ELECTRONICS AND PHOTONICS (EP) GROUP

Courses (all are 3 Credit courses)

EEE 6401: MOS Devices

The two terminal MOS Structure: flat-band voltage, inversion, properties of the regions of inversion and small signal capacitance. The four terminal MOS structure: charge-sheet model, strong inversion, moderate inversion and weak inversion. Threshold voltage-effects of ion implantation, short channel and narrow width. The MOS transistor in dynamic operation, small signal model for low medium and high frequencies, Non-ideal characteristics of MOSFET: channel-length modulation and short channel effects in MOSFETs. MOS scaling. Introduction to Multigate FET architecture: Double gate MOSFET, FinFET, Surrounding gate FET, high-K dielectric FETs, Tunnel FET (TFET)

EEE 6412: Heterostructures and Compound Semiconductor Devices

Introduction to III-V, II-VI and other compound semiconductors and their heterostrucutres; GaAs and GaN-based device technology. GaAs metal-semiconductor field effect transistor (GaAs MESFET): introduction, structure, equivalent circuits, current in linear and saturation for both long channel and short channel device, cut-off frequency, effect of source and drain resistances, gate resistance and application of GaAs MESFET. High electron mobility transistor (HEMT): practical HEMT structure and energy band line-up for both GaAs and GaN, introduction to newly proposed HEMT structures, equivalent circuit, HEMT noise, pseudomorphic and metamorphic HEMT and applications. Opto-electronic integration of compound semiconductor devices: heterojunction phototransistor and light amplifying optical switch and their applications. Low-temperature compound semiconductor electronics. Design consideration of MMICs and power MMICs using compound semiconductor devices.

EEE 6403: Quantum Phenomena in Nanostructures

Fundamentals of quantum mechanics: effective-mass Schrodinger Equation, matrix representation, Green's function: Fundamentals of nonequilibrium statistical mechanics: scattering and relaxation. Carrier transport: density of states, current, tunneling and transmission probabilities, introduction to transport in the collective picture. Basic principles of a few effective devices: resonant tunnel diode, super lattice, quantum wire and dot.

EEE 6404: VLSI Technology and Device Modeling

VLSI Si process technology. Si crystal growth and wafer preparation .epitaxial growth on Si substrate. Oxidation of Si. Lithography, diffusion: methods and models. Ion implantation, metallization. Overview and process flow of a CMOS and a BICMOS process. VLSI Si devices. Isolation techniques. Second ordereffects in BJT devices: base width modulation. Emitter current crowding, Kirk effect. Second order effects in MOS devices: short channel effects, narrow width effects. Device scaling rules. Device models. Compact models for bipolar devices. Ebers-Moll type model. Gummel-Poon type model and their implementation in SPICE.BJT model in SPICE2.Compact models for MOS transistor and their implementation in SPICE. Level 1,2 and 3 MOS model parameters in SPICE. Parameter extraction for bipolar and MOS device models. Geometry, process and temperature dependency of bipolar and MOS model parameters. Parameter optimization, statistics of parameters and statistical modeling.

Courses (all are 3 Credit courses)
EEE 6405: Advanced VLSI Design Trends and issues in high performance digital VLSI design: Low Power Circuit Design Issues: Reduction of static and dynamic power in CMOS circuits. Sleep circuits and multi-V_T techniques. Low power FinFET circuit design. Energy harvesting circuits. High Speed and low power memory circuit design: DRAM, SRAM and CAM circuits. Resistive memory devices: Crossbar memristor and memristor-MOS hybrid memory circuits. Algorithm and architecture for digital processors: Building block for signal processors, digital filters and signal processors, pipelined architecture. Implementation of DSP algorithms in Verilog/system Verilog, Synthesis and post-synthesis design validation, STA, timing closure, functional closure. Design of a simple RISC processor. Circuit design with emerging novel nano-devices and adaptive nano-computing. Hardware security: Hardware level IP protection and detection of hardware Trojan. Project on a real chip design.
EEE 6406: Testing VLSI Circuits Physical defects in VLSI Circuits. Complexity and economics of testing. Fault models: Stuck-at, Stack-on, Stack-open, bridging and delay faults. Testing combinational logic circuits: terminologies, path sensitization, fanout and reconvergence, fault matrix, fault collapsing. test generation using D-algorithm, Boolean difference and other methods. Testing sequential logic circuits: problems and remedies. Testability of different types of CMOS circuits for various faults .test invalidation. Robustly testable CMOS circuits. Test generation for static and dynamic MOS. Design for testability: different techniques of enhancing testability scan design techniques, built-in self (BIST) Built-in current sensors (BICS) for IDDQ testing of CMOS circuits. Error detecting codes and self-checking circuits. Testable design of regular array architectures and PLAS: Testable design of regular array architectures and PLAS: the concept of C-testability.
EEE 6407: Carbon Nanotechnology Nanomaterials and nanostructures: graphene, carbon nanotubes, fullerenes, molecules and organic nanostructures. Synthesis methods of nanostructures: electric arc, pulsed laser deposition, chemical vapor deposition (CVD); thermal CVD, catalytic CVD, micro wave CVD (MWCVD), plasma enhanced CVD (PECVD), spray pyrolysis. Physical and opto-electronic properties; characterization techniques. Applications: carbon nanotube and graphene based devices, bio-sensors, bio-inspired nanostructures, molecular motors, fuel cells and solar cells.
EEE 6408: Nano Systems Nanosystems and Devices: Introduction- nanomaterials, nanodevices, nanostructures. Nanoscale Lithography: X-ray, Electron-Beam and Ion-Beam; Soft Lithography; Scanning Probe Lithography. Advances in Device Technology: nanoscale silicon devices, process technology, present challenges. Self Assembled Nanocrystals: self assembly, surface defects and passivation, structures, energy levels, transitions, luminescence and lasing. Nano Electro Mechanical Systems (NEMS): stress in thin films, mechanical to electrical transduction, surface engineering techniques, process flow, NEMS actuators, high aspect ratio system technology. Nano Biotechnology: scope and dimensions; detection of biological species on electrical, mechanical and optical criteria; Bio functionality on silicon; Biochip sensors and systems- structures, process technology.

Courses (all are 3 Credit courses)
EEE 6413: Thin Film Technology Introduction to Thin Film Technology. Vacuum systems. Kinetic theory of gases. The physics and chemistry of vaporation/deposition mechanism. Physical vapor deposition and related techniques. Theories of epitaxy and nucleation, molecular beam epitaxy. Chemical vapor deposition techniques: reaction types, growth kinetics. Liquid and vapor phase epitaxy and related techniques. Theories of plasma and discharges. Sputtering (DC, RF and ECR). Atomic layer deposition (ALD), Pulsed laser deposition (PLD), Solution based deposition techniques (Sol-gel), spray pyrolysis.
EEE 6410: Semiconductor Characterization Technology Overview of semiconductor technology. Structural characterization: X-ray diffraction (XRD), low energy electron diffraction (LEED), reflection high energy electron diffraction (RHEED), atomic force microscopy (AFM), scanning tunneling microscopy (STM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Rutherford backscattering spectroscopy (RBS), energy dispersive x-ray analysis (EDX), Auger electron spectroscopy (AES), electron energy loss spectroscopy (EELS), secondary ion mass spectroscopy (SIMS), X-ray photoelectron spectroscopy (XPS), elastic recoil detection (ERD). Electrical characterization: resistivity measurements, Hall measurement, current-voltage (I-V), capacitance-voltage (C-V), deep level transient spectroscopy (DLTS), lifetime measurements. Optical characterization: optical transmittance and reflectance spectroscopy, ellipsometry, photoluminescence (PL), Raman spectroscopy, Fourier transform infrared spectroscopy.
EEE 6501: Electric and Magnetic Properties of Materials Electric Properties: Polarization, electrical conductivity and dielectric losses. Pyroelectric phenomena piezoelectric effect and electrostriction. Domain structure and peculiarities electric properties of ferroelectrics and anti-ferroelectrics. Structure and properties of some ferroelectrics and anti-ferroelectrics. Phase transition in ferroelectrics, fundamentals of spontaneous polarization theory. Magnetic Properties: Disordered magnetic, ordered magnetic. Domain structure of ferromagnetic crystals and magnetization processes. Anisotropy of ferroelectric crystals. Structure of some magnetically ordered crystals and reorientation transition. Piezomagnetic and magnetoelectric effect
EEE6503: Laser Theory Black body radiation and the Planck law. Stimulated and spontaneous emission, atomic and spectral line width, 3-level atomic, systems. Laser operation under steady state condition, laser output coupling and power. Q-switching and mode locking. Line broadening mechanisms: homogeneous and inhomogeneous broadening. Open resonator and Gaussian beam, stability criterion for optical resonators. Principles of operation of gas, solid state and semiconductor lasers. Dynamic characteristics and high frequency response of lasers. Lasers based on novel device physics and photonics
EEE 6505: Nanophotonics and Plasmonics Interaction of light with material; wave equation in matter from Maxwell's equations; Dielectric properties of insulators, semiconductors and metals; Interaction of light with microstructures and nanostructures; Optical properties of metal-dielectric composites; Photonic Crystals: Electromagnetic effects in periodic media; One-, two- and three-dimensional photonic crystals; Applications of photonic crystals: omni-directional reflection, light localization, photonic crystal fibers; Surface Plasmons: Surface plasmonpolariton at single interface, multilayer system, localized surface plasmons; Excitation of surface plasmonpolariton; Prism coupling, grating coupling; Application of surface plasmons; Sub-wavelength waveguides, plasmonic photovoltaics, plasmonic bio-sensors; Metamaterials: Electric metamaterials, magnetic metamaterials, negative index metamaterials, hyperbolic metamaterials.

Courses (all are 3 Credit courses)
EEE 6506: Advanced Photodetection System General introduction and design of photodetectors and photodetection systems: Performance and Figure-of-merits for photodetectors; Comparative study on different detector structures; Bandgap engineering and III-V materials; Opto-Electronic Integrated Circuits (OEIC) and receiver systems, receiver noise and other performance characteristics; Infrared Sensors; Quantum Dots; Focal Plane Arrays; Photovoltaic cells; Fabrication issues (leakage mechanisms – surface leakage, dark current, tunneling current, etc.); Optical properties relevant to detection systems, Biosensors; Nanosensors.
EEE 6511: Radio Frequency Integrated Circuit Design Overview of the CMOS transistor and passives from RF perspective, analyzing key concepts in modeling and noise behavior. An overview of various RF circuit blocks highlighting design architectures and circuit implementation tradeoffs. System specification and system level design of a wireless transceiver. RF block and system design parameters. Basic units in RF design: dB, dBm, dBc, S-parameters, 1 dB compression point, third order intercept point (IIP3, OIP3), Inter-modulation (IM2 and IM3), Spurious free dynamic range. Radio-frequency receiver amplifier design: Heterodyne, super-heterodyne and homodyne receiver. Design of Low noise amplifier, voltage controlled oscillators (VCOs), Mixer, PLL and Integrated Power Amplifier. RFIC layout.
EEE 6512: Nanoscale Device Modeling and Simulation Techniques Concepts of quantum mechanics and Operators Solution techniques of Schrodinger equation: Analytical models, Perturbation theory, Finite difference method, Finite element method, using basis functions for solving Schrodinger equation. Change of basis function, tight binding model for finding band structure of materials. Non-equilibrium Green's Function (NEGF) formalism: correlation and scattering functions, self energy and green's function, transmittance, current flow. Modeling of semi-infinite leads in NEFG formalism; Electron-photon, electron-phonon and electron-electron interaction in NEGF formalism. Solution and use of Poisson's equation for device simulation. The many-body problem: Multi-electron wavefunction, First-principles (ab-initio) simulation, Hartree-Fock (HF) approach, Density functional theory (DFT) Nanoscale simulation tools: Schrodinger-Poisson self-consistent simulation, HF and DFT simulations. Applications: Field Effect Transistor (FET) Simulation, Carrier transport in 1D, 2D and 3D.
EEE 6507: Terahertz Technology Terahertz gap, unique properties of terahertz waves; Current terahertz systems and their major technological challenges. Terahertz sources: Thermal, Vacuum electronic, Solid state electronic, Lasers, Optical pumping. Terahertz detectors: Photothermoelectric effect based uncooled detectors, Single-photon, Bolometers, Pyroelectric, Photoconductive antennas (PCA), Focal-plane arrays. Terahertz electronic components:Polarizers, Lenses and Mirrors, Waveguides, On-chip modulators. Spectroscopy: Time domain terahertz (THz-TDS), Frequency domain terahertz, and Optical pump-THz probe. Applications: Biology, Medicine, Space sciences, Security, Military, and Communications.
EEE 6508: Ultrafast Optics and Spectroscopy

Courses (all are 3 Credit courses)
Ultrafast phenomena, Propagation of laser beam, Pulse propagation and broadening, Dispersion, Nonlinear optics, Measuring ultrashort laser pulses, Generating ultrashort laser pulses, Mode-locking, Amplification of ultrashort laser pulses. Fundamentals of Spectroscopy: Absorption and emission of light, Spectral line shapes and broadening mechanisms; Optical Spectroscopy: Spectrometers, Interferometers, Detection of optical radiation; Advantages of lasers in spectroscopy, Fixed frequency lasers, Tunable coherent light sources, Nonlinear frequency conversion. Ultrafast laser spectroscopy: Time-resolved Pump probe and Femtosecond stimulated Raman Spectroscopy, Femtosecond Raman force microscopy. Applications: Femtosecond probing of photo catalysis, Microscopy, Time-resolved vibrational studies of excited state reaction dynamics, Ultrafast spin crossover dynamics, Real-time probing of a multidimensional potential energy surface, Ultrafast reaction dynamics of biomolecules.
EEE 6509: Solar Cells Introduction to basic solar cell operation; Thermodynamic limits and carrier statistics; Diode photo-response; Homojunction and Heterojunction solar cells; Light management in solar cells: Light trapping, Texturing, Anti-reflection coating; Silicon-based Monocrystalline, polycrystalline and Amorphous solar cells; Thin film and next generation solar cells: Multi-junction, Intermediate band and Hot-carrier solar cell, Quantum dot and nanowire solar cells, CIGS, CZTS, Perovskite and Organic Solar cells; Solar cell efficiency and economic considerations of solar cell design.
EEE 6510: Flat Panel Display Technologies Introduction to flat panel displays: emissive and non-emissive displays; display specifications; applications and types; Color science and engineering: Colorimetry and Photometry; Thin film transistors (TFTs) for display applications; Physics and operation of different types of displays: Liquid Crystal Displays (LCDs); Plasma display panels; Light emitting diode (LED) based displays; Organic Light Emitting Diodes (OLEDs) for display applications; Quantum dot (QD) displays; Field emission displays; Flexible displays; 3D displays; Touch screen technologies;
EEE 6411: Spintronic Devices Background and basic concepts of spin; Spinor and the Bloch sphere concept; Density matrix formalism for describing spin dynamics in a system; Spin transport and relaxation in solid systems; Magnetoresistance, spin injection, accumulation and extraction; Spin valves: Local and No-local geometries; Spin-FETs and Spin-BJTs: concept and operation principle; Spintronic based memory devices: Magnetic RAMs (MRAM), Spin-transfer torque (STT) RAM; Spin-optoelectronic devices: Spin LEDs and LASERs; Monolithic spintronics and all-spin logic devices; Quantum computing with spin; Neuromorphic computing using spintronic devices and systems.
EEE 6615: Advanced Electromagnetic Theory* Time varying and time harmonic fields. Wave propagation and polarization in different media. Electromagnetic theorems. Scattering of EM waves. Geometrical theorems of Diffraction and its applications. Integro-differential equations and its solutions. Derivation of Inverse Scattering Formulation: Microwave Imaging, Microwave antenna-theory and design: Aperture antennas, Horn Antennas, Broadband antennas: spiral & log periodic antennas. Advanced topics in EM theory: waveguide discontinuities and modal analysis, Excitation of Waveguides: electric and magnetic Currents, aperture Coupling, Periodic Structure: existence of Floquet modes. Introduction of EM software: HFSS, COMSOL or CST.

Courses (all are 3 Credit courses)
***This course also belongs to CSP group**
EEE 6606: Optical Waveguide Theory* Types of optical waveguides: optical integrated circuits and guiding structures. Basics of optical waveguide analysis: basic equations for light waves, polarization of light, reflection and refraction, wave equations. Guided and radiation modes in dielectric slab waveguides. Coupled mode theory. Analytical solution for optical waveguides: WKB method, Marcatili's method, effective index method, equivalent network method. Nonlinear optical waveguides. Plasmonic waveguides. Computer aided design of integrated optical waveguide devices. Application of photonics to microwave devices. ***This course also belongs to CSP group**