite: None

APME8003 ADVANCED INSTRUMENTATION FOR MATERIALS CHARACTERIZATION

Introduction of commonly used materials characterization methods (XPS, SEM, AFM, XRD, XRF, Raman, XPS), including their theory of operation and hands-on experience. Includes a discussion of the measurement process and instrumental analysis of samples.

Pre-requisite: None

APME8007 THIN FILM PHYSICS

Definition of thin films. Environment and molecular and plasma processes in thin film deposition. Cold and thermal plasma. Requirement for substrate, substrate cleaning. Formation of thin films. Properties of thin films. Mechanical, electrical, thermal, chemical, and optical properties of thin films. Thermal evaporation. Laser ablation, synthesis of nanomaterials. Electrical discharges used in thin film deposition. Practical electric discharge configuration for deposition of thin films, direct current electric discharges, radio-frequency discharges, microwave discharges, electron cyclotron resonance plasma, matching units, floating potential, bias potential, plasma potential, effective bias, self-bias. Physical deposition techniques. Chemical vapor deposition techniques (CVD). Other processing technologies.

Pre-requisite: None

APME8014 ADVANCED ELECTROCHEMICAL ENERGY CONVERSION AND STORAGE

This advanced course introduces principles, mathematical models and implementation of electrochemical energy conversion and storage. The principle of electrochemistry is introduced, including components of an electrolytic cell, Nernst's equation, thermodynamics and electrokinetics. The basic of power conversion is also introduced, including power electronics switches, converters and their control. The applications to batteries, solar cells, fuel cells and other emerging energy generation technologies are explored.

Pre-requisite: None

APME8020 ADVANCED OPTOELECTRONICS

Brief introduction of semiconductor physics and condensed matter physics. Theory of the interaction between light and matter. Optical gain, light transmission and absorption in media. Applications of light emission device and photo-electric transfer device. Principle and structure of selected photoelectric device.

Pre-requisite: None

APME8021 ADVANCED LASER SPECTROSCOPY TECHNOLOGY

Provide essential knowledge for the research frontiers in ultrafast laser spectroscopy and novel optical materials. Topics include: laser fundamentals, linear and nonlinear optical spectroscopy, time-resolved spectroscopy, single molecule spectroscopy, fluorescence and Raman microscopy, optical manipulation, optical properties of novel materials and some optoelectronic applications.

Pre-requisite: None

APME8022 TRANSMISSION ELECTRON MICROSCOPY

Introduction to imaging and diffraction analysis with transmission electron microscopy. Common sample preparation techniques. Basic diffraction theory and imaging principles using different imaging techniques, including bright field, dark field, high resolution and z-contrast imaging. Working principles of related compositional analysis techniques, including energy dispersive X-ray spectroscopy (EDS) and electron energy loss spectroscopy (EELS). Hands-on operation of the microscope can be optional.

Pre-requisite: None

APME8024 SPECIAL TOPICS IN APPLIED PHYSICS AND MATERIALS ENGINEERING

Any specialized topic in Applied Physics and Materials Engineering chosen by the staff member who has experience in that particular field, but the topic is not covered by the other postgraduate courses in the PhD Programme.

Pre-requisite: None

APME8025 ADVANCED QUANTUM MECHANICS

History and philosophy of quantum mechanics will first be reviewed in this course. Wave function and its statistical interpretation will be investigated. Time-independent Schrodinger equation will be discussed with some examples of infinite square well, finite square well and harmonic oscillator, etc. Then, hydrogen atom will be studied by Schrodinger equations in three dimensions. Furthermore, wave function of two-particle systems, atoms and solids will be introduced. The parts of application cover contents of perturbation theory, variational principle, WKB approximation and adiabatic approximation.

Pre-requisite: None

APME8027 RESEARCH ETHICS

The course provides students with an understanding of the following issues:

- The need for research ethics and the responsibility of the researcher (the student)
- The most common types of academic dishonesty (such as fabrication and plagiarism)
- How to avoid committing acts of academic dishonesty (such as through using citations and references)

Pre-requisite: None

APME8029 ADVANCED INORGANIC CHEMICAL SYNTHESIS

Brief introduction of chemistry basics and main focus on classic and emerging inorganic chemical synthesis methods as well as some physical and mechanical approaches for comparison. Some characterization techniques and their chemical principles. Implications of the inorganic synthesis techniques to the research and development in applied physics and materials science.

Pre-requisite: None

APME8030 ADVANCED MECHANICS OF MATERIALS

Basic training for students to understand the advanced mechanics of materials such as elastic behavior, inelastic behavior, anisotropic behavior, fracture behavior, and fatigue. With these knowledge, students will be able to analyze the materials mechanical behavior and wisely use the materials. Students with the knowledge of different mechanical behavior of materials, both isotropic and anisotropic.

Pre-requisite: None

APME8031 ADVANCED MICRO AND NANO-SYSTEMS: FROM FUNDAMENTALS TO APPLICATIONS

Overall introduction to miniaturization and microelectromechanical systems (MEMS); Fundamental physics of scaling in micro/nano-worlds; Overview of advanced micro/nano-fabrication materials & technologies & devices; Governing principle of physical phenomenon in micro/nano-scales, e.g. actuation, transduction, resonance, and manipulation, etc.; State-of-the-art applications of micro/nano-systems for interdisciplinary fields.

Pre-requisite: None

APME8032 ADVANCED ORGANIC-INORGANIC ENGINEERING MATERIALS

Briefly introducing basic knowledge of traditional engineering materials including polymer and cement. Mainly focus on: Introduction of organic/inorganic composite and nanocomposite materials; Introduction of polymeric admixtures for high-performance inorganic materials; Crystallization, surface and interface science of composite materials; Achievement of functionalization and ultimate mechanical properties for engineering composites; Design of advanced engineering composites; Industrial processing and application of engineering composites. Students will learn how to apply the basic knowledge of polymer, cement and composite into the design of advanced organic/inorganic engineering materials towards practical applications. They will also have a good impression for the real industrial use of engineering composites.

Pre-requisite: None

APME8033 NANOMATERIALS AND NANO CHEMISTRY

Introduction of low dimensional nanomaterials, e.g. carbon nanotube, graphene and transition metal dichalcogenides, and the corresponding methods of synthesis and characterization. Surface and interface modification of nanomaterials. Band-structure engineering of nanomaterials. Low-dimensional Van der Waals heterostructures. Applications of electronic devices, thermodynamics and fluid dynamics.

Pre-requisite: None

APME8034 SEMICONDUCTOR PHYSICS

Brief introduction of solid-state physics and crystallography. Mainly focus on the knowledge of semiconductor physics, condensed matter physics and semiconductor device physics: Intrinsic semiconductor, doped semiconductor and the carrier transportation in semiconductors will be introduced; the operating principles of some kinds of semiconductor devices will be introduced, such as pn junction, MS junction and FET, as well as the fabrication method and application in present. Also, some commercial semiconductor devices, such as LED and solar cells, will be introduced.

Pre-requisite: None

APME8035 ADVANCED MATERIALS SCIENCE AND ENGINEERING

A historical account of the discovery and development of materials science & engineering, including in-depth discussion of metals, ceramics, semiconductors, and other strongly-correlated electron systems. Fundamental knowledge in development of energy materials and single crystal growth, introduction of the modern neutron & synchrotron X-ray scattering techniques based on worldwide national large facilities, review of the most updated research achievements in the study of advanced functional materials such as spintronic, multiferroicity, superconductivity, spin frustration, spic ice, solar cell, battery, etc.

Pre-requisite: None

APME8036 ADVANCED ELECTROMAGNETISM AND MODERN SCATTERING TECHNIQUES

Magnetism is a very active and challenging subject since it represents a typical many-body problem and a complex application of quantum-mechanics, statistical physics and electromagnetism. During the last decades, new discoveries have emerged such as the high temperature superconductors and the colossal magneto-resistance manganite compounds. Besides bulk materials, magnetism of thin films and surfaces became a topic of great current interest. A promising new field of application emerges, so-called magneto-electronics with spin transistors. This progress is largely due to new experimental methods and only neutron and synchrotron X-ray scattering would be mentioned.

Pre-requisite: None

APME8037 RESEARCH WRITING

The course focuses on helping students to make academic presentations whether verbally (as in

a conference) or in writing (as in a paper). Topics include:

- How to write a research proposal
- How to structure a presentation (on paper and in power point)
- Tenses used in various parts of a paper presentation
- How to structure clear logical paragraphs
- How to be concise
- How to avoid ambiguity and different writing styles (for example, conventions for use of numbers, abbreviations, etc.)

Pre-requisite: None

APME8999 DOCTORAL THESIS

An independent investigation under the supervision of an institute staff member.

Pre-requisite: None

MASTER'S DEGREE PROGRAMMES

APME7001 DEVELOPMENT ON INNOVATIVE MATERIALS

In this course, seminar on latest development of applied physics and chemistry will be presented by students, faculty and guest speakers.

Pre-requisite: None

APME7002 ECO-FRIENDLY MATERIALS FOR SUSTAINABILITY

Introduction of materials and their relationship to environment, emphasizing the mitigation of the impact to the environments in various stages of material, including manufacturing, use and disposal. Topics covered include: materials and energy dependence; production and application of materials in industries; material lifecycle and its relationship to energy and carbon; material selection strategies, material sustainability, materials for low-carbon power, material efficiency, properties of engineering & natural materials and their relationship to environment and how to minimize the environmental impact arising from material disposal with new generation of recyclable-engineered materials.

Pre-requisite: None

APME7003 SUSTAINABLE ENERGY HARVESTING TECHNOLOGIES

This course covers the basic principles and recent advances in energy harvesting materials and technologies, with a focus on the role of materials and nanotechnology in the development of these technologies. The course will cover photovoltaic & bi-functional devices, thermoelectric, piezoelectric, triboelectric and pyroelectric energy harvesting, nuclear energy, water energy, wind energy, and the relevant materials and device considerations.

Pre-requisite: None

APME7004 TECHNOLOGIES FOR MATERIALS CHARACTERIZATION

Introduction of commonly used materials characterization technologies, including their theory of operation, hands-on experience, the measurement process and instrumental analysis of samples.

Pre-requisite: None

APME7005 ADVANCED ENERGY STORAGE TECHNOLOGIES

This course will give a general picture of energy society and different energy storage technologies, while focusing on some major ones (battery, capacitor, hydrogen and fuel cell). Some principles and important progress in energy storage technologies will be introduced in this course.

Pre-requisite: None

APME7006 SPECIAL TOPICS IN EMERGING MATERIALS

In this course, special topics in emerging materials will be presented by students, faculty and guest speakers.

Pre-requisite: None

APME7007 ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

In this course, the concepts and principles for the sustainable development shall be introduced. The impact of energy and environment on the sustainable society shall be discussed. The utilization and recycle of natural resources shall be introduced. The relationship among economics, climate, energy, and environment shall be presented.

Pre-requisite: None

APME7008 FUNCTIONAL MATERIALS

Provide an in-depth education in the field of materials science, an interdisciplinary area of knowledge that includes the study of structures, properties, processing, and applications. It covers traditional structural materials, functional materials, and nanomaterials. The course shows that the behavior of materials is directly linked to their fundamental structures, and how structures and hence properties may be altered through processing. Properties, processing, design and environmental protection and degradation will be considered. Case studies in materials selection will be included and some examples of state-of-the-art applications of novel materials will be given.

Pre-requisite: None

APME7009 INTRODUCTION OF SOLID STATE MATERIALS

In this course, the behavior of atoms and shared electrons in solids will be described by classical physics and quantum mechanics. The discussion of solid with crystalline structure will be one of the emphases. Some properties of crystal such as defects, disorder and thermal vibration will be studied. Then, band theory and motion of electron will be investigated.

Pre-requisite: None

APME7010 MATERIALS DESIGN

This course involves the design of materials from computational methods. Some popular simulations methods in the materials science will be provided. In this course, the students will understand the theory and mechanisms governing the various applications for designing materials and tailoring the properties to meet the needs.

Pre-requisite: None

APME7011 MICRO AND NANO SYSTEMS

This course mainly focuses on the overall introduction to the miniaturization, fabrication, and applications of micro/nano- electromechanical systems (MEMS/NEMS). The fundamental physics and governing formulas will be introduced, along with the typical phenomenon and principle in micro/nano- scales. Overview of the advanced micro/nano- fabrication technologies, e.g. photolithography, will be introduced to describe the fabrication of advanced micro/nano- devices. Some important phenomena in micro/nano- scales will be discussed including sensing, transduction, resonance, and manipulation, etc. Finally, the State-of-the-art applications of micro/nano-systems for interdisciplinary fields such as biomedical sensing, wearable devices, and lab-on-chip systems will be covered.

Pre-requisite: None

APME7012 PRINCIPLES OF QUANTUM MECHANICS

This course introduces the principle of quantum mechanics and its applications in materials. The students will study the knowledge of quantum mechanics, such as schrödinger equation, observables, mechanical quantities expressed by operators and representation transformation, and approximation method. There will be case studies on different materials with their properties related to quantum phenomena such as low dimensional materials, nanostructures and optoelectronic materials.

Pre-requisite: None

APME7013 SEMICONDUCTOR MATERIALS AND PHYSICS

Brief introduction of solid-state physics and crystallography. Mainly focus on the knowledge of semiconductor materials growth technology and semiconductor physics, include the topic below: typical semiconductors and their fabrications, electronic state in semiconductors, defects in

semiconductors, the carrier transportation in semiconductors, nonequilibrium carriers in semiconductors and semiconductor junctions. Working mechanisms of typical semiconductor devices are also introduced.

Pre-requisite: None

APME7098 PROJECT REPORT

An independent project under the supervision of an academic staff member. An independent project report focuses on combining existing academic theories with an evaluation of a case study or industrial project. The goal of this option is to facilitate the integration of practice with academic research.

Pre-requisite: None