Southern Illinois University at Carbondale

Fall 2012

ECE 550 Nanoelectronic Devices

Catalog Description: (A) **NanoTransistor**: Charge-based devices—MOSFETs, Advanced MOSFETs: Trigate FETs, FinFETs, SOI, SiGe, Ge and III-Vs, carbon nanotubes and Graphene ribbons, nanowires. Quantum Devices—single electron transfer devices (SETs), resonant tunnel diodes, tunnel FETs, quantum interference transistors (QUITs), quantum dot cellular automata (QCAs), quantum bits (qubits). Non-charge based devices—spinFET; (B) **NanoMemory**: Flash, PCM, Electrolyte, M/F RAM, Spin torque devices, DRAM, ZRAM; (C) **Energy-Related Devices**: Solar cells, LEDs/SSLs, thermoelectric devices, supercapacitors; (D) **NanoBio Devices**: Biosensors.

Course Total Credit Hours: 3
Lecture: 3   MWF 2:00 – 2:50 PM   EGRA 0210   **Office Hour**: TBD and by appointment
Prerequisites: Basic semiconductor devices, ECE 375 and ECE 447, or Instructor consent.

Objectives:

- Give a general introduction to different types of *conventional* and *novel* nanoelectronic devices for different applications. The target applications are *switching*, *memory*, *energy conversion/storage*, and *bionanoelectronics.*
- Understand the underlying *physical processes* governing the operation of these devices. Understanding of these processes would build on earlier semiconductor device courses, which introduced the student to the basic device concepts.
- Various *figures of merit* widely used for efficient device design and performance study will be addressed.
- Understand various *higher order effects* (e.g. short channel effects, quantum effects, discrete dopants and process variation) that influence today's nanoscale devices.
- Various *problems/challenges and technological bottlenecks* in the realization of nanoelectronic devices with desired and optimum performance will be discussed.
- Study different *novel and exploratory devices and alternative technologies* (non-charge based and fully quantum computation and information processing) as means of sustaining the semiconductor industries' growth in the coming years.
- Students will be *using in-house and freely available software* tools to study and analyze various aspects of nanoelectronic devices and expected to generate novel design ideas and find solutions to these technological problems.
- Communicate efficiently with the circuit/system designers and the science persons and give them essential feedback from *device* point of view.
- Demonstrate how *computer programming* (Matlab/Fortran/C/others) can facilitate learning of nanoscale phenomena and device design.

Laboratory Fees: None

Laboratory safety equipment: None

Instructor: Dr. Shaikh S. Ahmed, Associate Professor, ECE Department, SIUC
Course Committee: *Department of Electrical and Computer Engineering Faculty*.

Text Book: *The subject matter for this course will be heavily drawn from the research literature, and extensive references will be provided in the class notes*. A useful book:
Y. Taur and T.H. Ning, Fundamentals of Modern VLSI Devices, 2nd Edition, Cambridge University Press, 2009.

References:

- Yannis Tsividis and Colin McAndrew, *Operation and Modeling of the MOS Transistor*, 3rd ed. Oxford University Press, ISBN13: 9780195170153, 2010.
- V. Mitin, V. Kochelap, M. Stroscio, *Introduction to Nanoelectronics*, Cambridge University Press, 2008
- S. M. Sze, Kwok K. Ng, *Physics of Semiconductor Devices,* Publisher: John Wiley and Sons Inc., 2006
- J.P. Colinge, *Silicon-on-Insulator Technology: Materials to VLSI*, 2nd Ed., Kluwer, 1997
- E. F. Schubert, *Light-Emitting Diodes*, 2nd ed. University Press: Cambridge, 2008
- Dieter Schroder, *Advanced MOS Devices*, Addison Wesley Longman, November, 1987

Topical Outline (*Tentative*):

Introduction: Evolution in semiconductor device technology	1 lecture	2.2%
Fundamental principles of electronic devices	5 lectures	11%
MOS electrostatics: capacitance and threshold voltage	3 lectures	6.6%
MOSFET current-voltage characteristics	2 lectures	4.4%
Short channel and nanoscale effects	2 lectures	4.4%
Quantum effects	2 lectures	4.4%
Discrete impurity effects	1 lecture	2.2%
Power dissipation and leakage	1 lecture	1.1%
Silicon-On-Insulator (SOI) devices	2 lectures	4.4%
Advanced device architectures (Trigates, FinFETs, Nanowires)	2 lectures	4.4%
Alternative materials: SiGe	1 lecture	2.2%
Alternative materials: III-Vs	1 lecture	2.2%
Alternative materials: carbon nanotubes, graphene ribbons, and 2D monolayers	2 lectures	4.4%
Non-charge (Spin) based devices	1 lecture	2.2%
Quantum mechanical devices: tunnel FETs and SETs	2 lectures	4.4%
Semiconductor memory devices	4 lectures	8.8%
Energy-related (solar cells, solid-state lighting, thermoelectricity, supercapacitors)	4 lectures	8.8%
NanoBio devices (tentative)	2 lectures	4.4%

Grading:

Homework	20%
4 short tests (~30 minutes each)	40%
Final Exam	20%
Project	20%

Letter grade: **A**: 90-100 **B**: 80-89 **C**: 70-79 **D**: 60-69 **F**: <60