MSE 6010
Principles of Functional Materials

School of Materials Science and Engineering
Georgia Institute of Technology

Fall 2020

Course Objective	To introduce fundamental principles important to functional materials, including the nature and equilibrium of point defects; charge, mass, and energy transport in solids; electrical polarization in a wide range of frequencies; chemical, thermal, electrical, and mechanical interactions in solids; and several electrical characterization techniques.
Instructor	Meilin Liu
Backup Instructor	Nick Kane
Lecture	**2:00 – 3:15** pm Tuesday Thursday LOVE **183**
Office	Room 258 Erskine **Love** Building
Phone	404-894-6114
e-mail	meilin.liu@mse.gatech.edu
Office Hours	**4:00–5:00** Tuesday Thursday or by appointment
Teaching assistant	Weilin Zhang (MoSE 275)
Office Hours	To be determined
e-mail	Weilin.zhang@mse.gatech.edu
Prerequisite	Graduate standing; basic knowledge of crystal structures of materials
Homework	Homework will be assigned periodically and collected (but not graded) to assess the level of understanding. Solutions will be posted after homework is collected.
Exams/Assessment	Exam 1 (**September 22**) 100 points Exam 2 (**October 27**) 100 points Exam 3 (**December 1**) 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 the origin and equilibrium of point defects and their effect on properties of materials. 2. Become familiar with transport of charge, mass, and energy in materials under various conditions (such as chemical diffusion and electrical or thermal conduction) 3. Understand the mechanisms of electrical polarization (especially interfacial polarization) in material systems 4. Become familiar with several experimental measurements of materials properties, including impedance spectroscopy.
Academic Integrity	Students are reminded of the obligations and expectations associated with 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. Calculator (not one on an internet-connected device!) is OK during exam, but you should not need it much.
Course Type Expectation	Hybrid-touch point mode: most classes will be delivered remotely. However, there will be a few in-class activities observing social distancing during planned class sessions. Attendance at those events is strongly encouraged.

References

1. Physical Ceramics, Y. M. Chiang, D. Birnie, and W. D. Kinggery, Wiley, 1997.
2. Defects in Solids, R.J.D. Tilley, Wiley, 2008, QD921.T53
3. The Chemistry of Imperfect Crystals. Vols. 2&3, F.A. Kroger, North Holland/American Elsevier, 1974, QD478.K76.
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
		Point Defects and the Effect on Properties	*,1,2,3
4 weeks	Aug 18 to Sept 10	Defect Notations Equilibrium Defect Concentrations Defect Reactions Mass-Action Law/Electroneutrality approximation Ionic and Electronic Disorders in materials Brouwer's Approximation Non-stoichiometry: Solid-Gas Interactions Effect of Doping: Donors and acceptors Temperature Effect Charged Surfaces & Space Charge Region, Complex Defects	
	Sept-22	**Exam 1: Point Defects**	
		Transport of Mass, Charge, and Energy	***,1,4**
4 weeks	Sept 15 to Oct 13	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 15 to Oct 20	Thermal conduction, Thermoelectricity, Thermoelectric power Peltier heat, Thomason heat Thermoelectric cooler Thermoelectric generator	
	Oct 27	**Exam 2: Transport and Thermoelectricity**	
		Dielectric Properties	*,6,7
4 weeks	Oct 22 to Nov 24	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 1	**Final Examination (Tuesday 2:40 - 4:30 PM)**	

* Lecture notes

Requirements and Guidelines Specific to Fall 2020

The fall semester 2020 is especially challenging due to the Covid-19 pandemic and a growing awareness of racial inequities. The following information relates to specific services and guidelines for courses during this semester. The most up-to-date information on Covid-19 is on the TECH Moving Forward website and in the Academic Restart Frequently Asked Questions.

Expectations and Guidelines

Each of us has a responsibility to ourselves and our fellow Yellow Jackets to be mindful of our shared commitment.

- We are all required to wear a face covering while inside any campus facilities/buildings, including during in-person classes, and to adhere to social distancing of at least 6 feet. If an individual forgets to bring a face covering to class or into any indoor space, there will be a clearly marked supply of these in each building. If a student fails to follow Georgia Tech's policies on social distancing and face coverings, they will initially be reminded of the policy and if necessary, asked to leave the class, meeting, or space. If they still fail to follow the policy, they may be referred to the Office of the Dean of Students. Information on the Institute's policy on face coverings.
- Students are expected to sit in assigned seats and to come to class only on days that are assigned to them.
- Papers, projects, tests, homework, and other assignments will only be accepted in **electronic form** unless the assignment is a physical artifact.

Additional information is available in the Student Guidebook.

Instructor Illness or Exposure to Covid-19

During the fall 2020 semester, some faculty members may be required to quarantine due to exposure or isolate due to a Covid-19 diagnosis. Some disruption to classes or services is inevitable, but Georgia Tech is making every effort to ensure continuity of operations. As is the case in any semester, faculty may cancel a class if they have an illness or emergency situation and cover any missed material at their own discretion. If an instructor needs to cancel a class, they should notify students as early as possible.

Faculty who are staying home due to symptoms should monitor their health closely and consult with their school chair to determine if remote instruction or substitute instruction is most appropriate for the course. If they need to cancel a class repeatedly, a backup will be supplied in the form of a temporary substitute instructor or asynchronous work. No course will be canceled after the first class has occurred.

If you have not tested positive but are ill or have been exposed to someone who is ill, please follow the Covid-19 Exposure Decision Tree for reporting your illness.

Student Illness or Exposure to Covid-19

During the semester, you may be required to quarantine or self-isolate to avoid the risk of infection to others. Quarantine is the separation of those who have been exposed to someone with Covid-19 but who are not ill; isolation is the separation of those who have tested positive for Covid-19 or been diagnosed with Covid-19 by symptoms.

If you have not tested positive but are ill or have been exposed to someone who is ill, please follow the Covid-19 Exposure Decision Tree for reporting your illness.

During the quarantine or isolation period you may feel completely well, ill but able to work as usual, or too ill to work until you recover.

Remote courses and remote class sessions during hybrid courses. Unless you are too ill to work, you should be able to complete your remote work while in quarantine or isolation.

In-person courses and in-person class sessions during hybrid courses. When in isolation or quarantine you will be unable to attend in-person course sessions but your instructor may require you either to participate in the course remotely, complete some complementary work that parallels what you are missing in class, or make up some class work when you return.

If you are ill and unable to do course work this will be treated similarly to any student illness. The Dean of Students will have been contacted when you report your positive test or are told that it is necessary to quarantine and will notify your instructor that you may be unable to attend class events or finish your work as the result of a health issue. Your instructor will not be told the reason. We have asked all faculty to be lenient and understanding when setting work deadlines or expecting students to finish work, and so you should be able to catch up with any work that you miss while in quarantine or isolation. Your instructor may make available any video recordings of classes or slides that have been used while you are absent, and may prepare some complementary asynchronous assignments that compensate for your inability to participate in class sessions. Ask your instructor for the details.

CARE Center, Counseling Center, Stamps Health Services, and the Student Center

These uncertain times can be difficult, and many students may need help in dealing with stress and mental health. The **CARE Center** and the **Counseling Center**, and **Stamps Health Services** will offer both in-person and virtual appointments. Face-to-face appointments will require wearing a face covering and social distancing, with exceptions for medical examinations. Student Center services and operations are available on the **Student Center** website. For more information on these and other student services, contact the Vice President and Dean of Students or the **Division of Student Life**.

Accommodations for Students at Higher Risk for Severe Illness with Covid-19

Students may request an accommodation through the Office of Disability Services (ODS) due to 1) presence of a condition as defined by the Americans with Disabilities Act (ADA), or 2) identification as an individual of higher risk for Covid-19, as defined by the Centers for Disease Control (CDC). Registering with ODS is a 3-step process that includes completing an application, uploading documentation related to the accommodation request, and scheduling an

appointment for an "intake meeting" (either in person or via phone or video conference) with a disability coordinator.

If you have been approved by ODS for an accommodation, I will work closely with you to understand your needs and make a good faith effort to investigate whether or not requested accommodations are possible for this course. If the accommodation request results in a fundamental alteration of the stated learning outcome of this course, ODS, academic advisors, and the school offering the course will work with you to find a suitable alternative that as far as possible preserves your progress toward graduation.

Course Homeworks/Assignments/Papers

All course assignments will be submitted electronically via Canvas. *Point students to where these can be found in Canvas. If your students are expected to submit physical artifacts, share information on how they will be able to do this.*

Exam Proctoring *(if applicable)*

This course will use digital proctoring for exams (*indicate all or some of the exams)*. The following are required of students:

- Include important Honorlock technical requirements.
- Students must have a broadband internet connection
- Students must have a webcam and microphone
- Students must have a secure private location to take an exam
- Students will be asked to provide a picture ID and take a picture of themselves via a webcam as part of the exam process
- Honorlock is not compatible with Linux OS, Virtual Machines, tablets, or smartphones
- Honorlock requires the installation of Google Chrome and the Honorlock Chrome extension

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Course Attendance Structure:

Communicate to your students how class sessions will take place (synchronously, asynchronously or in-person). In case of in-class attendance, communicate your schema with which students are expected to attend in person (unless you have a large enough classroom space that can hold all your students in a physically distanced manner.) When students are not attending class in person, how should they engage in the course (e.g. remotely through live synchronous broadcast, complete specific course work asynchronously)?)

Election Day

The Faculty Executive Board endorsed the following request made by the student government: In order to increase the opportunities for students to vote on the national election day, Tuesday, November 3, course instructors are strongly encouraged to not schedule in-class assessment activities and to make available lecture recordings for students who are unable to attend regularly-scheduled classes that day.