MSE 4004 Materials in Electronic Applications

Credit hours and contact hours: 3-0-0-3

Instructor: Rosario Gerhardt

Textbook: No textbook used.

Suggested References:
1. Marc J. Madou, *Fundamentals of Microfabrication*, CRC Press Inc., 2nd edition, 2005
2. A.J. Moulson and J.M. Herbert*, Electroceramics: Materials-Properties-Applications*, Chapman & Hall, 2003
3. James W. Mayer and S.S. Lau, *Electronic Materials Science: For Integrated Circuits in Si and GaAs*, Macmillan Publishing, 1990
4. S.O. Kasap, *Principles of Electrical Engineering Materials and Devices*, McGraw-Hill Book Company, 2nd edition, 2001

Specific course information

Catalog description: Basics of photolithography, screen printing, and tape casting. Requirements for fuel cells, magnetic nanocomposites, flat-panel displays, gas sensors, piezoelectric acutators, photonic crystals, etc.

Prerequisites: MSE 3015 - Electronic, Optical & Magnetic Properties

Course: Selected Elective

Specific goals for the course

Outcomes of instruction:

Outcome 1: The student will develop a basic understanding of the importance of nanotechnology in the development of modern electronic devices.
Outcome 2: The student will demonstrate a working knowledge of the different patterning methods for making the majority of electronic devices as well as learn what material types are used with each method.
Outcome 3: The student will become proficient with the basic mechanisms' operative in electronic materials and the meaning of band gaps and charge carrier generation, transfer or recombination.
Outcome 4: The student will learn the concepts of bandgap and defect engineering in order to successfully design a desired composition for a given application.
Outcome 5: The student will learn the importance of material interfaces and their effect on the resultant properties of the materials and devices.

Outcome 6: The student will learn the importance of crystalline perfection and the differences between textured films, epitaxial films and polycrystalline films as well as amorphous materials.
Outcome 7: The students will learn about direct and indirect piezoelectric effect and its relationship to ferroelectricity and electrostriction and their use in non-volatile memory devices, actuators and sensors.
Outcome 8: The student will understand the differences between metallic, semiconducting, ionic, superconducting and insulating materials and their use in the appropriate devices.
Outcome 9: The students will learn to draw from the current literature and become quickly proficient on a given contemporary processing, device design or composition and be able to explain it to the rest of the class.

Student Outcomes:

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(2) An ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
(4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
(5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
(6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
(7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Topics covered:
1. Electronic material classes, crystal structures & defects in electronic materials
2. Tape casting, screen printing, inkjet printing, single crystal growth methods, combinatorial methods, colloidal synthesis methods, physical and chemical vapor deposition methods, molecular beam epitaxy, pulsed laser deposition, wet and dry chemical etching, FIB, ion milling.
3. Photolithography, mask design and pattern creation by deposition or etching. Soft lithography methods such as microcontact printing, dip pen nanolithography, nano-imprint lithography.
4. Basics of integrated circuit component fabrication and design. To develop an understanding of how materials are integrated into electronic and optoelectronic devices.
5. To learn to determine the corresponding structure-property-processing relationships as a function of composition, microstructure and patterning.
6. Materials requirements for gas sensors, fuel cells, solar cells, batteries, LEDs and displays for TVs and smart phones, piezoelectric devices and magnetic storage devices.
7. Scaling issues and packaging challenges.

8. Emerging materials and applications: TMDs, graphene, spintronics, optical integrated circuits and materials needed for 5G implementation.

Correlation between Outcomes of Instruction and Student Outcomes:

Outcomes of Instruction	**Student Outcomes**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1. The student will develop a basic understanding of the importance of nanotechnology in the development of modern electronic devices.	X			X	X		X
2. The student will demonstrate a working knowledge of the different patterning methods for making the majority of electronic devices as well as learn what material types are used with each method.	X	X		X	X	X	
3. The student will become proficient with the basic mechanisms' operative in electronic materials and the meaning of band gaps and charge carrier generation, transfer or recombination.	X	X		X	X		
4. The student will learn the concepts of bandgap and defect engineering in order to successfully design a desired composition for a given application.	X	X		X	X	X	X
5. The student will learn the importance of material interfaces and their effect on the resultant properties of the materials and devices.	X	X		X			X
6. The student will learn the importance of crystalline perfection and the differences between textured films, epitaxial films and polycrystalline films as well as amorphous materials.	X	X		X	X	X	X
7. The students will learn about direct and indirect piezoelectric effect and its relationship to ferroelectricity and electrostriction and their use in non-volatile memory devices, actuators and sensors.	X	X		X	X		
8. The student will understand the differences between metallic, semiconducting, ionic, superconducting and insulating materials and their use in the appropriate devices.	X			X			
9. The students will learn to draw from the current literature and become quickly proficient on a given contemporary processing, device design or composition and be able to explain it to the rest of the class.	X		X	X			X

School of Materials Science and Engineering Student Outcomes:

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(2) An ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
(3) An ability to communicate effectively with a range of audiences.
(4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
(5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
(6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
(7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.