**ChBE 6050: The Science and Engineering of Microelectronic Fabrication.**

Instructor: Paul A. Kohl (TA is assigned each semester)

Book: Fabrication Engineering at the Micro- and Nanoscale, Stephen A. Campbell, Oxford Press, 2013, ISBN: 978-0-19-986122-4

**Course Purpose:**

ChBE 6050 is an elective class for graduate students in ChBE interested in the fabrication of and materials used in semiconductor devices and their packages. This course is especially suited for graduate students whose research involves the chemical sciences aspect of semiconductor microfabrication. The electronics industry is the largest industry in the history of the world and has changed virtually every aspect of our lives. It has taken an historic growth path over the past 50 years based on our ability to microfabricate more efficient and higher performance components at an every lower cost. The basis for this historic growth trend, and the materials and techniques to achieve it will be presented.

An overview of semiconductor devices, including integrated circuits, solar cells, and microelectromechanical systems is then presented to better understand the goals of microelectronic materials and microfabrication. The microfabrication materials and processes are presented as a series of unit operations. The course will provide the fundamentals of materials synthesis, chemical and mechanical properties, and chemical reactions along with the future directions associated with each unit operation and material.

The lecture content of this course is the same as 4000 level undergraduate course. However, the graduate course has (i) extended laboratory experiences and demonstrations, (ii) a more detailed course project with greater depth of understanding, and (iii) additional assignments into research aspects of microfabrication, which can correspond to aspects of the graduate program.

**Course Details:**

The course will use the fabrication of a small integrated circuit as a test-case to demonstrate many of the unit operations involved in microfabrication. There will be four hands-on laboratory demonstrations-experiments in the GT Microelectronics Research Center to go along with the lectures. Students are required to participate in each of the four laboratory experiments/demonstrations. The observations and results from the laboratory experiments/demonstrations will be used in homework problems. Note: one in-class lecture will be eliminated in exchange for each experiment/demonstration session.

There will be a final ‘project’ due at the end of the class where students pick a topic of their choosing from the course and investigate that topic in some depth. The graduate students will perform an in-depth study of a research aspect with the general topic of chemical sciences within microfabrication.

Homework will consist of (i) select ‘number problems’ where the goal is to demonstrate a concept by performing and calculation, and (ii) short reading assignments from the course text book or photocopied reference material (distributed on T-Square). There will occasionally be a short quiz on the reading assignments. The quizzes will be at the start of class on some Mondays. Quizzes will be announced ahead of time.

There will be two tests. The first test will be about half way through the course. The second text will be ‘final exam’ and will focus on the material during the second half of the course.

The grading will be: Test #1-20%, Test #2-25%, Quizzes (about 8 will be given and the lowest score dropped)-20%, Homework (including those problems from lab)-25%, Project-10%.

**Syllabus**

Week 1 and 2: Introduction to microelectronic fabrication, semiconductor properties, device concepts and design, and transistor scaling.

Week 3: Thermal oxidation: Deal-Grove model for silicon dioxide growth, structure of dielectrics, and alternative high dielectric constant dielectrics (materials, synthesis and integration). This will also be the subject of laboratory experiment #1 where the growth kinetics for silicon dioxide is verified.

Week 4: Doping of semiconductors by diffusion and ion implantation: Solutions to Fick’s law and calculations for different diffusion boundary conditions are presented. The doping profiles for the test-case integrated circuit will be discussed.

Week 5 and 6: Photolithography and photoresist materials: Photolithography is the method of pattern creation and transfer in microelectronic processing. The principles of optical lithography will be presented including diffraction, transfer functions, optical sources, and masks. The technology of photoresists will be discussed including, the kinds of photoresists, synthesis of the materials, optical activity and chemical reactions, and processing of resists (exposure, developing and stripping). This will be the subject of a lab session where the effect of contrast and exposure dose are explored.

Week 7: Plasma processing: The use of plasmas in the fabrication of semiconductor devices will be discussed. The topics include the creation and nature of plasmas, plasma etching, and the use of plasmas deposition.

Week 8 and 9: Metallization: The physical, chemical and electrochemical deposition of metallic films will be presented. The dry deposition of metals includes the thermal and electron-beam evaporation of metal, and the sputtering of metal using plasma. The electrochemical deposition includes electroplating of copper on planar surfaces and superfilling in restricted areas. This will be the subject of a lab session where the quality, uniformity and patterning of a metal film will be performed.

Week 10: Process integration, yield and statistics: The principles of process integration and yield statistics will be presented.

Week 11, 12 and 13: Electronic packaging: There are many kinds of electronic packages and issues associated with packaging materials. Packaging types and methods will be discussed along with quantitative metrics and benefits associated with each type.

Week 14 and 15: Device performance, characterization, and modeling: The performance and characterization of transistors and integrated circuits will be presented. This will be the basis for a lab session where student test individual transistors, resistors and integrated circuits. The graduate students will be expected to perform in-depth analysis of the performance.

**Expected Outcomes:**

Upon completion of this course, the students are expected to have the following knowledge.

1. Understand the critical design parameters and operation of semiconductor junction devices, including diodes, light emitting diodes, photodetectors, solar cells and transistors.

2. Understand the reaction mechanism and rate equation for the oxidation of silicon.

3. Understand the role of photolithography in the microfabrication process along with the facilities, polymers and photoactive compounds used in photoresist, and the tradeoffs between the chemical events and physical equipment.

4. Understand the mechanism of doping semiconductors and be able to calculate conditions for the optimal device doping.

5. Understand the role and operation of plasma processing, including etching materials and depositing metals and insulators.

6. Understand the role of electronic packaging along with the materials, processes and design parameters.