POSTGRADUATE INSTITUTE OF SCIENCE

UNIVERSITY OF PERADENIYA

M.Sc. in Physics of Materials
2010/2011

1. INTRODUCTION

With the development of new technologies, materials play an increasingly important role in modern society. Thus, Materials Science has now become established as a discipline in its own right as well as an important area in the fields of Physics, Chemistry and Engineering. A sound knowledge in Science and Technology of materials is necessary for the efficient use of materials in industry. This aspect is particularly important for a developing country like Sri Lanka in achieving its development goals.

The broad aim of this postgraduate degree is to give a basic knowledge in Physics of Materials with emphasis on technologically important materials. Therefore this programme will provide an opportunity to train graduate students required for various industries and also to improve the knowledge and skills of personnel already employed in the industrial sector.

2. PROGRAMME ELIGIBILITY

The minimum requirement for enrolment is
(a) a B.Sc. Special Degree in Physics or Chemistry, or
(b) a B.Sc. General Degree in Science with Physics as a subject, or
(c) a B.Sc. in Engineering Degree with Materials Science component, from a recognized university, or
(d) any other equivalent qualifications acceptable to the Postgraduate Institute of Science (PGIS).

The number of candidates admitted to the programme in a given year will depend on the number of places available in that year. The selection will be based on merit. Candidates should be proficient in English as English will be the medium of instruction for the programme.

3. PROGRAMME FEE

(N.B. The Programme fees given below may be revised.)

	M.Sc. programme fee
local candidates	Rs. 90,000/-
SAARC countries	US $ 3,000/-
other countries	US $ 6,000/-

Programme fees shall be paid in two installments (50% at registration and the next 50% within six months from registration). Other payments including registration fee, medical fee, library subscription, examination fee and deposits (science and library) should be paid according to the procedure stipulated by the PGIS.

4. THE PROGRAMME STRUCTURE AND DURATION

This is a full-time programme consisting of course work and a research project. Course work will be conducted over a period of two semesters of 15 - weeks each (during weekends and/or weekdays). The entire programme duration will be about 15-18 months inclusive of 3-6 months for the research project. Satisfactory completion of a minimum of 24 credits of course work (with a GPA of not less than 3.00) is required for the programme in addition to the six credits allocated for the full-time research project (If the student obtains a GPA in the range

2.75 to 2.99, then he/she is eligible for the Diploma in Physics of Materials but not the M.Sc. Degree). Continuous attendance is compulsory during the period of research work. After successful completion of the research project, the student is eligible for the award of the M.Sc. Degree. Based on the performance by students in the taught courses, PGIS may upgrade the registration of such students to M.Phil. or Ph.D. programmes if they so desire.

Programme Summary

Course Code	Course No.	Lecture hrs.	Practical hrs.	Credits
Semester I				
PH500	Mathematical Methods and Computational Methods	30		2
PH 501	Quantum Mechanics and Statistical Physics	30	-	2
PH 502	Electron Theory of Solids	30	-	2
PH 503	Structure and Properties of Solids, Phase equilibria	30	-	2
PH 504	Semiconductors	30	-	2
PH 505	Ceramics Materials	30	-	2
PH 506	Polymers	30	-	2
PH 507	Solid State Ionic Materials	30	-	2
PH 508	Advanced Laboratory work	-	45	1
Semester II				
PH 516	Materials Characterization Techniques	45	-	3
PH 517	Magnetic Materials and Superconducting Materials*	15	-	1
PH 518	Glass and Glass Ceramics*	15	-	1
PH 520	Semiconductors Device Technology *	15	-	1
PH 521	Industrial Ceramics *	15	-	1
PH 523	Nuclear Materials *	15	-	1
PH 525	Metals and Alloys*	15	-	1
PH 526	Introduction to nanotechnology*	15	-	1
PH 598	Industrial Training *	-	-	1
PH 599	Research Project (six months)	-	-	6

** Elective Courses. Students are required to select any four elective courses.*

5. PROGRAMME CONTENTS

PH 500: Mathematical and Computational Methods in Material Physics (2 credits)

Solution of System of Linear Equations, Matrices and Determinants, Orthogonal functions, Fourier Transforms, Ordinary and Partial Differential Equations - Heat/Diffusion Equation, various solution techniques (Separation of Variables, Fourier Technique), Special Topics: Legendre Transform, Lagrangian Multipliers.
Classical and Modern Iterative techniques for Solving System of Linear Equations, Discrete Fourier Transform (DFT) and Fast Fourier Transforms (FFT), Numerical Solutions to Initial Value Problems - Euler Methods, Runge-Kutta Methods, Solutions to Partial Differential Equations - Finite Difference Methods, Finite Element Methods.
Solving Practical Problems in Physics using Computers.

PH 501: Quantum Mechanics and Statistical Physics(2 credits)

Quantum Mechanics: Applications of Schrödinger equation to 3-dimensional problems, Particle in a box, General potential problems, Spherical Harmonics, Harmonic oscillator, Solution using ladder operators, the H atom, Periodic lattice.
Statistical Physics: Introduction to classical and quantum mechanics, Thermodynamics, Probability distributions. Cannonical ensembles: Ensemble averages, Most probable distribution, Grand canonical ensemble, ensemble averages, Boltzman, Fermi-Dirac and Bose-Einstein Statistics, Ideal monoatomic and

diatomic gasses, Chemical equilibrium Degenerated Fermi-Dirac gas, photon statistics. Crystals: Vibrational spectrum of monoatomic crystals, phonons, point defects, Imperfect gasses, Virial coefficients, Basic methods and results of statistical mechanics. Simple applications of statistical mechanics, Quantum statistics of ideal gases.

PH 502: Electron Theory of Solids (2 credits)

Quantum mechanical free electron theory; Fermi energy; transport properties of the conduction electrons, Thermal conductivity, Dielecric response of free electron gas, Heat capacity, Paramagnetic susceptibility, Positive hall coefficient, Electronic mean free path, Electrical conductivity of free electron gas, Thermionic emission, Failure of the free electron model. Propagation of an electron in a periodic potential, Bloch theorem, Kronig-Penny model, Brillouin zones, Energy Bands in solids, Electron dynamics in an electric field, Effective mass of an electron, Concept of holes, Fermi surfaces; Electron dynamics in a magnetic field, Cyclotron resonance, De Hass-van Alphen effect, Calculation of energy bands, 2D electron gas in a magnetic field.

PH 503: Structure and Properties of Solids, and Phase equilibria (2 credits)

Structure and Properties: Structure-property relation, Atomic arrangement, Phase arrangement and crystal imperfections, Plastic deformation of crystalline materials, Strengthening mechanisms in crystalline materials, Deformations of materials, Mechanical failure of materials, Development of strong solids.

Phase rules: One component systems, Triple point, Critical point, Two component systems, Binary ideal liquid mixtures, Deviations from ideality, Partially miscible binary liquid mixtures, Distillation and fractional distillation of binary liquid mixtures, Two component solid - liquid systems, Solid solutions, Ideal solid solutions, Solids showing partial solid solubility, Eutectic systems, Peritectic systems, Compound formation, Congruent and incongruent melting, Introduction to 3-phase equilibria and representation in equilateral triangle based phase diagrams, Some examples of important phase equilibrium.

Lattice Dynamics: Theories of heat capacity of solids; Lattice vibrations, Phonons, Phonon Scattering.

PH 504: Semiconductors (2 credits)

Introduction to Semiconductors: Charge carrier motion in semiconductors, Defects and impurities in semiconductors; excitons, polarons, optical absorption, direct and indirect band gap semiconductors, Metal-Metal, Metal-Semiconductor; Semiconductor-Semiconductor Junctions. Ohmic contacts, Junction potential, action of a p-n junction; Zener diode, p-n-p and n-p-n transistors.

Semiconductor Devices: Solar cells, Light detecting devices, Solar energy materials, Technology of crystalline Si solar cells, Fabrication, assembling and encapsulation of Si-based solar cells. Thin film solar cells, Amorphous silicon solar cells, CdS, GaAs and CdS/CdTe solar cells, Photo Electrochemical Cells (PEC), Semiconductor lasers, Light emitting diodes

PH 505: Ceramic Materials (2 credits)

Old and new ceramics, Oxide and non-oxide ceramics, Mechanical, Thermal, electrical, magnetic and optical behavior; Piezo electric ceramics, Bio ceramics, Electronic and electro-optic ceramics, Powder processing, sintering, techniques for forming and densifying ceramics; Microstructure of Ceramics; Quality assurance; Failure analysis; toughening of ceramics; Reliability testing.Ceramic Composites, Ceramic Coatings and Films, Design, fabrication and properties of nanocomposites; Production, characterisation, application of thin and thick films.

PH 506: Polymers (2 credits)

Introduction to Polymers: A brief overview of important properties of polymers, conventional polymers, synthesis of polymers and characterisation, structure-property relationships. Properties of polymers: Rheology, industrial applications and special purpose polymers, Conjugated systems, synthesis of conjugated polymers; Charge transport and electrical conductivity, Optical properties; Applications of conjugated polymers.

PH 507: Solid State Ionic Materials (2 credits)

Solid Electrolytes: Solid electrolytes, diffusion and ionic conductivity, requirements for fast ion conduction, theoretical models and Arrhenius relationship. Representative examples: α-AgI, Na-β-Al_2O_3, Li_3N, ZrO_2, α-Li_2SO_4. Composite materials and grain boundary effects, Binary and ternary systems, Solid solutions, Sample preparation, Ionic conductivity measurements by impedance spectroscopy, Electronic conductivity and transference number.

Solid Polymer Electrolytes: Polymeric structure, Salt-polymer complexes, Ionic transport and VTF equation, systems based on polyethylene oxide (PEO) and other polymers, Proton conducting polymers.

Electrode Materials: Electrode/electrolyte interface, Electrode potentials, Electrochemical intercalation. Cathode materials: MnO_2, TiS_2, V_6O_{13}, V_2O_5, LiV_3O_8, $LiCoO_2$ and $LiMn_2O_4$. Anode materials: metals, alloys, LiAl, LiC_6 etc. Conducting polymers as electrode materials.

Solid State Ionic Devices: Solid state batteries, LiI/I battery; Na/S battery, rechargeable lithium batteries with polymer electrolytes, lithium rocking-chair batteries and examples. Fuel cells, sensors and electrochromic devices.

PH 508: Advanced Laboratory work (1 credit)

Synthesis of materials, Powder preparation, Sol-gel method, Shape forming techniques, Solid state sintering, Vacuum evaporation, CVD, MOCVD, Electro-chemical methods, Sputtering, Determination of physical properties.

Characterisation of materials: XRD, DSC, DTA, TGA, Spectophotometry, I-V and C-V techniques, Four-probe technique, Impedance spectroscopy, Measurements of magnetisation and susceptibility by different methods, Neutron activation analysis.

PH 516: Material Characterization Techniques (3 credits)

Electron Microscopy and X-ray Methods: Instrument Construction, Comparison of Imaging principles with optical microscope, Scanning Electron Microscope(SEM), Image formation, signal processing and contrast mechanisms, secondary and back-scattered electrons; Transmission Electron Microscopy (TEM), image formation, electron diffraction, TEM applications, high resolution imaging; Sample preparation techniques for TEM and SEM; Analytical spectra, X-ray emission and EELS, Quantitative X-ray analysis. X-ray diffraction (XRD) techniques, basic principles, determination of unit cell dimensions and lattice types, powder diffraction principles, techniques and applications in the characterisation of materials; Single crystal method, technique and measurements; Structure factors, Fourier and Patterson maps, structure determination and refinements. XRF, XAFS etc.

Thermal Analysis and Optical Spectroscopy: Differential Scanning Calorimetric (DSC), Differential Thermal Analysis (DTA), Thermo Gravimetry Analysis (TGA); Determination of melting points, phase transition temperatures, heats of phase transition.

Use of optical (UV, visible and IR) reflectance, and transmission spectroscopy for characterization of materials, determination of energy gaps in semiconductors, inter-band transitions; Optical transmission, in electrochromic materials; Grating monochromators, lock-in-technique; Modulation techniques; Fouriar transform spectroscopy (FTIR) for materials characterisation. NMR and Nuclear Methods: NMR and ESR techniques, Determination of trace elements using charged particles and neutron activation analysis. Determination of material properties using absorption, scattering and nuclear mechanisms of nuclear radiations.

PH 517: Magnetic Materials and Superconducting Materials (1 credit)

Magnetic materials: Classification of materials; Ferromagnetic domains, Domain walls, Paramagnetic resonance, Nuclear magnetic resonance, Ferromagnetic resonance, Spin waves.

Application of paramagnetic resonance and Faraday rotation, Permanent magnets, transformers and ferrites, Magnetic parametric amplifiers, Data storage, Magnetic recording.

Superconductivity: The superconducting state, BCS theory, Josephson effect, High temperature superconductivity. Applications of superconductors.

PH 518: Glass and Glass Ceramics (1 credit)

Glass formation, Thermodynamic and kinetic aspects, Structure of glass materials, Physical and chemical properties of glasses, Ionically conducting classes, mixed conducting glasses. Phase separation of simple glasses, Crystallization of glasses and concept of glass-ceramics, properties and application of glass-ceramics. Glass ceramic composites

PH 520: Semiconductor Device Technology (1 credit)

Crystal Growth; Doping Techniques, Bridgeman and Czochralski methods, Chemical Vapor Deposition (CVD), Liquid Phase Epitaxy (LPE), Molecular Beam Epitaxy (MBE) etc., Device Fabrication Methods; Alloy Method, Diffusion method, Planer Method and Ion Implantation. Semiconductor Devices; Integrated circuit technology SLI, MSI, LSI, VLSI, Photolethography, fabrication of pn junctions, BJT and FET, IC resistors and capacitors, Solid state memories RAM, ROM, EPROM etc.

PH 521: Industrial Ceramics (1 credit)

Raw materials, Introduction to silicate chemistry, purification of raw materials, ceramic bodies and glazes, preparation of ceramic bodies and glazes. Shaping and drying , firing and kilns, ceramic products. Technologically important ceramics, Environmental issues related to the ceramic industry.

PH 523: Nuclear Materials (1 credit)

Nuclear units, nuclear radiation, radiation sources, natural radiation, interaction of radiation with matter, cross-section, stopping power, attenuation, radiation exposure and dose, permissible limits, radiation shielding, build

up factors, shielding materials, design of shielding facilities, radiation detection, detector materials, nuclear reactors, reactor materials.

PH 525: Metals and Alloys (1 credit)
Introduction to metallurgy, Factors significant in metallurgy, Stages in the extraction of a metals, Location of ores, ore dressing, extraction processes, Pyrometallurgical processes, Hydrometallurgical processes, Ellingham diagrams and the extraction of metals, Exaction of some selected elements (Cu, Al, Mg, Zn, Ni, Sn, Pb, Ni), Alloys- Ferrous and non-ferrous alloys, T-T-T diagrams, Allotropic forms of iron, Iron-Carbon system, Cast irons, Steels, effect of alloying elements on properties and microstructure of a steel, Al, Ni, Cr based alloys - Properties and applications

PH 526: Introduction to nanotechnology (1 credit)
Introduction to nanotechnology, Characterization and manipulation of extremely small objects, nanoscale objects, Microscale objects, Size effects of properties observed in thin films, colloids and nanocrystals.
Conventional microfabrication including thin film deposition, lithography, chemical etching and electrodeposition. Analytical techniques: Electron Microscopy, Electron and X-ray Diffraction, Ellipsometry, Photoelectron, Optical and Ion spectroscopy and Probe Microscopy. Unconventional methods**:** soft-lithography and self-assembly.
Applications in Micro and Nano technology including Microelectronics, Microfluidics, Micro Electro Mechanical Systems (MEMS) and Molecular Electronics.

PH 599: Research Project (6 credits)
A research project to be decided in consultation with the programme coordinator, will be carried out under the guidance of an internal supervisor (and if necessary, external supervisor). Each candidate is requested to submit a dissertation on completion of the research project and to make an oral presentation.

7. PROGRAMME EVALUATION

Programme evaluation will be as stipulated in the PGIS Hand Book 2002.

8. TEACHING PANEL

Prof. H.M.N. Bandara, Dept. of Chemistry, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), M.Sc., Ph.D.(Ast)
Dr. P.W.S.K. Bandaranayake, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Perad.), Ph.D.(Perad.)
Prof. M.A. Careem, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), Ph.D.(London)
Dr. R.L.N.Chandrakanthi, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Perad.), Ph.D.(Perad.)
Prof. G.A. Dissanayake, Emeritus Professor, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), Ph.D.(Cantab.)
Prof. M.A.K.L.Dissanayake, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), M.S., Ph.D.(Indiana)
Dr. P. Ekanayake, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Perad.), Ph.D. (Germany)
Pro. R.P.Gunawardena, Department of Chemistry, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), Ph.D.(Aberdeen.)
Dr. N.F. Hettiarachchi, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc. (Cey.), Ph.D. (Hull)
Dr. L.R.A.Kalinga Bandara, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Perad.), Ph.D.(Perad.)
Dr. U. Karunasiri, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), M.Sc.(Pitt), M.Sc.(UCLA), Ph.D.(UCLA)
Prof. B.S.B. Karunaratne, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), Ph.D.(Warwick)
Dr. H.M. Nasir, Dept. of Mathematics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Jaffna), M.Eng.(Tokyo), D.Sc(Tokyo)
Prof. J.S.H.Q. Perera, Dept. of Chemistry, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), Ph.D.(Br.Col.)

Prof. K. Premaratne, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), M.S., Ph.D.(Hawaii)
Prof. R.M.G. Rajapakse, Dept. of Chemistry, Faculty of Science, Univ. of Peradeniya
B.Sc.(Perad.), Ph.D.(London)
Dr. S.D. Rosa, Dept. of Physics, Faculty of Science, Univ. of Colombo
B.Sc.(Colombo), M.Sc. Ph.D.(Pitttsburg)
Dr. V. Seneviratne, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Perad.), Ph.D.(Oklahoma)
Prof. W. Siripala, Dept. of Physics, Faculty of Science, Univ. of Kelaniya
B.Sc.(Perad.), M.Phil. Ph.D. (CUNY)
Prof. D.T.B. Tennakoon, Dept. of Chemistry, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), Ph.D. (Wales)
Dr. Chandana Udawaththa, Dept. of Chemistry, Faculty of Science, Univ. of Peradeniya
B.Sc.(Perad.), Ph.D.(Perad.)
Dr. R.L. Wijayawardena, Dept. of Physics, Faculty of Science, Univ. of Peradeniya
B.Sc.(Cey.), M.S., Ph.D.(Suny)

Recommended Books:

1. Introduction To Ceramics (2nd Ed.) W.D. Kingery, H.K.Bowen and D.R. Uhlmann, John Wiley & Sons.
2. Modern Ceramic Engineering (2nd Ed.) David W. Richerson, Marcel Dekker, Inc.
3. Piezoelectric Ceramics Bernard Jafee and Willium R. Cook , Academic Press.
4. Glass Ceramis P.W. McMillan, Academic Press.
5. Electron Microscopy In The Study Of Materials P.J.Grundy and G.A. Jones, Edward Arnolds.
6. X-Ray Diffraction Procedures Harold P. Klug and Leroy E. Alexander, John Wiley & Sons.
7. Sol-Gel Science: The Physics and Chemistry of Sol-Gel Processing C.J. Brinker and G.W. Scherer, Academic Press Inc.
8. Solid Polymer Electrolytes: Fundamentals and Technological Applications Fiona M. Gray , VCH Publishers, Inc.
9. Physics Of Amorphous Materials (2nd Ed.) S.R. Elliott (Longman Scientific & Technical, UK.
10. Superionic Solids And Solid Electrolytes: Recent Trends eds. Amulya L. Laskar and Suresh Chandra, Academic Press, Inc.
11. High Conductivity Solid Ionic Conductors: Recent Trends And Applications ed. Takehiko Takahashi, World Scientific Publishing Co.
12. Lithium Batteries: New Materials, Developments and Perspectives ed. G. Pistoia (Elsevier Science).
13. The Electronic Structure And Chemistry of Solids P.A. Cox (Oxford University Press, New York).
14. Physics of Semiconductor Devices S.M. Sze, John Wiley & Sons.
15. Electronic Devices And Components J. Seymour, Longman.
16. Introduction to Nuclear Engineering (2 nd Ed.) J.R. Lamarth, Addision Wesley Pub. Inc.
17. Fundamentals of Microfabrication, Marc J Madou.
18. Fundamentals of Nano- and Microengineering, Sergey Edward Lyshevski

PROGRAMME COORDINATOR

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