MSE 460: Electronic Materials, Devices and Processing

Course Description: This class introduces students to materials used in modern electronic and optoelectronic devices. The progress of microelectronic industry is largely driven by the development and introduction of new materials. The structure, chemistry, and processing of materials are closely related to their electronic and optical properties and therefore the device characteristics. This course will cover the processing of electronic materials, the materials science and engineering of semiconductors, the physics behind the operations of various electronic and optoelectronic devices, and the adoption of different materials and processing techniques to deliver the desired device performances.

Course Objectives: Students will be able to understand the operational mechanism of various electronic and optoelectronic devices, and how their performances are limited by material properties. Students will develop the technical insight into the choice of the most appropriate materials and processing techniques for different applications, and obtain a grasp of the most important challenges. The goal is to help students develop a background in semiconductor materials and semiconductor processing for related jobs, and more importantly to prepare them for future research in this field in graduate school if they would like to seek a career in the Research and Development sector of the semiconductor industry.

Prerequisites: MSE 304

Lectures: 10:00-10:50 am, Monday/Wednesday/Friday
Location: 305 MSEB

Zoom link for the first week.
Join Zoom Meeting
https://illinois.zoom.us/j/89756291123?pwd=Q0JqTzNSMzBFV2pmRS9oZUFqQ0dBUT09

Meeting ID: 897 5629 1123
Password: 874958

Instructor:

Prof. Qing Cao (Email: qingcao2@illinois.edu)

Office hour: Friday 2-3 pm or by email appointment

TA: Bao Lam (Email: baohl2@illinois.edu)

Office hour: TBA

Grading:

Homework:	20% (4% * 5)
Midterm Exam	40%
Final Exam:	40%

Homework Protocol

Homework will be posted on gradescope.

For quantitative problems:
Correct Numerical Answer 20%
Correct Reasoning 40%
Correct Units 20%
Legible Work Shown 20%

For Qualitative problems:
Reasoning is clear and logical 40%
Factual statements are correct and based on course material 40%
Response is legible with correct spelling and grammar 10%
If requested, Figures or Diagrams are clear and well labeled (if not requested, these points go to the reasoning category) 10%

Exams:
1) One page of notes is allowed in the exam.
2) Mid-term will be 1 hour and the final will be 2 hours.
3) Exams will be a mixture of qualitative and quantitative questions. The questions will cover a very broad range topics covered in the lecture.

References

Semiconductor processing: Robert Doering and Yoshio Nishi, Handbook of Semiconductor Manufacturing Technology 2nd Edition, CRC Press, 2008.

Device physics: S. M. Sze and Kwok. K. Ng, Physics of Semiconductor Devices 3rd Edition, Wiley & Sons, 2007.

Materials science and engineering of semiconductors: Angus Rockett, The Materials Science of Semiconductors, Springer, 2008.

Syllabus:

Lecture 1: Introduction and Orientation

Lecture 2: Overview of Electronic Materials

Lecture 3: Free electron Fermi gas

Lecture 4: Energy bands

Lecture 5: Carrier Concentration in Semiconductors

Lecture 6: Shallow dopants and Deep-level traps

Homework 1

Lecture 7: Silicon Materials

Lecture 8: Oxidation

Lecture 9: Doping

Lecture 10: Drift and diffusion

Lecture 11: Generation and recombination

Homework 2

Lecture 12: Electrostatics of p-n junctions (I)

Lecture 13: Electrostatics of p-n junctions (II)

Lecture 14: Current Voltage Characteristics of p-n Junctions

Lecture 15: Metal Semiconductor interface and Schottky Diode

Lecture 16: Lithography I: Basics and Photoresist Chemistry

Lecture 17: Lithography II: EUV and Novel Patterning Techniques

Homework 3

Lecture 18: Etching Overview

Lecture 19: Wet Etching

Lecture 20: Dry Etching

Lecture 21: Mid-term Review

Lecture 22: Light Emitting Diodes

Lecture 23: LED Materials

Lecture 24: Physics of Solar Cells

Homework 4

Lecture 25: Mid-term Exam

Lecture 26: Solar cell-Materials (I)

Lecture 27: Solar cell-Materials (II)

Lecture 28: Materials Deposition: PVD

Lecture 29: Materials Deposition: CVD (I)

Lecture 30: Materials Deposition: CVD (II)

Homework 5

Lecture 31: Transparent Conductive Oxide

Lecture 32: Electrostatics of MOS Capacitor

Lecture 33: C-V Characteristics of MOS Capacitor

Lecture 34: Operation of MOSFET

Lecture 35: Subthreshold Region of MOSFET And Device Scaling

Lecture 36: Velocity Saturation

Lecture 37: Short channel effects

Homework 6

Lecture 38: Non-ideal semiconductor-gate dielectric interface

Lecture 39: High-k/metal gate

Lecture 40: 3D Channel and New Channel Materials for MOSFETs

Lecture 41: Fabrication Flow of Si MOSFETs

Lecture 42: Electrodeposition

Lecture 43: Final Review

Final exam

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/.

Academic dishonesty will result in a sanction proportionate to the severity of the infraction, with possible sanctions described in 1-404 of the Student Code (https://studentcode.illinois.edu/article1/part4/1-404/). Every student is expected to review and abide by the Academic Integrity Policy as defined in the Student Code: https://studentcode.illinois.edu/article1/part4/1-401/. As a student it is your responsibility to refrain from infractions of academic integrity and from conduct that aids others in such infractions. A short guide to academic integrity issues may be found at https://provost.illinois.edu/policies/policies/academic-integrity/students-quick-reference-guide-to-academic-integrity/. Ignorance of these policies is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Covid Safety

Following University policy, all students are required to engage in appropriate behavior to protect the health and safety of the community. Students are also required to follow the campus COVID-19 protocols.

Students who feel ill must not come to class. In addition, students who test positive for COVID-19 or have had an exposure that requires testing and/or quarantine must not attend class. The University will provide information to the instructor, in a manner that complies with privacy laws, about students in these latter categories. These students are judged to have excused absences for the class period and should contact the instructor via email about making up the work.

Students who fail to abide by these rules will first be asked to comply; if they refuse, they will be required to leave the classroom immediately. If a student is asked to leave the classroom, the non-compliant student will be judged to have an unexcused absence and reported to the Office for Student Conflict Resolution for disciplinary action. Accumulation of non-compliance complaints against a student may result in dismissal from the University.

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/.

Academic dishonesty will result in a sanction proportionate to the severity of the infraction, with possible sanctions described in 1-404 of the Student Code (https://studentcode.illinois.edu/article1/part4/1-404/). Every student is expected to review and abide by the Academic Integrity Policy as defined in the Student Code: https://studentcode.illinois.edu/article1/part4/1-401/. As a student it is your responsibility to refrain from infractions of academic integrity and from conduct that aids others in such infractions. A short guide to academic integrity issues may be found at https://provost.illinois.edu/policies/policies/academic-integrity/students-quick-reference-guide-to-academic-integrity/. Ignorance of these policies is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Anti-Racism and Inclusivity Statement

The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/**).** Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Disability-Related Accommodations
To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

Family Educational Rights and Privacy Act (FERPA)
Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

Religious Observances
Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.