EE 597X TRANSPORT IN NANOSCALE TRANSISTORS

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Course Objectives: The modern day commercial MOSFETs have decananometer dimensions paving the way for non equilibrium carrier transport in these devices. The goal of the course is to introduce the fundamentals of carrier transport in semiconductors starting from Boltzmann transport equation and discuss the successive approximations in the context of modern devices. Ballistic as well as collision dominated transport will be discussed and the modern MOSFET experimental device characteristics analyzed to understand the ballistic efficiencies in these devices.

Expected Student Audience: Graduate students doing research in broadly understood semiconductor electronics, photonics, spintronics etc; EE majors, Materials Science and Eng., Eng. Science, and Physics.

Prerequisites: EE 442, EE 542 or equivalent

Course Contents:
a) Electron dynamics
- Boltzmann Transport Equation (BTE)
- Solving the BTE in equilibrium
- Evaluating moments of the distribution function

b) Off-equilibrium transport in devices
- Hydrodynamic
- Simplified approximations to carrier distribution function (displaced Maxwellian)
- Energy relaxation mechanisms

c) Ballistic and quantum ballistic transport
- Solving the ballistic BTE
- Resistance of a ballistic conductor
- Quasi-ballistic transport
- Example: Carbon nanotube; ultra short channel MOSFET, high mobility quantum wells etc.
- Quantum ballistic transport: Solving the wave equation for a ballistic device
- Non equlibirum Green's Function Formalism

d) Collision-dominated transport
- Relaxation time approximation
- Balance equations
- Carrier Scattering in bulk and in low-dimensional systems
- Low-field mobility (Si, GaAs, InGaAs), conductivity mass tensor
- Mobility in 1D, 2D, and 3D
- High-field transport in bulk semiconductors
- Monte Carlo simulation (brief description)

e) Term papers assigned to students to analyze transport in various nanoscale devices (e.g 30 nanometer gate length commercial MOSFETs and emerging devices such as FINFETs, Nanowire FETs, Qunatum-Well FETs, tunnel FETs,1D nanowire FETs)

Educational Objectives: To improve understanding of the relative importance of scattering limited transport versus ballistic transmission of carriers in modern semiconductor devices. To expose graduate students specializing in semiconductor science and engineering to the process of identifying the mechanisms which limit the modern-day device performance and seed new ideas for future improvement.

Software Tools: Sentaurus™ TCAD, NextNano3™, Matlab Scripts

Textbook: Angel based lecture notes, reprints of classic papers, Recommended Textbooks: S. Datta, “Atoms to Transistors”, M. Lundstrom “Fundamentals of Carrier Transport”, S. Datta “Electronic Transport in Mesoscopic Systems”