NIIT University

Eramus+ sponsored NU-NanoEl Capacity Development Project-

An International Initiative

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A. <u>Brief information of courses</u>:

1. Course 1

Course I is titled "**Introduction to Nanoelectronics: Science & Technology Basics".**

It deals with the sciences (Physics and chemistry) necessary to understand and work on Nanoelectronics. It has 10 units dealing various aspects of physics, chemistry, biology and electronics. Further, functional nanomaterials with their variable properties will be discussed. Consequently, molecular electronics to nanoelectronics will be focussed with nanolithography. After studying these 10 units, the student will be able to relate the nanomaterial properties with phenomena of basic sciences.

2. Course 2

Course 2 is titled "**Nanoelectronics: Processes, Computation and Design".**

Course 2 will be covering engineering science basics of nanoelectronics with potential of silicon technology. This course consists of 11 units, which consequently deal with MEMS and biology-inspired concepts. Further, these units also deal with Nanoelectronics and computational techniques, and will be covering biochemical and quantum-mechanical computers, parallel architectures, computing and softcomputing systems for nanoelectronics, complex integrated systems and their properties. Last 6 units will cover nanoelectronic circuit components and systems.

3. Course 3

Course 3 is titled "**Nanoelectronics Systems: Future Nanoelectronic Devices and Manufacturing processes"**

Course 3 will be focused on nanoelectronics systems: manufacturing processes and applications. In this course, first 4 units will be covering concepts of microelectronics to nanoelectronics with VLSI techniques and their limits. Units 5 to 9 will be focused on future nanoelectronic devices in detail. By the end of this course, student will be able to appreciate the importance of paradigm shift of science & technology in case of nanoelectronics vis-à-vis the present day VLSI technology.

4. Course 4

Course 4 is titled "**Nanoelectronics Systems: Applications- Quality living with Smart Future, Present to Future Business Systems".**

Course 4 mainly concentrates on the changing scenario of business and manufacturing aspects. This course is structured in a fashion where the teacher can use class room teaching, or project oriented learning or value creating industry practice method. The aim of this course is to make the student walk confidently to a nanoelectronic industry for work. Further, this course discusses in detail contrast between present and future business systems, future manufacturing units and business challenges. The course ends with case studies on existing Indian and European global nano-industries.

B. **Brief Descriptions of 4 Course Units**:

1. Course – 1 Introduction to Nanoelectronics: Science & Technology Basics

1.1 **Nanoscience and Nanotechnology:** Fundamentals of Frontiers; History of Nanotechnology, Nanostructure classification, Basics of Nanotechnology, Science and effect of Nanoscale system on Nanotechnology, Quantum confinement, Origin and theories of molecular electronics, Concepts of Single molecule magnates, Organic polymers.

1.2 Synthesis and Characterization Techniques of Nanomaterials: Top down and Bottom up techniques, Scanning electron microscope, Transmission electron microscope, Energy-dispersive X-ray spectroscopy, Atomic Force Microscope, Scanning tunneling microscope and millipede memory.

1.3 **Fuctionalization and Property Analysis of Nanomaterials:** Quantum dots, Core/shell, Quantum well heterostructures, Nanocomposites, Synthesis and physicochemical properties of Carbon allotrope (Fullerenes, Graphene, Carbon Nanotubes and Buckypaper), Layered Nanostructures and their Variable properties.

1.4 Nanolithography: Concepts and Theory: Principals of Nanolithography-electron beam lithography, Ion –Beam sculpting, Nanoimprint lithography, Photo lithography.

1.5 Molecular electronics to Nanoelectronics: Moleculators, Molecular wire, Methodology of Nanoelectronics, IC fabrications, Micro and Nano electronic systems and technology, Nano circuits, Nanowires, Quantum Wire and Quantum Well, Concepts of Lab on Chip (LOC)**,** Nanomotor, Nanopore, Nanosensor, Fabrication of Quantum point contact and basics of Synthetic Molecular Motors.

1.6 **Technology basics - Basics of Nanoelectronics:** Physical Fundamentals, Electromagnetic Fields and Photons, Quantization of Action, Charge, and Flux, Electrons Behaving as Waves (Schrödinger Equation), Electrons in Potential Wells. Photons interacting with Electrons in Solids, Diffusion Processes.

1.7 **On way to Nanoelectronics:** The Development of Microelectronics, Region of Nanostructures, Complexity Problem, Challenge initiated by Nanoelectronics.Milestones of Silicon Technology, Estimation of Technology Limits.

1.8 **Potentials of Silicon Technology:** Band Diagram of Semiconductor, Band Diagrams of Inhomogeneous Semiconductor Structures, Different Types of Transistor Integration,Microminiaturization, Methods and Limits of Microminiaturization in Silicon.

1.9 **Microelectronic and Mechanical Systems (MEMS)**: Technology of Micromechanics, Micromechanics for Nanoelectronics, NanoSensors, Integrated Optoelectronics.

1.10 **Biology-Inspired Concepts:** Biological Networks, Biological Neurons, Function of a Neuronal Cell, Biological Neuronal Cell on Silicon, Modelling of Neuronal Cells by VLSI Circuits, Neuronal Networks with local Adaptation and Distributed Data Processing.

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2. Course 2: Nanoelectronics Processes, Computation and Design

2.1 Nanoelectronics Processes - Biochemical and Quantum-mechanical Computers: DNA Computer Information Processing with Chemical Reactions, Nanomachines, Parallel Processing, Parallel Processing, Quantum Computer, Bit and Qubit, Coherence and Entanglement, Quantum Parallelism.

2.2 Parallel Architectures for Nanosystems: Basics of Information Theory, Data and Bits, Data Processing, Architectural Principles, Mono- and Multiprocessor Systems, Some Considerations to Parallel Data Processing, Influence of Delay Time, Power Dissipation and Parallelism, Architectures for Parallel Processing in Nanosystems.

2.3 Nanoelectronics computation - Computing Systems in Nanoelectronics: Classic Systolic Arrays, Processors with Large Memories, Processor Array with SIMD and PIP Architecture, Reconfigurable Computer, Teramac Concept as a Prototype.

2.4 Softcomputing and Nanoelectronics: Methods of Softcomputing, Fuzzy Systems, Evolutionary Algorithms, Connectionistic Systems, Computational Intelligence Systems, Characteristics of Neural Networks in Nanoelectronics, Local Processing, Distributed and Fault-Tolerant Storage, Self-Organization.

2.5 Complex Integrated Systems and their Properties: Nanosystems as Information-Processing Machines, Nanosystems as Functional Blocks, Information Processing as Information Modification, System Design and its Interfaces, Evolutionary Hardware, Requirements of Nanosystems.

2.6 Nanoelectronics Design – Circuits and Systems - Integrated Switches and Basic Circuits: Switches and Wiring, Ideal and Real Switches, Ideal and Real Wiring, Classic Integrated Switches and their Basic Circuits, The Transistor-a Classic Switch, Conventional Basic Circuits, Threshold Gates,Fredkin Gate.

2.7 Q**uantum Electronics:** Quantum Electronic Devices (QED), Upcoming Electronic Devices, Electrons in Mesoscopic Structures, Examples of Quantum Electronic Devices, Short-Channel MOS Transistor, Split-Gate Transistor, Electron-Wave Transistor, Electron-Spin Transistor, Quantum Cellular Automata (QCA), Quantum-Dot Array.

2.8 Bioelectronics and Molecular Electronics: Bioelectronics, Molecular Processor, DNA Analyzer as Biochip,Molecular Electronics, Switches based on Fullerenes and Nanotubes, Polymer Electronics, Self-Assembling Circuits, Optical Molecular Memories.

2.9 Nanoelectronics with Tunneling Devices: Tunneling Element (TE), Tunnel Effect and Tunneling Elements, Tunneling Diode (TD, Resonant Tunneling Diode (RTD, Three-Terminal Resonant Tunneling Devices,Technology of Digital Circuit Design Based on RTDs, Memory Applications, Basic Logic Circuits,Dynamic Logic, Digital Circuit Design Based on the, RTBT, RTBT Threshold, RTBT Multiplexer.

2.10 Single-Electron Transistor (SET): Principle of the Single-Electron Transistor, Coulomb Blockade, Performance of the Single-Electron Transistor, SET Circuit Design and technology, Wiring andLogic and Memory Circuits, SET Adder as an Example of a Distributed Circuit, Comparison Between FET and SET Circuit Design.

2.11 Nanoelectronics with Superconducting Devices: Macroscopic Characteristics, Macroscopic Model, Superconducting Switching Devices, Josephson Tunneling Device, Elementary Circuits, Memory, Associative or Content-Addressable Memory, SQUID - Superconducting Quantum Interferometer Device, LC-Gate, Magnetic Flux Quantum - Quantum Cellular Automata, Quantum Computer with Single-Flux Devices, Single Flux Quantum Device – SFQD, Rapid Single Flux Quantum Device – RSFQD, Application of Superconducting Devices, Integrated Electronics, FET Electronics -A Comparison, Electrical Standards.

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3. Course – 3: Nanoelectronics Systems: Future Nanoelectronic Devices and Manufacturing processes

3.1 Microelectronics to Nanoelectronics - Preliminaries of VLSI Circuits: Transistor integration process, VLSI techniques, Moore's law, Limits on VLSI circuits, Insight to Atom, Microminiaturization, Technology limits.

3.2 Nanoelectronics to Future Electronic Systems: Basics of Nanoelectronics, Electro-magnetic fields and photons, Quantization of Action, Charge and Flux, Electron wave theory and Schrodinger equation, Electrons in potential wells, Photons interacting with electrons in solids, RF interference and their effects.

3.3 Nanoelectronics and challenges: Replacement technologies, Nanoelectronic switches and wiring, Future Nanoelectronic switches and circuits, Circuit building to circuit fabrication, Nanomagnet as switch, Nanoelectronic basic switch, Nanosystem fabrication –challenges.

3.4 Limits on Nanoelectronic products: A Survey about the Limits, Replacement of Technologies, Energy Supply and Heat Dissipation, Parameter Spread as Limiting Effect, The Limits due to Thermal Particle Motion, The Debye Length, Thermal Noise, Reliability as Limiting Factor, Physical Limits, Thermodynamic Limits**,** Relativistic Limits, Quantum-Mechanical Limits, Equal Failure Rates by Tunneling and Thermal Noise, Removal of Uncertainties by Nanomachines, Uncertainties in Nanosystems, Uncertainties in the Development of Nanoelectronics.

3.5 Future Nanoelectronic Devices - Quantum Electronics: Upcoming Electronic Devices, Electrons in Mesoscopic Structures, Examples of Quantum Electronic Devices, Short-Channel MOS Transistor, Split-Gate Transistor, Electron-Wave Transistor, Electron-Spin Transistor, Quantum Cellular Automata (QCA), Quantum-Dot Array. Quantum Electronic Devices (QED).

3.6 Bioelectronics and Molecular Electronics: Bioelectronics, Molecular Processor, DNA Analyzer as Biochip, Molecular Electronics, Switches based on Fullerenes and Nanotubes, Polymer Electronics, Self-Assembling Circuits, Optical Molecular Memories.

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3.9 Nanoelectronics with Superconducting Devices: Macroscopic Characteristics, Macroscopic Model, Superconducting Switching Devices, Josephson Tunneling Device, Elementary Circuits, Memory, Associative or Content-Addressable Memory, SQUID - Superconducting Quantum Interferometer Device, LC-Gate, Magnetic Flux Quantum - Quantum Cellular Automata, Quantum Computer with Single-Flux Devices, Single Flux Quantum Device – SFQD, Rapid Single Flux Quantum Device – RSFQD, Emerging RF Nano Devices, Application of Superconducting Devices, Integrated Electronics, FET Electronics -A Comparison, Electrical Standards.

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4. Course 4: Nanoelectronics Systems: Applications- Quality living with Smart Future, Present to Future Business Systems

4.1 Quality Living & Smart Future - Data/Information origination, storage and processing, Safety, Cyber security and IP, Transportation Sector, Banking and Finance, Entertainment, Health Care – Medical systems, Heritage sector, Education, Employment and Entrepreneurship sector, Green Energy, Energy storage, Energy saving systems, Energy management, Alternate energy sources, Batteries**.**

4.2 Project Concept: Market Potential; Competitive Advantage; Project Information, Project Location, Infrastructure Availability, Connectivity, Raw Material, Manpower, Key Players, Machinery Suppliers, Potential Collaboration Opportunities, Key Considerations; Project Financials, Approvals & Incentives, Key Department Contacts.

4.3 Present to Future Business Systems - Future Manufacturing units: Present manufacturing units to Foundries, Importance of Fabrication Foundries, Optimum Business model for Nanoelectronic system production, Small scale Vs. large scale industries with reference to Nano electronic Business, Future India – "Software or fabrication", self-assembly techniques, Nanoelectronic path to future India.

4.4 **Business Challenges:** Resource management, Unit level and State level, National policies for NanoIndia**,** Human resource development, future jobs, College curriculum and training, manufacturing systems, Supply chain management and Future accountancy system, waste management**.**

4.5 Instrumentation and reliability aspects in manufacturing: Conventional to Nanoelectronic measurement systems, Measurement and control of Nanosystems using nanosensors, Quality control aspects, Self-diagnosis and auto system testing and validation.

4.6 Case studies on Existing Indian Nano-Industries

4.7 **Case studies** on Existing Asian Nano-Industries

4.8 **Case studies** on Existing European/Global Nano-Industries

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