MSE 6334 – Materials for Energy Storage and Conversion

School of Materials Science and Engineering
Georgia Institute of Technology

Spring Semester 2026

Course **Objective**	To provide students with a fundamental understanding of the scientific principles and emerging strategies for transferring, capturing, and storing energy from diverse resources, as well as the latest developments and materials challenges in energy storage, conversion, and harvesting; and to emphasize design guidelines for developing new materials that support a clean, secure, and sustainable energy future
Lecture	**11:00-12:15** pm **M W** in **Kendeda 210**
Instructor	Meilin Liu, Zhitao Kang
Office	Love 258
Phone	404-894-6114
E-mail	meilin.liu@mse.gatech.edu;
Office Hour	**M W** 2-3:00 pm
TA	TBD
Homework	Homework problems will be assigned periodically, and solutions will be provided at a later time. While HW will be collected, it will not be graded since solutions to past HW assignments are available, awarding credit for HW may not be entirely fair. However, completing the homework remains a crucial part of the learning process.
Exam/Term paper	**Exam 1 (100)** – Electro-***physical*** energy storage/conversion (March 9) **Exam 2 (100)** – Electro-***chemical*** energy storage/conversion (May 1) **Term Paper (100) –** Energy ***materials/devices*** (May5)
Grading Basis	>90% A guaranteed >80% B guaranteed >70% C guaranteed >60% D guaranteed
Learning Accommodations:	Kindly inform me if you have a documented disability or specific needs requiring accommodation. We will ensure appropriate accommodations in accordance with the Office of Disability Services (https://disabilityservices.gatech.edu). However, this must be arranged in advance (within the first two weeks).

Learning Objectives:	Upon completion of this course, students will • Develop a strong foundation in the fundamental principles and mechanisms governing energy storage, conversion, and harvesting. • Gain a deep understanding of the thermodynamic and kinetic factors that control energy storage and conversion processes. • Critically evaluate key materials properties and challenges that limit the performance of energy storage and conversion technologies. • Apply these principles to design and propose advanced materials solutions that address current challenges and enable next-generation energy technologies.
Academic Integrity	Students are reminded of the obligations and expectations associated with the Georgia Tech Academic Honor Code and Student Code of Conduct, available online 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. Academic misconduct refers to any act that may improperly distort student grades or other student academic records. Such acts include but are not limited to the following: • Possessing, using or exchanging improperly acquired written or verbal information in the preparation of exams or assignment • Submission of material that is wholly or substantially identical to that created or published by another person or persons, without adequate credit notations indicating authorship (plagiarism); • **Obtaining details/help on tests and assignments from students previously enrolled in the course** Scholastic dishonesty by a few is unfair to the students who are honest. Please help us keep the grading fair and the learning opportunity in this course as equitable as possible.
Electronic Devices	**During class**, be sure to **turn off and put away all electronic devices**, including cell phones, smartphones, laptops, tablets and similar devices) that can be used to view Internet web pages, or to communicate voice, data, text or graphic messages. **During an exam**, the only electronic device that you may have out and available for use is a **commercially available calculator**.

References

1. Lecture notes – will be posted on Canvas
2. R. A. Hinrichs and M. H. Kleinbach, *Energy: Its Use and the Environment*, 2005
3. D. R. Lovett, *Tensor Properties of Crystals*, 1999; QD 911.L69
4. J.F. Nye, *Physical Properties of Crystals*, Oxford, Third Edition, 2001.
5. T. Ikeda, *Fundamentals of piezoelectricity*, Oxford, 1990.
6. E. Subbarao, ed., *Solid Electrolytes and Their Applications*, Plenum, 2nd Ed., 1991- QD 565. S665
7. R. P. O'Hayre et al., *Fuel Cell Fundamentals*, 2009
8. Robert A. Huggins, *Advanced Batteries: Materials Science Aspects*, 2008
9. Additional references on *solar energy* to be given later

The referenced materials are available in the library and will be placed on a two-hour reserve for student use.

Canvas

Lecture notes, assignments of homework problems, homework solutions, announcements and other materials relevant to the course will be posted on Canvas. It is the student's responsibility to check their e-mail and Canvas on a regular basis.

Attendance and Tardiness

While there is no formal attendance policy, it is hoped that you feel attending class is important to your learning and for success in this class. Even for an excused absence, it is your responsibility to find out what was missed. Test questions may include material covered exclusively in class; therefore, missing class could negatively impact your course grade.

It is disruptive to the class when someone arrives late (or leave early). Try to come to class on time or a few minutes early to get prepared for class.

Institute Absence Policy
https://catalog.gatech.edu/rules/4/

Seeking Assistance

I would be more than happy to meet with students to provide assistance with course material and/or other school and career related issues. Please feel free to stop by during my office hours or email me to arrange a time to meet. While I can usually be flexible on arranging a meeting time, I may be unavailable to meet with students without an appointment.

Please give yourself sufficient time to study for exams. If you have a specific question or need clarification of a topic, please discuss it with me at least **one day** before the scheduled exam. **Questions regarding test material will NOT be answered or discussed on the day of the exam.**

MSE 6334: Topical Outline

# of weeks	Date	Topics	Ref
		Introduction	1,2
1 wk	Jan 12-14	Global energy issues; Materials science to transcend energy challenges; Materials for energy transformation processes Introduction to Thermodynamics/Kinetics/Crystallography	
		Electro-physical Energy Storage & Conversion	*,1,3,4,5
3 wks	Jan 21 to Feb 9	Introduction to anisotropy and tensors Thermodynamic formulation of physical interactions: **Thermal**, **mechanical**, and **electrical** interactions Piezo-, pyro-, & ferro-electricity Electro-physical energy transformation processes Materials challenges for piezoelectric generators and capacitors; the latest developments in new materials	
2 wk	Feb 11 to Feb 23 **March 9**	**Thermoelectricity**: Transport of Charge and heat Thermoelectric Phenomena Materials challenges for thermoelectric generators **Exam 1: Electro-physical energy storage/conversion (100 pts)**	1,3,4,5
		Solar Energy Conversion	1
2 wks	Feb 25 to Mar 11	Fundamentals of photovoltaic materials Thin-film, multijunction photovoltaic cells Materials challenges for high-efficiency solar cells Latest development in new materials	
		Electrochemical Energy Storage & Conversion	1,6,7,8
6 wks	Mar 16 to Apr 27	Solid-state ionics and ionic conductors Electrode processes and electrode materials **Fuel cells**: SOFCs and PEM fuel cells **Batteries**: Li-ion and Li-air batteries **Electrochemical Capacitors** Mixed ionic-electronic conductors (MIECs) for **H_2 production** and **fuel reformation** Materials challenges for electrochemical transformations **Photo-electrochemical solar cells** Fundamentals of photo-electrochemical processes Materials challenges, Recent developments of novel materials	
Friday	**May 1**	**Exam 2: Electrochemical energy storage/conversion (100 pts)**	**11:20–1:10**
Tuesday	**May 5**	**Term Paper Due (100 pts)**	

Guidelines for Term Paper

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Objective	To acquaint students with a specific topic of current research in energy storage, conversion, or harvesting and to inspire student's creativity in developing novel materials, processes, or devices for *clean* and *sustainable* energy.
Topic	You may choose any topic that is closely related to the materials covered in the class (such as piezo-electric, thermo-electric, solar, or electro-chemical materials), provided that it falls outside the focus of your thesis research, in order to broaden your knowledge basis. Appropriate topics include *knowledge-based design*, *processing*, *characterization*, or *application* of key materials for energy storage, conversion, or harvesting. Most importantly, select a topic that genuinely interests you, as this will allow you to fully demonstrate your creativity and insight. Please feel free to reach out if you would like suggestions or guidance in choosing a topic.
Format	The term paper should consist of • Title, author, and affiliation • Abstract (approximately 100-150 words) • Introduction (significance of the topic) • Critical review of current literature: Identification of *critical challenges/opportunities for new directions* • *Your novel approaches to overcome the challenges/solutions* • References • Figures with captions Length: about 10 pages (double-spaced) or 2,000 to 2,500 words, excluding references and figures
Due Dates	**March 16** A *title*; a short *abstract* (100–150 words) – a topical description of your proposed term paper; a brief description of your thesis research (a few sentences); and the name of your research supervisor. **May 5** This is will give me enough time to read and grade the term papers.
References	**Journals** related to materials for energy applications such as *Joule, Nature Energy, Energy Environ. Science, Adv. Energy Materials; Nano Energy, Adv. Materials* **Proceedings Volumes** of recent meetings on related topics

DEI:

Georgia Tech values diversity and inclusion; we are committed to a climate of mutual respect and full participation. Our goal is to create learning environments that are usable, equitable, inclusive, and welcoming. If there are aspects of the instruction or design of this course that result in barriers to your inclusion or accurate assessment or achievement, please notify the instructor as soon as possible. Students with disabilities should contact the Office of Disability Services to discuss options of removing barriers in this course, including accommodations. ODS can be reached at 404.894.2563, dsinfor@gatech.edu or disabilityservices.gatech.edu.

CRSH (Create Resistance to Sexual Harassment)

MSE is committed to a community that actively resists sexual and gender harassment. If you see or experience any of the following: sexual harassment, domestic and dating violence, sexual assault and stalking, resources are available:

- **Confidential VOICE Advocates** (www.voice.gatech.edu) can provide support 24/7 and explore resources and options. If after hours, call GTPD dispatcher at 404-894-2500 and ask to speak to the On-Call VOICE Advocate. You do not need to make a report nor provide any information other than your phone number for a VOICE advocate to contact you.
- Sexual violence or harassment can be reported directly to Georgia Tech's **Title IX Coordinator**, James Newsome, (404) 385-5583 burnsnewsome@gatech.edu

Faculty, Staff and TAs are mandatory reporters and are required to inform the Title IX Coordinator should they become aware that you or any student has experienced sexual violence or sexual harassment.

Website: For more information about MSE CRSH, click the link:
https://www.mse.gatech.edu/values/crsh