EECS 521 SYLLABUS

Description:

This is a graduate level course aimed to provide students a comprehensive understanding on nanoelectronics, and covers both novel MOSFET device structures and emerging research device structures based on the bottom-up paradigm.

We plan to fill the gap between the fast pacing research in nanotechnology and the current graduate curricula which focus on conventional CMOS devices. We will begin by first performing an in-depth analysis of the device principles and factors that affect the performance of MOSFET, followed by discussions on the challenges and technological innovations (boosters) that are currently being developed to sustain the historical trend of transistor scaling. Following that, we will carry out a critical survey of emerging research devices that may drive technology beyond CMOS.

Topics include transistor device principles and scaling rules, high-k dielectrics, mobility enhancement factors, SOI devices, ballistic and single-electron devices, nanowires and nanotubes, and molecule and spin based devices.

Prerequisite: EECS 421 or permission by instructor.

Textbooks:

Fundamentals of Modern VLSI Devices by Yuan Taur and Tak H. Ning
Cambridge University Press, 1st edition (October 13, 1998) ISBN: 0521559596

Nanoelectronics and Information Technology by Rainer Waser
John Wiley & Sons 2 edition (April 22, 2005) ISBN: 3527405429

Reference books:

* *Physics of Semiconductor Devices* By S. M. Sze and K. K. Ng
Wiley-Interscience (October 27, 2006), 3rd edition
ISBN: 0471143235

* *The Physics of Low-Dimensional Semiconductors* by John H. Davies
Cambridge University Press (December 13, 1997), ISBN: 052148491X

Physics of Semiconductor Devices by M. Shur
Prentice Hall (January 26, 1990), ISBN: 0136664962

Grading:

Homework 50%
Term paper 45%
Participation 5%

meeting time : MW, 9:00-10:30am
location : 3427 EECS

office : 2417-A EECS Building
regular office hours: MW, 10:30-11:30am
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Schedule:

1. Introduction. (1 lecture)
   (ITRS 2005, PIDS, ERD)
2. Energy bands. (1 lecture)
   Free electron model, Fermi surfaces, carrier density, density of states, energy bands (nearly-free electron model and tight-binding model), effective mass. (Waser 3, Davies 2)
3. Electrons and holes in Si. (1 lecture)
   Intrinsic carrier concentration, envelope function, doping, Si and GaAs lattice and band structures, valley degeneracy, HH and LH bands, surface states. (Waser 3, Davies 2)
4. Electrical transport. (1 lecture)
   Boltzmann transport equation, scattering time approximation, mobility, Einstein relation, scattering mechanisms, phonons, screening (Waser 3, Davies 2)
5. Minority carrier diffusion equation and P/N junctions (1 lecture)
   minority carrier lifetime, diffusion currents, build-in potential (Taur 2.2)
6. MOS capacitor (1 lectures)
   C-V, interface charges (Taur 2.3)
7. MOSFET devices (2 lectures)
   Drain-current model, I-V characteristics, subthreshold region, channel mobility, (Taur 3)
8. Short channel and hot carrier effects (2 lecture)
   Velocity saturation, high field effects, breakdown, substrate current (Taur 3.2,2.4)
9. CMOS device design (1 lecture)
   Threshold voltage design, discrete dopant effects, effective channel length. (Taur 4)
10. CMOS performance factors (1 lectures)
    S/D resistance, parasitic capacitances, quantum capacitance, gate resistance, interconnect R and C, gate delay. (Taur 5)
11. CMOS scaling and novel device concepts (3 lectures)

Scaling rules, high-k dielectrics, metal gates, SOI devices, double gate devices, strained Si (Taur 4.1, 5.4, Waser 13)

12. Schottky barriers and Ohmic Contacts (1 lecture)
    Metal/semiconductor interfaces, transport mechanisms, Ohmic contacts. (Sze 5)
13. Heterostructure devices (1 lecture)
    Band bending at the interface, modulation doping, HEMT (Shur 2.12)
14. Quantum size effects (1 lecture)
    3D, 2D, 1D structures, Resonant tunneling devices (Sze 9, Shur 7.6)
15. Ballistic transistors (1 lecture)
    Ballistic transport, “contact” resistance, ballistic FET (notes)
16. Single electron devices (1 lecture)
    Coulomb blockade phenomena, Single electron transistors (Waser 16)
17. Carbon nanotube devices (1 lectures)
    Band structure, growth, transport, CNTFET (Waser 9)
18. Nanowire devices (1 lecture)
    Growth, electrical and optical devices, devices on flexible substrates (notes)
19. Molecular Electronics (1 lecture)
    Single molecule devices, crossbar structures (Waser 20)
20. Magnetism and Spintronics (2 lectures)
    Magnetic materials, Magnetoresistance effects, spin injection, SFET (Waser 4, 24)
21. Quantum computing (1 lecture)
    Quantum parallelism, qubits, entanglement, teleportation. (notes)