MSE 6010
Principles of Functional Materials

School of Materials Science and Engineering
Georgia Institute of Technology

Fall 2024

Course Objective	To introduce fundamental principles essential to functional materials, including band structures, electronic defectsproperties, and the transport of charge, mass, and energy in solids; electrical polarization across a wide range of frequencies; and the chemical, thermal, electrical, and mechanical interactions in solids. It also covers several electrical characterization techniques.
Instructor	Meilin Liu
Backup Instructor	Xueyu Hu
Lecture	**Monday Wednesday 11:00 – 12:15** pm J. E. Love **299**
Office	Room 258 Erskine **Love** Building
Phone	404-894-6114
e-mail	meilin.liu@mse.gatech.edu
Office Hours	**M W 2:00–3:00** or by appointment
Teaching assistant	Nikhil Govindarajan (MoSE 3271)
Office Hours	To be determined
e-mail	ngovindarajan8@gatech.edu
Prerequisite	Graduate standing in MSE and basic knowledge of crystal structures of materials
Homework	Homework will be assigned periodically and collected (but not graded) to assess understanding. Solutions will be posted after the homework is collected.

Exams/Assessment		
	Exam 1 **September 30**, 11:00 - 12:20 pm (80 minutes)	100 points
	Exam 2 **November 6**, 11:00 - 12:20 pm (80 minutes)	100 points
	Exam 3 **December 6**, 11:20 - 1:00 pm (100 minutes)	100 points
	Total	**300** points

Grading Basis	Scale
	>90% **(>270** points) **A** guaranteed
	>80% **(>240** points) **B** guaranteed
	>70% (>**210** points) **C** guaranteed
	>60% (>**180** points) **D** guaranteed

Learning Objectives:	Upon completion of this course, students will be able to: 1. Understand band structure and electronic properties of materials 2. Gain familiarity with the transport of charge, mass, and energy in materials under various conditions (e.g., chemical diffusion, electrical and thermal conduction) 3. Understand the mechanisms of electrical polarization, with a focus on interfacial polarization in material systems 4. Become familiar with several experimental techniques for measuring material properties, including impedance spectroscopy.
Academic Integrity	Students are reminded of their obligations under the Georgia Tech Academic Honor Code and Student Code of Conduct, available at www.honor.gatech.edu. Academic dishonesty will not be tolerated, including cheating, lying about course matters, plagiarism, or helping others commit a violation of the Honor Code.
Learning Accommodations	For students with documented disabilities, we will make classroom accommodations in accordance with the ADAPTS office (http://www.adapts.gatech.edu). However, this must be arranged in advance.
Electronic Devices	Silence cell phones during class. A calculator (not one on an internet-connected device) is allowed during the exam, but you should not need it much.
Course Type Expectation	Most classes will be delivered in person in the classroom. However, there may be a few online lectures in case I will have to attend one or two review meetings. Recordings of these lectures will be posted on Canvas.

References

1. Electrons in Solids, An Introductory Survey, 3rd Edition, R. Bube, 1992.
2. Physical Ceramics, Y. M. Chiang, D. Birnie, and W. D. Kinggery, Wiley, 1997.
3. B.N. Figgis & M.A. Hitchman, Ligand Field Theory and Its Applications; Wiley-VCH, 2000.
4. Jean-noel Chazalviel, Coulomb Screening by Mobile Charges – Applications to Materials Science, Chemistry, and Biology, Birkhauser, 1999.
5. S. O. Kasap, Principles of Electronic Materials & Devices, McGraw-Hill, 3nd Edition, 2007
6. Kwan Chi Kao, Dielectric Phenomena in Solids, Elsevier, 2004
7. T. Ikeda, Fundamentals of piezoelectricity, Oxford, 1990

* Lecture notes

Class Schedule (MSE 6010)

Lecture #	Date	Topics	Ref
		Electronic properties of solids	*,1,2,3
4 weeks	Aug 19 to Sept 16	Introduction Physical principles Electrons in Solids Crystal Field Theory Band structure of ceramic materials Band conduction Hopping conduction, Ionic energy bands Temperature Effect Charged Surfaces & Space Charge Region, Complex Defects	
	Sept-30	**Exam 1: Electronic properties of solids**	
		Transport of Mass, Charge, and Energy	*,2,4
4 weeks	Sept 18 to Oct 21	Irreversible Thermodynamics Phenomenological transport Equations Definition of transport properties/coefficients Electrical conduction, The 4-probe measurements, Hall effect Chemical diffusion; Nernst-Planck-Poisson system Relaxation of a single kind of species: Diff. and dielectric relaxation Relaxation of two kinds of species - Ambipolar diffusion Mobility of minority carriers Haynes-Shockley Experiment Microscopic transport mechanisms	
		Thermoelectricity	*,5
1 weeks	Oct 23 to Oct 28	Thermal conduction, Thermoelectricity, Thermoelectric power Peltier heat, Thomason heat Thermoelectric cooler Thermoelectric generator	
	Nov 6	**Exam 2: Transport and Thermoelectricity**	
		Dielectric Properties	*,6,7
4 weeks	Oct 30 to Dec 2	Concept of electrical polarization Electrical polarization in a static field Electrical polarization in an alternating field Polarization mechanisms Resonance spectra, Relaxation spectra Concept of impedance spectroscopy Impedance functions Equivalent circuit approximation Wagner-Maxwell model Interfacial polarization Piezoelectricity, Ferroelectricity, and pyroelectricity Ferroelectric materials and Applications	
	Dec 6	**Exam 3: Dielectric Properties (11:20 - 1:00)**	

* Lecture notes