POSTGRADUATE INSTITUTE OF SCIENCE (PGIS)

UNIVERSITY OF PERADENIYA

M.Sc. in Nanoscience and Nanotechnology

2016/2017

1. INTRODUCTION

Nanoscience and Nanotechnology are fast growing areas of Science and Technology which span the entire spectrum of science and technology including next generation electronics, engineering materials, advanced materials and coatings, devices, computers, medicine, textiles, sports equipment, polymers, biology, agriculture, food science, etc. The western countries as well as our neighbouring countries such as India, Thailand, Korea, Singapore, *etc.* have already taken steps to train manpower to carry out Research and Development (R&D) activities on this fast growing area of science. Nanotechnology is considered the next generation Industrial Revolution without which the industrial sector cannot sustain. Sri Lankan state and private sectors are highly enthusiastic on developing nanotechnological research and development activities and to facilitate this task, Sri Lanka Institute for Nanotechnology (SLINTEC) has already been formed.

The M.Sc. programme will cover a broad range of disciplines to enable the trained graduates to make an objective judgment of the scientific importance and technological potential of developments in micro- and nanotechnologies and to perform a range of activities related to Nanoscience and Nanotechnology. The study programme will thus prepare the student to take the challenge of meeting not only national needs in diverse areas of nanoscience and nanotechnology but also to continue toward advanced studies anywhere in the world.

2. PROGRAMME ELIGIBILITY

Applicants seeking admission to this programme must have one of the following degrees/qualifications from a recognized university.

(a) a B.Sc. Special Degree in Physics or Chemistry, or
(b) a B.Sc. General Degree in Science with Physics and/or Chemistry as a subject, or
(c) a B.Sc. Engineering Degree, or
(d) any other equivalent qualification acceptable to the Postgraduate Institute of Science (PGIS).

Only a limited number of candidates will be admitted to the programme in a given 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. 175,000/-
SAARC countries	US $ 4,200/-
Other countries	US $ 7,700/-

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 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 Postgraduate Diploma in Nanoscience and Nanotechnology 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.

Programme Summary

Course Code	Course Title	Lecture hrs.	Practical hrs.	Credits
Semester I				
CHN 501	Introduction to Nanoscience and Nanotechnology	15	-	1
PHN 502	Basic Physics for Nanoscience and Nanotechnology	30	-	2
CHN 503	Nanochemistry	30	-	2
CHN 504	Characterization Techniques for Nanomaterials	15	-	1
CHN 505	Biochemistry related to Nanoscience and Nanotechnology	15	-	1
PHN 506	Carbon Nanotubes and Particles	15	-	1
CHN 507	Nanoscience and Nanotechnology Laboratory I	-	90	3
CHN 508	Nanoscience and Nanotechnology Laboratory II	-	60	2
CHN 597	Scientific Writing, Research Methodology and Seminar	15	-	1
Semester II				
PHN 516	Applications of Nanomaterials in Local Industries	30	-	2
PHN 517	Nanotechnology in Energy Conversion and Storage*	45	-	3
PHN 518	Nanoelectronic Devices*	30	-	2
CHN 519	Nanobiotechnology and Nanotechnology in Healthcare*	45	-	3
CHN 520	Business Enterprise, Economics and Research Policy in Nanotechnology*	30	-	2
CHN 521	Environmental Nanotechnology*	30	-	2
CHN 599	Research Project (3 - 6 months)			6

** Optional courses. Students are required to obtain 8 credits from optional courses (No. of Credits offered: Compulsory Courses = 16, Optional Courses = 12, Research Project = 06).*

5. PROGRAMME CONTENTS

CHN 501: Introduction to Nanoscience and Nanotechnology (1 Credit)

Nanotechnology Timeline and Milestones, Overview of different nanomaterials available, Potential uses of nanomaterials in electronics, robotics, computers, sensors in textiles, sports equipment, mobile electronic devices, vehicles and transportation. Medical applications of nanomaterials.

PHN 502: Basic Physics for Nanoscience and Nanotechnology (2 Credits)

Introduction to Quantum and Statistical Physics: Electrons as waves, wave mechanics, Schrödinger equation and particle in a box, Heisenberg's Uncertainty Principle, Introduction to the operator formalism-bas, kets, expectation values, Spin and exclusion principle, Boltzmann distribution, indistinguishable particles, Fermi-Dirac and Bose-Einstein distributions.
Introduction to Solid State Physics: Crystal structure: free electron theory of metals, band theory of solids, metals and insulators, Semiconductors: classification, electrons and holes, transport properties, size and dimensionality effects, Quantum size effects in semiconductor quantum dots and nanowires, The p-n junction and the bipolar transistor; metal-semiconductor and metal-insulator, Semiconductor junctions; field-effect transistors, MOSFETs, CMOS: heterostructures, high-electron-mobility devices, HEMTs, Quantum Hall effect, Introduction to single electron transistors (SETs): quantum dots, single electron effects, Coulomb blockade.
Introduction to magnetism and superconductivity: Basic Magnetic Phenomena; paramagnetism, ferromagnetism, ferrimagnetism, anti-ferromagnetism, neon-magnetism, grant and colossal magnetoresistance: ferrofluids, Basic superconductivity phenomena, flux quantization and Josephson effects.

CHN 503: Nanochemistry (2 Credits)

Novel physical chemistry related to nanoparticles such as colloids and clusters: different equilibrium structures, quantum effects, conductivity and enhanced catalytic activity compared to the same materials in the macroscopic state.
Exploitation of self-assembly and self-organization to design functional structures in 1D, 2D or 3D structures. Examples to emphasize on self-assembled monolayers.
Role of polymers in lithography resists, as well as self-organization of more complicated polymer architectures such as block copolymers and polymer brushes.
Nanomaterials (Nanoparticles, nanoclusters, quantum dots synthesis): Preparation and Characterization: "Top-Down" and "Bottom-Up" approaches of nanomaterial (nanoparticles, nanoclusters and quantum dots) synthesis: Top-down techniques: photolithography, other optical lithography (EUV, X-Ray, LIL), particle-beam lithographies (e-beam, FIB, shadow mask evaporation), probe lithographies, Bottom-up techniques: self-assembly, self-assembled monolayers, directed assembly, layer-by-layer assembly. Pattern replication techniques: soft lithography, nanoimprint lithography. Pattern transfer and enhancement techniques: dry etching, wet etching, pattern growth techniques (polymerization, directed assembly). Combination of Top-Down and Bottom-up techniques: current state-of-the-art.

CHN 504: Characterization Techniques for Nanomaterials (1 Credit)

Characterization Techniques Related to Nanoscience and Nanotechnology: Compositional surface analysis: XPS, SIMS, Contact angles. Microscopies: optical microscopy, fluorescence and confocal microscopy, TEM, SEM, Probe techniques: Scanning tunneling microscopy (STM), Atomic force microscopy (AFM), Scanning Nearfield Optical Microscopy SNOM, Scanning Ion Conducting Microscopy (SICM). Ellipsometry, Neutron Scattering and XRD, Spectroscopic Techniques: UV-visible, FT-IR, Raman, NMR, ESR. Electrochemical Techniques: Voltammetric techniques, AC Impedance Analysis.

CHN 505: Biochemistry related to Nanoscience and Nanotechnology (1 Credit)

Basic Aspects of Molecular Biology: Structure and function of proteins, antibodies, enzymes and implications for processing. Nucleic acids: DNA, RNA. Lipids: structure, role in membranes. The mammalian cell: Internal organization, specialized cells such as nerve cells. Building up of nano-structures that incorporate biological molecules as components of the system. Use of biological design strategies as removable scaffolds and templates for the bottom-up assembly of nanomaterials. Applications of nanotechnology in biotechnology: killing cancer cells, providing oxygen and artificial mitochondria.

PHN 506: Carbon Nanotubes and Particles (1 Credit)

Synthesis and purification of carbon nanotubes, Single-walled carbon nanotubes and multiwalled carbon nanotubes, Structure-property relationships, Physical properties, Applications.

CHN 507: Nanoscience and Nanotechnology Laboratory I (3 Credits)

Some selected experiments will be done from the list of experiments given below.

Synthesis of nanometre scale particles of colloidal semiconductors such as TiO_2, CdS, ZnO, SnO_2, Cu_2S, CuCNS, Cu_2O, $BaTiO_3$, $SrTiO_3$ by wet chemical methods, hydrothermal methods, and pyrolytic or high temperature methods.
Characterization of colloidal semiconductor materials by UV-visible spectroscopy, XRF studies, XRD methods and determination of particle size using XRD half peak width.
Determination of conductivity type by Mott-Shottky plots, cyclic voltammetry and AC-impedance analysis.
Deposition of thin films of semiconductor nanostructures by doctor blading, screen printing, and using the Langmuir-Blogett film casting techniques.
Dye sensitization of semiconductor nanosctructures and construction of solar cells.
Synthesis and characterization of nanoparticles of technologically valuable natural minerals such as hydroxyapatite, ferric phosphate, colloidal silica nanoparticles and their characterization by XRD, XRF, FT-IR methods.
Clay-polymer nanocomposites: Clay-ionically conducting polymer nanocomposites and determination of their ionic conductivities by AC impedance analysis, clay-electronically conducting polymer nanocomposites and determination of their electronic and ionic conductivities through AC impedance analysis and current-time plots at constant applied potential using blocking and non-blocking electrodes.
Synthesis of layered double hydroxides and investigation of anion separation using layered double hydroxides.

Pillard clays and clay-polystyrene, clay-poly(vinyl alcohol), clay-poly(methyl methacylate), clay-polyacylonitrile, clay-poly(ethylene oxide) nanocomposites and determination of their mechanical and thermal properties.
Covalent attachment of semiconductor nanoparticles into textile fibres and textile materials. Investigation of stain-resistant properties and antimicrobial activities.
Preparation of mosquito-repellent textiles.
Carbon nanotubes and carbon nanoparticles: Preparation of carbon nanotubes by pyrolysis of organic gases/Pyrolytic thermal treatment of graphite followed by annealing. Purification of carbon nanotubes, Investigation of extent of purification using XRD, SEM studies of carbon nanotubes (to be carried out elsewhere), Extraction of carbon nanoparticles from vehicle exhausts, Characterization and Particle size analysis using XRD.
Top-down approach to nanoparticles of local minerals: crushing, grinding and milling, Preparation of graphite nanoparticles.
Preparation of colloidal graphite nanoparticles and investigation of their technological uses as lubricants.
Preparation of self-assembled monolayers and their characterization using AFM, contact angle measurements, AC-impedance analysis.

CHN 508: Nanoscience and Nanotechnology Laboratory II (2 Credits)

Protein extraction and purification; Chromatographic techniques, SDS-PAGE, Protein quantification, DNA extraction from animal, plant and bacteria cells, Agarose and Gel electrophoresis.

CHN 597: Scientific Writing, Research Methodology and Seminar (1 Credit)

Compulsory for all students: Each student is required to present a seminar under the supervision of a staff member assigned by the course coordinator.

The nature and concepts of research, types of research and tools of research, research design and conceptualization, operationalization measurement and causality, survey of research and data collection techniques, strategies for data analysis and their applications, scientific and technical writing, writing research reports/thesis and scientific papers, compilation of bibliography, information gathering through internet and use of electronic resources.

PHN 516: Applications of Nanomaterials in Local Industries

Applications of nanoscience and nanotechnology in Sri Lankan industries: Garment industry: Smart textiles with antimicrobial properities, stain-resistant properties, mosquito-repellent properties, nanosensors to detect body temperature, pressure, pulse rate, and so on. Rubber industry: Clay-rubber nanocomposites, carbon nanotube-rubber nanocomposites. Activated carbon industry: Applications of activated carbon nanostructures in supercapacitors, gas separation, catalysis. Local minerals for advanced industries: Graphite, ilmanite, quartz, mica, rutile, zircon, feldspars, gems etc. Electronics industry: Solar cells, electronic components, light-emitting diodes, liquid-crystal display devices, electronically conducting polymers, ionically conducting polymers, batteries, fuel cells.

PHN 517: Nanotechnology in Energy Conversion and Storage (3 Credits)

Improvements in solar energy conversion and storage; better energy-efficient lighting; stronger and lighter materials that will improve energy transportation efficiency; use of low-energy chemical pathways to break down toxic substances for remediation and restoration; and better sensors and controls to increase efficiency in manufacturing and processing.
Energy Storage: Fuel Cells, Carbon Nanotubes for energy storage, Hydrogen Storage in Carbon Nanotubes, Use of nanoscale catalysts to save energy and increase the productivity in industry, Rechargeable batteries based on nanomaterials.
Goals for the next 5-10 years – solutions and barriers in Nanotechnology and energy.

PHN 518: Nanoelectronic Devices (2 Credits)

Nanoscale electronic, optical, liquid crystal and magnetic devices, Spintronic devices including spin valves and MRAM devices, nanoscale semiconductor electronic devices including CMOS at sub-15 nm gate length, III-V and wide band gap devices, solid state devices for quantum computation including Josephson junctions and quantum dots, nanoscale photonic devices including photonic band gap materials. Nanoscale liquid crystal display and nondisplay devices, organic electronic devices.

CHN 519: Nanobiotechnology and Nanotechnology in Healthcare (3 Credits)

Doctor-Patient Interface: Testing Devices in the Doctor's Office. e.g. of blood and urine samples for Home / Ambulance / Bedside Monitoring.
Underpinning Electronic and Optical Techniques: Amperometric sensors, Potentiometric sensors including chemically sensitive field effect transistors, Optical sensors including evanescent field sensors and optical waveguide sensors, Surface Plasmon Resonance sensors, Resonant Mirror sensors, Capillary Fill Devices, Electro-mechanical Devices such as cantilever bridge sensors.
Underpinning Biological Techniques: Enzyme-based assays, Antibody-based assays, Nucleic acid-based techniques e.g., Polymerase chain reaction (PCR), Lab-on-a-chip.
Applications in the Pharmaceutical Industry: Adaptation of above techniques for large analyte panel testing e.g., Lab-on-a-chip in screening in drug development, Development of techniques for process control in pharmaceutical industry.
Applications in Medical Research Laboratories: Development of instrumentation for understanding bioprocesses.
Applications in the Hospital Environment: Implantation of large scale integrated circuits, e.g., to bypass lesion in paraplegia and provide muscle control, Nanotechnology in devising hybrid systems in which electronic and neural elements communicate. Novel nanoscale imaging agents at the research level.
Bionanomachines in action: Biomolecules; Structure and function of Proteins, Polysaccharides, Lipids, Nucleic acids; DNA and RNA.
Biomolecular design and Biotechnology: Recombinant DNA technology, Biomolecular structure determination, Molecular Modeling.
Structural principles of Bionanotechnology: The raw materials; biomolecular structure and stability, Protein folding, Self assembly, Self-organization, Molecular recognition, Flexibility
Functional principles of Bionanotechnology: Information driven nano-assembly, Energetics, Chemical transformation, Regulation, Biomaterials, Biomolecular motors, Traffic across membranes, Biomolecular sensing, Self replication, Machine-Phase bionanotechnology.

Bionanotechnology today: Basic capabilities, Nanomedicine, Molecular design using biological selection, Harnessing molecular motors, Artificial life, Hybrid materials, Biosensors**.**
The future of Bionanotechnology: Ethical considerations, Case studies.

CHN 520: Business Enterprise, Economics and Research Policy in Nanotechnology (2 Credits)

Nanotechnology landscape and commercially attributable sectors, tools to map, understand and segment the nanotechnology marketplace, Frameworks for developing nanotechnology marketplace, management issues, Costing strategies, commercialization strategies, Intellectual Property Issues, Societal Impacts, Health and Safety Issues, Customer understanding, marketing, social and policy issues arising from the development of nanotechnology, ethics. Nanotechnology in sustainability and wealth of nations, organizations and entire industries in the future. How the nations prepare talent, intellectual property, capital and technical expertise to develop the petro-economy, healthcare products and power supply to the nation. Funding strategies/ Education policies in the world and Sri Lanka. Worldwide Research Activities. Tools and Nanoproduct Development. Present Global Nanotechnology efforts.

CHN 521: Environmental Nanotechnology (2 Credits)

Reduced waste and improved energy efficiency.
Waste remediation: Nanoporous polymers and their applications in water purification, Photo-catalytic fluid purification. Energy conversion. Hierarchical self-assembled nano-structures for adsorption of heavy metals. Pollution by Nano-particles.

CHN 599: Research Project (6 Credits)

Students are required to carry out a research project of 3-6 month duration related to Nanoscience/Nanotechnology. Whenever possible, each student is assigned with a supervisor from among the panel of teachers. Arrangements could also be made to pursue research studies at institutions other than the relevant faculties of University of Peradeniya. In such circumstances, the student is assigned with two supervisors: an internal supervisor from the panel of teachers and an external supervisor from the institution where the research project is carried out.

6. COURSE COORDINATORS

Appearing within square brackets are the course numbers for which each coordinator is responsible. Each course will be conducted by the respective coordinator and associated experts identified by the respective course coordinator.

Professor HMN Bandara, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Aston) [CHN 504, CHN 507]
Dr. LRAK Bandara, Department of Physics, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Perad.) [PHN 518]
Professor MA Careem, Department of Physics, University of Peradeniya
B.Sc. (Cey.), Ph.D. (Lond.) [PHN 506]
Mrs. S Ileperuma, Science Library, University of Peradeniya.
B.Sc. (Perad.), MLH (Col.) [CHN 597]
Dr. ADHK Kankanamge, Department of Economics, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Oklahoma) [CHN 520]
Professor BSB Karunaratne, Department of Physics, University of Peradeniya
B.Sc. (Cey.), Ph.D. (Warwick) [PHN 516]
Dr. N Karunaratne, Department of Chemistry, University of Peradeniya
B.Sc. (Col.), Ph.D. (Br. Col.) [CHN 505]
Professor HMDN Priyantha, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Hawaii) [CHN 521]
Professor RMG Rajapakse, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Lond.) [CHN 501, CHN 507, CHN 508, CHN 599]
Dr. RGS Rajapakse, Department of Molecular Biology & Biotechnology, University of Peradeniya, *B.Sc. (Perad.), Ph.D. (Japan)* [CHN 508, CHN 519]
Prof. K Premaratne, Department of Physics, University of Peradeniya
B.Sc. (Cey.), M.S., Ph.D. (Hawaii) [PHN 502, PHN 517]
Dr. L Samaranayaka, Faculty of Engineering, University of Peradeniya
B.Sc.Eng. (Perad.), MIEEE, AMIESL, Ph.D. (Tech. Lic.) [PHN 518]
Dr. VN Seneviratne, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Cambridge) [CHN 503]

OTHER RESOURCE PERSONS

Dr. RMW Amaradasa, National Science Foundation (NSF), Colombo.
B.Sc. (Perad.), Ph.D. (Sri Lanka)
Professor BMR Bandara, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (ANU)
Dr. NC Bandara, PGIS, University of Peradeniya
B.Sc. (Perad.), M.Sc. (New Orleans), Ph.D. (New Orleans)
Dr. WMAT Bandara, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (TIT)
Dr. PWSK. Bandaranayake, Department of Physics, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Perad.)
Dr. RLN Chandrakanthi, Department of Physics, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Perad.)
Professor MAKL Dissanayake, Department of Physics, University of Peradeniya
B.Sc. (Cey.), M.S., Ph.D. (Indiana)
Dr. P Ekanayake, Department of Physics, University of Peradeniya
B.Sc. (Perad.), M.Sc. (Perad.) Ph.D. (MLU-Germany)

Dr. CV Hettiarachchi, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (TIT)
Professor OA Ileperuma, Department of Chemistry, University of Peradeniya
B.Sc. (Cey.), Ph.D. (Arizona)
Professor V Karunaratne, Department of Chemistry, University of Peradeniya
B.Sc. (Col.), Ph.D. (Br. Col.)
Dr. N Kottegoda, Department of Chemistry, University of Sri Jayawardanepura
B.Sc. (Perad.), Ph.D. (Cambridge)
Dr. S Maithripala, Faculty of Engineering, University of Ruhuna
B.Sc.Eng.(Perad.), M.Phil. (Perad.), M.Sc. & Ph.D. (TTU, Texas)
Dr. MGYU Manavadevi, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Wayne State University)
Dr. AN Navaratne, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Hawaii)
Professor ADLC Perera, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (TIT)
Dr. VA Seneviratne, Department of Physics, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Oklahoma)
Professor R Silva, Advanced Technology Institute, University of Surrey, UK
B.A., M.A., Ph.D. (Cantab) CEng CPhys FIEE FInstP
Dr. V Sivakumar, Department of Physics, University of Peradeniya
B.Sc. (Perad.), Ph.D. (Georgia State University)
Professor SAR Weerasuriya, Institute of Fundamental Studies, Hantana Road, Kandy.
B.Sc. (Perad.), Ph.D. (Sri Lanka)
Professor A Wickramasinghe, Department of Chemistry, University of Peradeniya
B.Sc. (Perad.), Ph.D. (FRG)

7. PROGRAMME COORDINATORS

Prof. R. M. G. Rajapakse
Department of Chemistry,
University of Peradeniya,
Peradeniya
Tel.: 081 2394442
E-mail: rmgr@pdn.ac.lk

Prof. R. G. S. C. Rajapakse
Department of Molecular Biology & Biotechnology Faculty of Science
University of Peradeniya
Peradeniya
Tel.: 081 2394502
E-mail: sanathr@pdn.ac.lk

Dr. A. C. A. Jayasundara
Department of Chemistry
Faculty of Science
University of Peradeniya
Peradeniya
Tel: +94 81 2394425
Email: acaj@pdn.ac.lk