Emerging Functional Materials/MTEN6015/5115
Course Syllabus
Spring Semester 2025

Instructor Information:

Instructor:	*Dr. Donglu Shi*
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Phone Number:	*513 556 3100*
Zoom:	*https://ucincinnati.zoom.us/s/9377684662#success*
Office Hours:	*2:00 – 2:30 pm Wednesday*
Contact Preferences:	*The best way to reach me is via email. If you have not received a response, please try to contact me again, this time via phone. Please leave a message if I don't answer.*
TA:	

General Course Information:

Course Number:	*MTEN6015/5115*
Course Title:	*Emerging Functional Materials*
Credit Hours:	*# Credit hours: 3*
Contact Hours:	*# Contact Hours: 45 to 48 hours*
Meeting Days/Times:	*MWF/ 2:30-3:25 pm*
Prerequisites:	*Any 2000-3000 level physics and chemistry courses in the engineering programs.*
Course Description:	***Overview**:* *Striving for the COP26 goal of achieving net-zero emissions by 2050, amidst global healthcare challenges, materials science faces unprecedented challenges and exciting research opportunities in energy sustainability, environmental resilience, bio-safety, and healthcare solutions. It plays a pivotal role in creating innovative materials and structures with distinctive properties for both energy and healthcare applications. Material science significantly propels the development of various energy materials, ranging from the harvesting and conversion of energy to storage and generation. This includes advancements in solar cells, lithium-ion batteries, green hydrogen generation, and nanomaterials tailored for medical purposes, encompassing diagnosis, imaging, drug and gene delivery, and cancer precision medicine.* *The course "Emerging Functional Materials" is intricately designed to prepare students for the forefront of contemporary energy materials and biotechnologies. It fosters a comprehensive understanding of advanced materials science and engineering, offering hands-on experience in defining and resolving challenges within this multifaceted context. Graduates of this course will emerge ready to contribute meaningfully to the intricate intersection of materials, energy, and healthcare.*

***Course description**: This dual-level course addresses critical issues in advanced materials, with a primary focus on two key areas: energy materials and healthcare materials. In the realm of energy materials, the course explores a wide array of technologies, covering advanced materials in energy harvesting, conversion, generation, storage, and transport. Topics include photovoltaic, photothermal, thermoelectric, batteries, supercapacitors, high-efficiency green hydrogen, and superconductors. On the healthcare front, the course introduces bio-inspired nanohybrids, including recent advancements and challenges in medical diagnosis, therapeutics, biosensing, virus detection, medical devices, and environmental safety. Furthermore, the course imparts novel synthetic techniques for developing next-generation living materials, effectively bridging the gap between materials science and biotechnology.*

Applying major materials science fundamentals, the course equips students to design, synthesize, and develop unique nanomaterial systems that transcend traditional classifications like metals, ceramics, and polymers. Special attention is given to creating advanced materials with heterostructures for varied and tunable properties, hierarchically-organized structures with multilength-scales, and bio-synthetically assembled materials that mimic natural processes—all tailored to meet specific requirements with meticulously designed functionalities.

In addition to mastering these fundamental materials science concepts, students will also develop transferable skills vital for their careers in the field. They will learn effective collaboration techniques, adaptability in interdisciplinary research environments, and the ability to synthesize and apply complex scientific principles. Moreover, the course will provide guidance on post-graduate planning, helping students envision potential career paths in materials science, engineering, biotechnology, and related fields. By the end of the course, students will be well-equipped to pursue advanced studies, research opportunities, and industry careers, armed with a comprehensive understanding of cutting-edge materials technologies and their real-world applications.

***Purpose**: This course is designed with the goal of intellectually challenging students to investigate novel materials and their properties, especially in applications related to green energy, human well-being, and the establishment of a secure built environment. It transcends the boundaries of inspiring innovative ideas in materials science by actively fostering creative thinking. Simultaneously, the course is dedicated to nurturing a heightened awareness of ethics and global issues among students.*

Course Delivery Mode:

This course is a face-to-face, in-person course. This means that class will be conducted entirely via in-person class meetings that take place at the location noted. To learn more about accessibility at the University of Cincinnati, visit https://www.uc.edu/about/accessibility-network.html

Course Location and/or Access:

Course lectures will be held in Baldwin.

All course materials can be found on Canvas (accessible via canopy.uc.edu). Assignments, lecture notes, videos, etc. will be posted on the course site in Canvas. Some review lectures for preparation of midterm and final exam will be conducted using Zoom at https://ucincinnati.zoom.us/s/9377684662#success. Invitations that link to scheduled live online lectures will be posted on the course site in Canvas.

Course Learning Outcomes:

Upon successful completion, students will acquire the knowledge and skills to:
Demonstrate critical and creative thinking in the design of new materials and structures, providing unique properties crucial for energy and medical applications.
Understand fundamental advancements in novel advanced materials design and synthesis, characterization of new properties, and their applications in innovative energy and medical contexts. This knowledge will enable them to gain new insights into their dissertation/thesis research.
Grasp the key challenges in global energy, healthcare, and the environment, and comprehend current strategies for addressing them through advanced materials science and engineering.
Demonstrate effective collaboration and adaptability in highly interdisciplinary research and working environments.
Articulate the basic principles of cutting-edge technologies used in energy and nanomedicine.
Possess awareness of the societal and environmental impacts associated with nanotechnologies.
Moreover, this course is designed to directly connect with students' career education and post-graduate planning. Through discussions, case studies, and in-depth analysis of real-world applications, students will develop a strong foundation in advanced materials science and engineering. They will explore how these principles are applied in industry settings, preparing them for future careers in energy technology, medical device manufacturing, environmental sustainability, and related fields. The course also aims to inspire and encourage students to pursue graduate degrees, providing them with the necessary skills and knowledge to excel in advanced academic research and contribute to the field's ongoing advancements. By engaging with current industry trends and challenges, students will gain valuable insights into the professional landscape and potential career paths within the materials science and engineering domain. This course aims to equip students with the knowledge, critical thinking abilities, and awareness of industry demands necessary to excel in their chosen careers and contribute meaningfully to scientific advancement and technological innovation.

Course Resources:

Reference books and Materials:	*Energy Materials - Fundamentals to Applications* *1st Edition - August 15, 2021, Editors: Sanjay Dhoble, N. Kalyani, B. Vengadaesvaran, Abdul Arof* *eBook ISBN: 9780128237113, Paperback ISBN: 9780128237106* *Advanced Healthcare Materials, Ashutosh Tiwari (Editor),* *ISBN: 978-1-118-77359-8* *Understanding Nanomedicine: ISBN:9789814303521, 9814303526*
Supplemental Textbooks and Materials:	*Lecture Notes*
Required Software or Hardware:	*N/A*

AI Policy

In this course, students are encouraged to use Generative AI Tools like ChatGPT to support their work. However, not all use cases of Generative AI are appropriate in this course. Students may use these tools for the following purposes: Grammar checking - Translation - Programming - Generation of schematic diagrams. Other uses beyond this list will be considered academic misconduct. Please do not hesitate to ask if you are unsure if your specific application is appropriate in this course. Students should exercise caution with the output of Generative AI tools – they often generate incorrect statements despite attempts to steer them toward correctness. Students are responsible for verifying the accuracy of the outputs it provides.

Course Assignments:

Assignments	
Homework 1	Electronic structures, energy band theory, density of states, Fermi-Dirac distribution,
Homework 2	Advanced materials and their energy applications: energy harvesting, conversion, storage
Midterm	March 2025
Homework 3	Advanced materials for nano biomedicine: quantum dots, superparamagnetic nanoparticles
Homework 4	Nanoparticles for medical diagnosis and therapy
Final exam	April 2025

Grading:

Final numerical grades for the course are determined based on the following weights for assignments.

Assignment:	**Weighting:**
Homework:	*25 %*
Midterm:	*35 %*
Final Exam:	*40 %*
Total:	100%

Final letter grades for the course will be determined using your final numerical grade and the following ranges. Please note that the instructor reserves the right to modify the range for each letter grade. However, the ranges posted here provide the minimum score you must achieve in order to guarantee yourself the grade indicated.

Numeric Ranges

Grade:	**Range:**
A	*92-100*
A-	*89-92*
B+	*86-89*
B	*82-86*
B-	*79-82*
C+	*76-79*
C	*72-76*
C-	*69-72*
D+	*66-69*
D	*62-66*
D-	*59-62*
F	*Below 59*

Qualitative scale (from UC Registrar at https://www.uc.edu/about/registrar/grades-and-transcripts/transcript-ordering/grading-scales.html)

Course Schedule:

Week	Chapters	Topic	Assignments
1		Introduction of Advanced Materials	
2	Chapter 1	Overview of Current Critical issues in Green Energy and Biomedicine	
3	Chapter 2	Quantum Mechanics, Schrodinger Equation, The Infinite Potential Well, Electron in Free space, Energy Band Theory, Density of States, Fermi-Dirac Distribution,	Homework 1
4	Chapter 3	Semiconductor Materials and Structures, Intrinsic Carrier Concentration, Doping, Recombination Energy, Solar Cells, Spectral Loss, Solar Cell Operation, Design of Silicon Cells	
5	Chapter 4	Advanced Materials for Energy Conversion and Generation:, Piezoelectrics, Dielectrics, Thermoelectrics, Perovskites, Superconductors, Soft Magnetic Materials	Homework 2
6	Chapter 5	Advanced Materials for Energy Storage and Devices: Flywheels, Super Capacitors, Superconducting Energy Storge, Lithium-Ion Batteries, Tokamak, Hydrogen Storage in Graphene	
7	Chapter 6	Advanced Photonic Materials for Solar Harvesting: Photonic Nanocavities, Plasmonic Nanoparticles, Photothermal Films, Wave-Length Segregators, Spectral Selective Nano Hybrids	
8	**March**		**Midterm**
9	Chapter 7	Introduction to Nanomedicine: Status and Challenges	
10	Chapter 8	Nanomaterials for Nano Biomedicine: Liposomes, Quantum Dots, Superparamagnetic Fe3O4, Gold Nanoparticles, Carbon Nanotubes, Polymeric Micelles, RNA Nanoparticles	Homework 3
11	Chapter 9	Nanomaterials for Medical Diagnosis, Nanoparticle-Based Contrast Agents for Imaging, Magnetic Nanoparticles for MRI, Biosensors, Upconversion Nanoparticles, Florescent Nanoparticles	
12	Chapter 10	Nanoparticles for Medical Therapy, Polymeric Nanoparticles for Gene/Drug Delivery, Nanoparticles for Cancer Photothermal Therapeutics, Nanoparticles for Magnetic Hyperthermia	Homework 4
13	Chapter 11	Nanomaterials for Biosensing: Strategy for Cell Targeting, Surface-Charged Nanoparticles for Cancer Cell Detection, Biosensors for Virus Detection, Magnetic Lateral Flow Immunochromatographic Assay	
14	**April**		**Final Exam**

Course Policies:

Classroom Management Policies
No cell phones, webcams on in classroom during class.

Attendance and/or Participation

- *As in all university courses, attendance and participation are important measures of student success. In this course, attendance is not recorded. Your attendance and participation are still expected. Missing an exam or activity without previous approval will result in failing that exam or activity.*
- *Students who anticipate missing a class for reasons such as religious holidays, sports, etc. should contact me to make arrangements in advance and will, of course, be required to complete any missed assignments or coursework.*
- *If you are sick or asked to quarantine due to potential COVID-19 exposure, please do not attend class in person. Please notify me of your situation as soon as possible and we will discuss how to accommodate your participation in class remotely.*
- *If you have an unexpected IT issue that prevents your participation in a synchronous online session of the course, please 1) contact UC IT for help in resolving your technical issue (https://www.uc.edu/about/ucit/help.html or 513-556-HELP) and notify me as soon as possible of the reason for your absence so that we can make arrangements for any missed material.*

Class Cancellation

- *If the University closes due to inclement weather or other emergency situations, there will be university-wide announcements via email and also to your cell phone number on record through the automatic University emergency text messaging system. Students should notify the University if they change their cell phone number to ensure they will receive these important emergency communications. As soon as possible following the University closure, I will post an announcement on Canvas with instructions for how the material for the day will be covered.*
- *Reviews for midterm and final of this course will be conducted "live" online at scheduled times. If issues with technology prevent me from starting the class at the scheduled time, please wait at least 15 minutes to allow me time to attempt to resolve the issue and start the session late, or to communicate alternative plans via a Canvas announcement. If I am unable to get a message out in that time, I will communicate to the class as soon as I am able.*
- *This course will be entirely conducted in-person on campus. If our classroom becomes unavailable for any reason, I will post an announcement on Canvas to update the class with information on alternative plans (which may be to reschedule to a different room, to conduct the in-person activity on a different day, or to hold the class session online at https://ucincinnati.zoom.us/s/9377684662#success).*

Academic Integrity

Ethics and integrity are core values that should guide our conduct and decisions as members of the UC community and as engineering and technology professionals. Course assignments and tests are designed to have educational value and prepare you to be a competent and ethical professional. Therefore, material presented by you to satisfy course requirements is expected to be result of your own original scholarly efforts, unless collaboration is explicitly allowed on a particular assignment.

University Rules, including the Student Code of Conduct and other documented policies of the department, college, and university related to academic integrity, will be enforced. Any violation of these regulations, including acts of plagiarism or cheating, will be dealt with on an individual basis according to the severity of the misconduct, and can result in severe consequences, including potential dismissal from the college after the second offense.

Accessibility
UC is committed to providing all students full and equal access to learning opportunities. UC's Office of Accessibility Resources is the official campus office that works to arrange for reasonable accommodations for students with an identified physical, psychological, or cognitive disability (learning, ADD/ADHD, psychological, visual, hearing, physical, cognitive, medical condition, etc.). Students are encouraged to contact the Accessibility Resources office to arrange for a confidential meeting to discuss services and accommodations. Contact should be initiated as soon as possible to allow for adequate time for accommodations to be arranged.

UC is also committed to providing full and equal access to our electronic and information technology, including websites, electronic files, digital course content, and software/applications. If you experience difficulty in using any of the digital content associated with this course, even with the assistance of available Student Accessibility Resources, please let your instructor know.

Contact Information: Accessibility Resources Clifton: AccessResources@Uc.edu

Information regarding the Accessibility Policy can be found in the UC Student Resources Canvas site.

Title IX
Title IX is a federal civil rights law that prohibits discrimination on the basis of a person's actual or perceived sex, gender, gender identity, gender expression, or sexual orientation. Title IX also address instances of sexual violence, dating or domestic violence, and stalking. If a student discloses a Title IX issue to a faculty member, the faculty member is required to forward that information to the Title IX Office. The Title IX office will follow up with the student and discuss how the University can take steps to address the impact on the student and the community. They will also inform the student of their rights and direct them to available resources. The priority is to make sure students are safe and successful here at the University of Cincinnati. Students are not required to talk to anyone in the Title IX Office. Students may also directly report any instance of sex or gender-based discrimination, harassment or violence to the Title IX office at 513-556-3349. Students who wish to know more about their rights and resources on campus, they can consult the Title IX website or contact the Title IX office directly at 513-556-3349.

Counseling Services
Students have access to counseling and mental health care through the University Health Services, which can provide both psychotherapy and psychiatric services. UC's Counseling & Psychological Services (CAPS) provides students access to professional counseling services as well as numerous options for help online, via mobile apps, group sessions, and peer-to-peer programs. CAPS conducts free virtual consultations via the "Let's Talk" program. CAPS also has a an "embedded counselor" available in CEAS, located in CEAS and just for CEAS students. Please see CAPS embedded in CEAS for scheduling information. Students are encouraged to seek assistance for anxiety, depression, trauma/assault, adjustment to college life, interpersonal/relational difficulty, sexuality, family conflict, grief and loss, disordered eating and body image, alcohol and substance abuse, anger management, identity development and issues related to diversity, concerns associated with sexual orientation and spirituality concerns, as well as any other issues of concern.

Inclusivity
This class is committed to the fundamental principles of academic freedom and human dignity. Diversity in all forms is something we welcome, we foster, and we prize. We believe that honest attempts to understand the perspectives of others facilitates learning, and we will strive to achieve this goal at all times. We strongly disavow discrimination -- including harassment -- on the basis of race, national or ethnic origin, religion, sex or gender identity, disability, age, sexual orientation, or veteran status. We expect that each of us will hold one another accountable for maintaining these ideals.

All are welcome and considered a valuable addition to the university community. You should consider my classroom as an inclusive and safe space to express your ideas and viewpoints. **No discrimination is accepted or tolerated in this course.** It is the goal for you to be successful and to thrive to your highest potential. UC Notice of Non-Discrimination

Religious Accommodations
Ohio law and the University's Student Religious Accommodations for Courses Policy 1.3.7 permits a student, upon request, to be absent for reasons of faith or religious or spiritual belief system or participate in organized activities conducted under the auspices of a religious denomination, church, or other religious or spiritual organization and/or to receive alternative accommodations with regard to examinations and other course requirements due to an absence permitted for the above-described reasons. Not later than fourteen days after the first day of instruction in the course, a student should provide the instructor with written notice of the specific dates for which the student requests alternative accommodations. For additional information about this policy, please contact the Executive Director of the Office of Equal Opportunity and Access at (513) 556-5503 or oeohelp@UCMAIL.UC.EDU.

Special Statement on COVID-19
UC's COVID-19 Public Health Webpage contains the most up-to-date policies and practices regarding COVID-19 precautions at UC. Remember, sick and/or quarantined students should not come to class. Instead, please contact the instructor to discuss appropriate online accommodations.