To: The Engineering Faculty

From: The Faculty of the School of Materials Engineering
Date: October 9, 2023
Re: Concentration in Semiconductors and Microelectronics for Bachelor of Science in Materials Science and Engineering.

The Faculty of the School of Materials Engineering has approved adding a concentration in semiconductors and microelectronics for a Bachelor of Science in Materials Science and Engineering.

Justification:
As materials will play a key role in Purdue's Comprehensive Semiconductors and Microelectronics Program, the proposed concentration provides Materials Engineering students with a focused educational path in this field.

Description:
Students in the School of Materials Engineering take 6 technical electives that they can use to tailor their degree towards a specific technical area. Of these six electives, two may be support area electives and do not need to be directly related to MSE. This framework provides the functional basis for the proposed concentration. The following describes the proposed concentration in semiconductors and microelectronics in Materials Engineering.

_____
David Bahr, Head
School of Material Engineering

Concentration in Semiconductors and Microelectronics for Bachelor of Science in Materials Engineering

Students in the School of Materials Engineering take 6 technical electives that they can use to tailor their degree towards a specific technical area. Of these six electives, two may be support area electives and do not need to be directly related to MSE. This framework provides the functional basis for the proposed concentration. The following list the requirements for a concentration in semiconductors and microelectronics in Materials Engineering.

MSE Undergraduate core courses:
These are the key courses taken by all MSE students that provide the background for the semiconductors and microelectronics technical electives.

MSE 23000: Structure and Properties of Materials Engineering
Prerequisites: CHM 11500 and MA 16500.

MSE 27000: Atomistic Materials Science
Concurrent Prerequisites: MA 26100, MA 26500 (or MA 26200), MSE 23000

MSE 33500: Materials Characterization Laboratory
Prerequisites: MSE 235

MSE 37000: Elec, Opt, and Mag. Props. of Materials
Prerequisites MSE 23000, MSE 27000, PHYS 24100 (or PHYS 27200)

MSE Technical Electives (3 required from the following list)

- For the MSE degree, 6 technical electives are required.
- *For a concentration in semiconductors and microelectronics*, three of those technical electives should come from the following list.

1) MSE 50200 Defects in Solids (Prerequisites: Senior or graduate standing)
Structures and interactions of point, line, and planar defects in solids, with emphasis on properties of defects. Generic basis of defect energies and interactions, with reference to specific materials and material classes as examples. Types of point defects found in crystals, their origins, interactions, and motion. Overview of dislocation theory and point-defect/dislocation interactions. Structural aspects of surfaces and interfaces, including point and line defect interactions.

2) MSE 51000 Microstructural Characterization Techniques

(Prerequisites: MSE 335 or Senior standing)

A broad variety of analytical tools will be presented. The intent is to allow the student to make an educated selection of characterization techniques, or critical analysis of published data, for materials and defect analysis. The techniques will be assessed in terms of the probe type and material response, of what device and specimen requirements are typical, and of what data can or cannot be derived from each type of analysis

3) MSE 52300 Physical Ceramics

(Prerequisites: Senior standing)

This graduate-level course aims to provide students an understanding of the physical nature of modern ceramic materials, of how their properties and functionality are determined by their physical, chemical, and structural properties as well as by defects and by the synthesis methods and processing conditions employed for their fabrication. Starting from basic concepts describing the atomic structure and chemical composition of ceramic materials, the course will discuss the role of defects, synthesis, and processing conditions in determining the multiplicity of technologically important properties exhibited by modern ceramic materials for a wide range of applications ranging from the microelectronic industry to aerospace and energy materials.

4) MSE 54800 Deposition Processing of Thin Films and Coatings

(Concurrent Prerequisite: MSE 33000 or graduate standing)

Processing and microstructural development of thin films and layered structures. Includes vapor, liquid, and reactive processing, as well as layer modification by annealing and beam techniques.

5) MSE 58500 Magnetic Materials: Physical Properties and Applications

(Prerequisites: MSE 330 and MSE 370 or graduate standing)

This course provides an introduction of the basic physical and structural properties that determine the functionality of magnetic materials and devices. Starting from basic concepts on the physics of magnetism, materials synthesis and device fabrication, the functional requirements of magnetic materials for diverse applications will be discussed. Magnetic material properties depend on the electronic structure of the constituent elements and their electronic interactions. These interactions are controlled by their atomic arrangement, microstructure, defects, and strain fields that distort the local atomic order. Furthermore, the role of reduced dimensionality on the physical and functional properties of nanoscale materials will be discussed.

6) MSE 57000 Introduction to Materials Modeling and Informatics

(Prerequisites: MSE 270 and MSE 370 or Graduate Standing)

This course provides an introduction at the graduate level to theory and methods for simulating the structure and properties of materials. The course will provide a broad initial overview of many atomistic modeling techniques including ab-initio, classical molecular dynamics (MD) and Monte Carlo (MC) simulations, followed by a detailed examination of density functional theory (DFT) over several weeks, transitioning on to high-throughput computations and dealing with

materials datasets, and finishing with an introduction to materials informatics techniques and a few lectures on training and deploying machine learning models for materials design. Students will obtain an essential understanding of quantum and classical theory and become acquainted with practical methods for running DFT simulations, as well as combining such simulations with simple machine learning and data science methods for accelerated materials design. Existing and new tools on nanoHUB, access to open-source simulation software, and writing simple Python code will be utilized for all necessary coursework and exercises.

7) *One* of the following non-MSE courses:

ECE 30500 Semiconductor Devices

Introduces and explains terminology, models, properties, and concepts associated with semiconductor devices. Provides detailed insight into the internal workings of the "building-block" device structures such as the pn-junction diode, Schottky diode, BJT, and MOSFET.

OR

ECE 59500 Integrated Circuit/MEMS Fabrication Laboratory

This course is an updated version of ECE 55700 and will provide students state-of-the-art knowledge in the area of Micro and Nanofabrication Technology. Course topics include substrate, oxidation, lithography, etching (dry and wet), thin film deposition (physical vapor deposition, chemical vapor deposition, atomic layer deposition, epitaxy), diffusion and ion implantation, chemical mechanical polishing, metallization, packaging and integration. The course will include both lectures and hands-on training.

8) Other classes can be added later.

Examples: The following are two courses that have recently been taught but still have temporary course numbers. These can be included in the concentration once approved and assigned permanent course numbers.

MSE 49700 Electronics Packaging and Heterogeneous Integration

(Prerequisites: Junior standing)

Note: temporary course number.

This course provides a broad, hands-on introduction to principles and practices of electronics packaging. The course is broadly divided into four major modules as well as other smaller modules. The major modules provide a practical background (as it relates to electronic packaging) in electrical, thermal, mechanical and materials characterization. Design considerations as well as materials selection in the above topics will also be addressed. The minor modules include package fabrication and assembly, radiation hardening, and statistical modeling and data analysis. The class will be primarily lab-oriented with 1 lecture each week and 4 hours of hands-on lab.

MSE 59700: Solid State Materials

(Prerequisites: MSE 370 or senior standing)

Students will be introduced to the fundamental theory of solid-state materials and their many properties. Using atomistic and electronic level descriptions, this course will cover electrical, optical, magnetic, dielectric, and thermal properties of materials, their physical origins, and some theoretical methods to investigate them. In-person and online lectures, regular quizzes and homework assignments, and critical reading of published literature will be utilized in this course