CSIR Two-year Post-graduate Research Training Programme on Advanced Semiconductor Electronics at CEERI, Pilani

(2009-2010)

Introduction

The modern information, communications and computing technology revolution that has swept through and changed the human society beyond recognition over the last four decades owes its existence to the continued advancement in semiconductor technologies.

Whether it is the ever more powerful microprocessor chips that are in our desktops and laptop computers, or it is the flashing laser lights transporting giga-bits of information per second over fiber-based networks powering the Internet, or it is the variety of microsensors, microelectro-mechanical systems (MEMS) and microsystems that are now making their way into our everyday lives, it is the advances in semiconductor electronics that is scripting all this progress.

The ubiquitous cell phone in our pockets or the flat screens of our computer screens and TV sets, all owe their existence to the innovations in semiconductor electronics. New nano-scale electronic devices are expected to mark the beginning of a new era of technology and innovation revolution in the coming years.

About the Programme

This PG research training programme aims to provide in-depth exposure to the engineering concepts, scientific principles, research methodology and hands-on experience on advanced real-life R&D projects in different specializations of semiconductor electronics. Students completing this two-year programme will be fully research-enabled and industry-ready.

The first semester of the programme focuses on core subjects and associated laboratories related to semiconductor electronics covering the essentials of semiconductor sciences and technology.

The second and third semesters offer advanced elective courses for specialization in the areas of :

- MEMS and Microsensors.
- Nanoelectronics.
- VLSI Design.
- Optoelectronics and Photonics.

The third and fourth semesters give the opportunity to the candidates to effectively utilize the knowledge acquired through the courses towards advanced R&D project work and dissertation in their specialization areas.

The laboratory facilities and research expertise of the distinguished scientists acting as faculty and mentors further adds to the programme's uniqueness.

Number of Seats in the Programme

The total number of seats available is 12 with the following distribution among the specializations :

- MEMS and Microsensors : 03
- Nanoelectronics : 03
- VLSI Design : 03
- Optoelectronics and Photonics : 03

Allotment of specializations will be done based on the candidate's performance and preference at the end of the first semester.

Mode of Payment

The programme fees at CEERI can be deposited using the following modes :

1. NEFT Bank Transfer : Amount needs to be transferred to the saving account number 61033385318 of Director, CEERI at SBBJ, Pilani (IFSC code SBBJ0010398) with appropriate narration statement.

2. Demand Draft : Issued in favour of “Director, CEERI” payable at Pilani and post it by speed post or registered letter to “Director, CEERI, Pilani – 333 031” with your name and “PGRP-ASE” written in pencil on the reverse side of the demand draft.

The hostel boarding and lodging charges will need to be made on periodic basis, as applicable.

Other Details (Admission Process, Eligibility, Fellowship, Important Dates, *etc*.)

Please visit the CSIR website <http://www.csir.res.in/>.

About CEERI

To know more about CEERI's current R&D activities, laboratory facilities and past achievements, please see <http://www.ceeri.res.in/>.

Semester-wise Scheme for Advanced Semiconductor Electronics

Semester-I

Subject Code	Subject	Credits
ASE 101	Physics of Semiconductor Materials and Devices	3
ASE 102	Unit Processes in Semiconductor Technologies	3
ASE 103	CMOS Digital VLSI Design	3
ASE 111	Lab: Device Physics and Simulation	2
ASE 112	Lab: Unit Processes in Semiconductor Technologies	2
ASE 113	Lab: Physical CMOS-based Design	2
ASE 151	Technical Communications	1

Semester-II

Subject Code	Subject	Credits
ASE 201	Characterization Techniques for Semiconductor Materials, Technologies and Devices	3
ASE 20x	Elective-I	3
ASE 20x	Elective-II	3
ASE 221	Lab: Characterization and Measurement Techniques	2
ASE 22x	Lab/Seminar: Elective-I Related	2
ASE 22x	Lab/Seminar: Elective-II Related	2
ASE 251	Project Management Techniques	1

MEMS and Microsensors (Elective-I and Elective-II)

Subject Code	Subject	Credits
ASE 202	MEMS Technology, LTCC and Packaging	3
ASE 203	Physics and Design of MEMS and Microsensors	3
ASE 222	Lab: MEMS Technology, LTCC and Packaging	2
ASE 223	Lab: Design of MEMS and Microsensors	2

Nanoelectronics (Elective-I and Elective-II)

Subject Code	Subject	Credits
ASE 204	Nanoelectronic Devices and Technologies	3
ASE 205	Advanced VLSI Technologies and Devices	3
ASE 224	Lab: Nanoelectronic Technologies	2
ASE 225	Lab: VLSI Technology Process Simulation and Seminar on Advanced VLSI Technologies	2

VLSI Design (Elective-I and Elective-II)

Subject Code	Subject	Credits
ASE 206	CMOS Analog Design	3
ASE 207	Advanced VLSI System Architectures	3
ASE 226	Lab: CMOS Analog Design	2
ASE 227	Lab: HDL-based Digital Design	2

Optoelectronics and Photonics (Elective-I and Elective-II)

Subject Code	Subject	Credits
ASE 208	Optoelectronic Materials, Devices and Technologies	3
ASE 209	Photonic Materials, Devices and Technologies	3
ASE 228	Lab: Optoelectronic Devices and Technologies	2
ASE 229	Lab: Photonic Devices and Technologies	2

Semester-III

Subject Code	Subject	Credits
ASE 30x	Elective-III	5
ASE 311	Project Work and Seminar	12

Elective-III

Subject Code	Subject	Credits
ASE 301	Mixed Signal Design + Lab	5
ASE 302	CAD for VLSI Design + Lab	5
ASE 309	Advanced Self-Study (Special Topic)	5

Semester-IV

Subject Code	Subject	Credits
ASE 401	Dissertation Seminar and Viva-voce	4
ASE 402	Dissertation Report	14

Course Descriptions

ASE 101 : Physics of Semiconductor Materials and Devices (3-0-0) ***3 Credits***
Faculty : Dr. J. Akhtar

Semiconductors; inorganic and organic, Single crystalline, polycrystalline, porous, amorphous Crystal structures and material properties; Si, GaAs, SiC; Energy band diagrams; Dielectric constant, Permeability, permittivity, Sheet resistance, resistivity, mobility, thermal conductivity and heat dissipation; Electromagnetic theory, Piezo-resistive and piezoelectric effects, Defects, Dislocations and micro-plasma, Phonon dynamics, Ion-solid interactions, Semiconductor equations, Minority carrier life time, Avalanche breakdown phenomena, Hall effect, Soft magnetic materials, Theory of p-n junction, Schottky barrier, MOSFETs and MESFETs, IMPATTs and BARRITTs, Rectifiers, Oscillators and Detectors, Photovoltaics and solar cell, Solid state sensors and transducers, MOS analysis.

ASE 102 : Unit Processes in Semiconductor Technologies (3-0-0) ***3 Credits***
Faculty : Dr. G. Eranna

Crystal growth techniques, wafer preparation and shaping, chemical cleaning, thermal oxidation, photo-lithography, chemical etching (wet and dry), chemical vapor deposition techniques, thermal diffusion, ion implantation, metalization, chemical mechanical polishing, rapid thermal processing.

ASE 103 : CMOS Digital VLSI Design (3-0-0) ***3 Credits***
Faculty : Dr. A. Karmakar

Introduction to MOSFET from designer's viewpoint; MOS inverter : static and switching characteristics; MOS capacitor; Layers in VLSI design; Design rules and technology interface; Stick diagrams and Layout design; Propagation delay, Fan-out consideration; CMOS Latch-up; Scaling; Combinational MOS logic circuits : pass-transistors/transmission gates, primitive logic gates, complex logic gates; Sequential MOS logic circuits : latches and flip-flops; Dynamic logic circuits; Clocking issues; CMOS subsystem design.

ASE 111 : Device Physics and Simulation Laboratory (0-1-3) ***2 Credits***
Faculty : Dr. J. Akhtar

Analytic and numerical methodology, Device modeling; Poisson's equation solver in 1D; Poisson's equation solver in 2D and 3D; Heat dissipation modeling; Avalanche breakdown voltage estimation; Device modeling using MEDICI; F-D approximation, SoR iterative method, Crack-Nicholson scheme;
Material modeling.

ASE 112 : Unit Process in Semiconductor Technologies Laboratory (0-1-3) ***2 Credits***
Faculty : Dr. G. Eranna

Laboratory discipline and safety; wafer preparation and shaping; chemical cleaning; thermal oxidation, photo-lithography; wet chemical etching; dry etching; chemical vapor deposition; thermal diffusion; ion implantation; metalization.

ASE 113 : CMOS-based Physical Design Laboratory (0-1-3) ***2 Credits***
Faculty : Dr. A. Karmakar

Laboratory discipline and practices; SPICE simulation; Schematic editor, Layout editor, DRC, LVS; Transfer and output characteristics NMOS transistor, parameter variations; CMOS inverter design, inverter threshold, noise margin, propagation delay; Layout of CMOS inverter, n-well design rules, LVS, static and transient characteristics, DRC; 2-input NAND/NOR gate; D latch and flip-flop; Post-extract simulation.

ASE 151 : Technical Communication (1-1-0) ***1 Credit***
Faculty : Sh. Raj Singh

Role and importance of communication; Effective oral and written communication; Technical report writing; Technical/R&D proposals; Research paper writing; Letter writing and official correspondence; Notices, agenda, minutes; Oral communication in meetings, seminars, group discussions; Use of modern aids.

ASE 201: Characterization Techniques for Semiconductor Materials, Technology and Devices (3-0-0) ***3 Credits***
Faculty : Dr. K. J. Rangra; Dr. J. Akhtar; Dr. G. Eranna

Resistivity, Contact resistance, barrier height, carrier and doping concentration, mobility and carrier life time measurement techniques; Test structures for technology characterization; Analysis of surfaces, interfaces, thin films and devices; E-beam based techniques, Scanning Electron Microscopy and allied techniques; Material Analyses Techniques; Scanning Probe Techniques; Ion beam based techniques; Interferometry based techniques for materials and device characterization; Optical characterization.

ASE 202 : MEMS Technology, LTCC and Packaging (3-0-0) ***3 Credits***
Faculty : Dr. V. K. Khanna; Sh. B. D. Pant; Dr. P. K. Khanna

Review of Silicon crystal and unit processes; Processing steps for MEMS device fabrication; photo-lithography and backside mask alignment; Surface and bulk micro-machining techniques; Deep reactive ion etching; LIGA process; Wafer-level bonding and packaging techniques; LTCC technology, materials, LTCC process steps, bonding and packaging; Testing and characterization of technology; Reliability and residual stress issues.

ASE 203 : Physics and Design of Microsensors (3-0-0) ***3 Credits***
Faculty : Dr. Ram Gopal; Dr. K. J. Rangra

Overview of Microsensors; Mechanical properties of materials and essentials of structural mechanics; Electro-mechanical, magneto-mechanical and piezo-based sensing; Structural elements for MEMS and microsensors (Beams, plates, cantilevers, bridges and diaphragms); Electrostatic sensing and actuation (parallel plate and torsional structures, time domain analysis); Micro-fluidics; Scaling laws and miniaturization; Micro-system design principles; MEMS simulation and design Tools; RF MEMS; Reliability issues in microsensors; Examples and applications of MEMS microsensors.

ASE 204 : Nanoelectronic Devices and Technologies (3-0-0) *3 Credits*
Faculty : Sh. Anil Kumar

Low-dimensional structures (Quantum well, quantum wire, quantum dot, quantum confinement); Confinement energy level, band-gap enhancement, absorption-emission spectra, blue shift, luminescence; Nanoelectronic Devices (Single electron box, coulomb blockade, single electron transistor, pump, turnstile, trap, memory); Simulation, Modeling of single electron devices and applications; Technology for fabrication of nano-structures and nanoelectronic devices; Next generation lithography techniques; Characterization of nanoscale materials and nanodevices.

ASE 205 : Advanced VLSI Technologies and Devices (3-0-0) *3 Credits*
Faculty : Dr. R. K. Nahar

Overview of VLSI technology; Effect of scaling on MOS devices and interconnections; Hot electron degradations and drain engineering structures; Process and material requirements for VLSI devices; Advanced thin-film deposition and VLSI process techniques; High-k dielectric and low-k dielectric materials; Process integration of high-k metal gate for nano-scale CMOS technology; Device characterization, failure diagnosis and reliability measurements; Carrier transport mechanisms, velocity saturation, ballistic transport; Nano-scale MOSFET, FinFET and Multigate FET; Emerging research materials and future devices.

ASE 206 : CMOS Analog Design (3-0-0) *3 Credits*
Faculty : Dr. S. C. Bose

Basic concepts of transistors and diodes, their modeling, large-signal and small signal analysis, CMOS technology, clock feed-through; Reference sources : bias circuits, band-gap reference circuit, cascode current mirror; Single-stage amplifier, common source amplifier, drain and gate amplifier, differential amplifier; Operational amplifier; Comparators; Switched-capacitor circuits; Introduction to data converters; Issues of analog layout and device noise.

ASE 207 : Advanced VLSI System Architectures (3-0-0) *3 Credits*
Faculty : Dr. A. S. Mandal; Sh. Raj Singh; Dr. A. Karmakar

Introduction and review of basic computer architectures, CISC and RISC processors; Pipelining, hazards, exception handling, optimization techniques, synchronous and asynchronous pipelining; Memory organization, caches, virtual memory, memory management; Arithmetic circuits, algorithms and architectures for high-radix adders , multipliers, sine-cosine and exponential computation; Instruction-level parallelism, super-scalar, super-pipelined and VLIW architectures, array and vector processors; Multiprocessor architectures and parallel architectures, synchronization, memory consistency; DSP architectures; Performance improvement techniques; ASIP; Low-power architectures; Fault-tolerant architectures; Case study on Algorithm-to-Architecture; Future trends.

ASE 208 : Optoelectronic Materials, Devices and Technologies (3-0-0) *3 Credits*
Faculty : Dr. C. Dhanvantri

Optoelectronic Materials; Growth of Epitaxial materials; Characterization of Epitaxial Materials; Optoelectronic Devices (Light Emitting Diodes, Semiconductor Lasers, UV, Visible and IR Photo-detectors

and Receivers, Solar Cells); Compound semiconductors and advanced electronic devices; Compound Semiconductor Technologies; Packaging of compound semiconductor components; Applications and trends.

ASE 209 : Photonic Materials, Devices and Technologies (3-0-0) ***3 Credits***
Faculty : Dr. S. Pal

Introduction to Photonics; Basic photonic components and their technologies; Propagation of Electromagnetic waves; Optical waveguides and optical fibers; Principle of optical fiber communications, Transmission capacity, Dispersion and losses in optical fiber; Coupled mode theory in guided wave systems; Materials and fabrication technologies; Types of waveguides; Optical MEMS; Basic photonics devices and components; Packaging of photonic devices; Applications of photonic devices and recent trends.

ASE 221 : Characterization and Measurement Techniques Laboratory (0-1-3) ***2 Credits***
Faculty : Dr. K. J. Rangra; Dr. J. Akhtar; Dr. G. Eranna

IV/CV Measurements; Resistivity, thickness, thin film surface and bulk defects; grain size measurement; AFM/STM surface analysis; stress and deformation measurements.

ASE 222 : MEMS Technology, LTCC and Packaging Laboratory (0-1-3) ***2 Credits***
Faculty : Sh. B. D. Pant; Dr. P. K. Khanna

Laboratory practices; Wafer cleaning; Lithography : front and backside alignment; Bulk micro-machining; DRIE process; LPCVD; Metalization; Wafer bonding; Surface planarization; Wafer dicing; LTCC process; Packaging.

ASE 223 : Design of MEMS and Microsensors Laboratory (0-1-3) ***2 Credits***
Faculty : Dr. Ram Gopal; Dr. K. J. Rangra

MEMS design tools; Design of pressure sensors of various types; Design of gas sensors of various types; Acoustic, Ultrasonic, micro-resonator, ISFET; RF MEMS design and simulation.

ASE 224 : Nanoelectronic Technologies Laboratory (0-0-3) ***2 Credits***
Faculty : Sh. Anil Kumar

Fabrication of metal thin films by sputtering/e-beam/resistive-heating and measurement of film thickness by making steps using wet etching; Simulation of single electron devices using SIMON; Simulation of inverter circuit using SET in SIMON; Operation of AFM/STM; Analysis of AFM/STM images; Study of annealing effect on roughness/grain size of metal films by AFM/STM imaging and analysis.

ASE 225 : VLSI Technology Process Simulation Laboratory and Seminar on Advanced VLSI Technologies (0-1-3) ***2 Credits***
Faculty : Dr. R. K. Nahar; Dr. G. Eranna

This course involves a literature search / review of the development of current research materials, process methodologies, fabrication technologies, simulation, analysis of results and novel applications.

ASE 226 : CMOS Analog Design Laboratory (0-1-3) *2 Credits*
Faculty : Dr. S. C. Bose

I-V characteristics of MOSFET, estimation of early voltage; Clock feed-through and its minimization; Bias generation architecture simulation; Band-gap reference circuit simulation; Design and simulation of various amplifiers; Design and simulation of 2-stage CMOS operational amplifier; Layout of analog circuits.

ASE 227 : HDL-based Digital Design Laboratory (0-1-3) *2 Credits*
Faculty : Dr. A. Karmakar

Introduction to HDL; Simulation of behavioral, RTL, data-flow and structural HDL code; Sub-system design using HDL : various adder architectures, BCD arithmetic, various counters, traffic-light controller; mini-project. *(Either VHDL or Verilog will be used as the HDL for the laboratory.)*

ASE 228 : Optoelectronic Devices and Technologies Laboratory (0-0-3) *2 Credits*
Faculty : Dr. C. Dhanvantri

Lift-off process for Ohmic Contact on GaAs substrate; TLM measurements for specific contact resistance; RIE process for GaAs etching; LI Characteristics of 980 nm Laser Diode; Transistor characteristics of GaAs Power MESFET; LED Characteristics; Photoluminescence characterization of GaN epitaxial material; Characterization of PIN-FET Receiver Module.

ASE 229 : Photonic Devices and Technologies Laboratory (0-0-3) *2 Credits*
Faculty : Dr. S. Pal

Measurement of refractive index and thickness of planar waveguides; Propagation loss measurement of planar waveguides; Design of 1x2 and 1x4 optical power splitter; Measurement of insertion loss, uniformity and polarization-dependent loss of a packaged 1x8 optical splitter at C+L band region; Design and simulation of Bragg gratings; Waveguide patterning by photo-lithography; Testing of MUX/DEMUX by DWDM test set-up; Chip-level testing: alignment of DUT (in a diced chip) to the source and the detector with x-y-z alignment stages.

ASE 251 : Project Management Techniques (1-1-0) *1 Credit*
Faculty : Sh. Raj Singh

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Resource allocation; Time management; Project monitoring and control; Project documentation.

ASE 301 : Mixed Signal Design (3-0-3) *5 Credits*
Faculty : Dr. S. C. Bose

Device noise analysis, Friis rule; Sample-and-hold circuits; Architectural exploration of A-to-D and D-to-A converters; Low-power converters; Sigma-Delta converters; Analog and digital filters; PLL : phase detector, VCO, frequency synthesizer; Low-noise amplifier; Active and passive mixer; Case study of converters and PLLs.

The laboratory component will cover Sample-and-hold circuit design and simulation; Design and simulation of comparators; Design and simulation of converters; group mini-projects.

ASE 302 : CAD for VLSI Design (3-0-3) *5 Credits*
Faculty : Sh. Raj Singh; Dr. A. S. Mandal

Overview of design flow and methodologies; Schematic and Layout editors; Overview of CIF; Partitioning algorithms; Placement algorithms; Routing algorithms; HDL-based design flow and CAD tools; High-level synthesis algorithms; Simulation tools and logic simulation mechanisms; Future trends.

The laboratory component will have a mini-project covering the design and implementation of the above CAD algorithms.

ASE 309 : Advanced Self-study on Special Topics (0-0-6) *5 Credits*
Faculty : Senior Scientists

This course involves readings from published literature or books about new frontiers on a specific topic. A technical report needs to be submitted and a seminar on the special topic needs to be presented.

List of Faculty

S. No.	Name	Designation	Discipline
1.	Dr. Chandra Shekhar	Director	Microelectronics/VLSI Design
2.	Sh. Raj Singh	Scientist G	Microelectronics/VLSI Design
3.	Dr. A. S. Mandal	Scientist F	Microelectronics/VLSI Design
4.	Dr. S. C. Bose	Scientist E-II	Microelectronics/VLSI Design
5.	Dr. A. Karmakar	Scientist E-I	Microelectronics/VLSI Design
6.	Dr. V. K. Dwivedi	Ex-Scientist G	MEMS Technology
7.	Dr. V. K. Khanna	Scientist G	MEMS/VLSI Technology
8.	Dr. Ram Gopal	Scientist F	MEMS Technology/Devices
9.	Sh. B. D. Pant	Scientist F	MEMS Technology
10.	Dr. P. K. Khanna	Scientist F	HMC Technology
11.	Dr. K. J. Rangra	Scientist F	MEMS Devices/Design
12.	Dr. R. K. Nahar	Scientist G	VLSI Technology
13.	Dr. J. Akhtar	Scientist G	Semiconductor Devices
14.	Sh. Anil Kumar	Scientist F	Nanoelectronics
15.	Dr. G. Eranna	Scientist E-II	VLSI Technology
16.	Dr. C. Dhanvantri	Scientist F	Optoelectronics/Photonics
17.	Dr. Suchandan Pal	Scientist E-I	Optoelectronics/Photonics