CEE 6315 Environmental Nanotechnology

Semester: Fall, 2021 **Time:** MW 11:00 AM – 12:15 PM **Location:** Ford ES&T L1125

Instructor: Dr. Xing Xie, Office: ES&T 3236, E-mail: xing.xie@ce.gatech.edu, Phone: (404) 894-9723

Backup instructor: Dr. Yongsheng Chen, E-mail: Yongsheng.chen@ce.gatech.edu

Office hour: By appointment. After class is often the best for a quick chat.

Course description: This is a graduate level course to introduce the environmental aspects of nanotechnology. The course will be divided into two primary sections: 1) fundamentals of nanomaterials and nanotechnology, including physical and chemical phenomenon at nanoscale, nanomaterial synthesis, fabrication, and manipulation, and techniques to characterize nanomaterials; and 2) the environmental applications of nanotechnology (water treatment, air purification, environmental sensors, etc.).

Course objectives: Upon successful completion of this course, the student will be able to: understand the basic concepts of nanoscience and nanoengineering; list common procedures and tools to synthesize, fabricate, and assemble nanomaterials; identify the appropriate techniques for nanomaterial characterization; assess journal papers, scientific reports, and professional documents relevant to environmental nanotechnology; discuss the near term and future environmental applications of nanomaterials; and describe the process and challenges to employ nanotechnologies in environmental systems.

Recommended prior knowledge: College-level physics and chemistry.

Course website: https://canvas.gatech.edu/

Reference books (online access available through library):

Book 1: Cao, Guozhong. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications. 2004.

Book 2: Leng, Yang. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods. John Wiley & Sons, 2013.

Book 3: Mark R. Wiesner and Jean-Yves Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials, 2nd Edition, McGraw Hill, 2016.

Book 4: Boris I. Kharisov, Oxana V. Kharissova, and H. V. Rasika Dias, Nanomaterials for Environmental Protection, Wiley, 2014.

Book 5: Manoj Kumar Ram, E. Silvana Andreescu, and Ding Hanming, Nanotechnology for Environmental Decontamination, McGraw Hill, 2016.

Course modality: In person. The instructor will try the best to be flexible in accommodating the students' needs. Attendance will not be counted towards your final grade. "The Flipped Classroom" model will be applied for about half of the course. A flipped classroom is an instructional strategy and a type of blended learning, which aims to increase student engagement and learning by having students complete readings at their home and work on live problem-solving during class time. It moves activities, including those that may have traditionally been considered homework, into the classroom. For more explanation, please check this Wikipedia link, https://en.wikipedia.org/wiki/Flipped_classroom.

In a flipped classroom, students will watch lecture recordings at home **in advance**, while engaging discussion and problem solving in the classroom with the guidance of the instructor. Students can join the classroom discussion remotely, but these sessions will not be recorded.

Grading: Homework, 30%; Exams, 35%; Final project, 35%.

Grade definition: http://www.registrar.gatech.edu/students/gradingsystem.php

Course guidelines & policies:

Homework (30%): Multiple homework sets will be assigned. The homework should be submitted on Canvas by the end of the day they are due unless specified otherwise. For late submissions, 0.5 point per day deduction will be applied to the homework grade. You may discuss the general approach to the problems with classmates but should try to work independently on the actual solutions.

Exam (35%): One closed book exam will be given. Students can prepare a 1-page letter-size cheat sheet for the exam. The instructor may provide necessary equations. Students may need a calculator. Calculators must not have any communication capability: you cannot use a mobile phone as a calculator. A make-up exam will only be permitted for extremely difficult situations that are considered prohibitive enough and with prior permission from the instructor or proper documents for the absence.

Final Project (35%): Each student will be required to work on a final paper relevant to the environmental applications of nanomaterials: pick a recently published research article (available online between **October 27, 2020** and **October 20, 2021**); summarize the article; review the article, propose future research, and discuss the potential of the application described in the article for practical implementation. The title of the paper should be: Comment on "the original title of the article you pick". The paper should be divided into three sections as follows.

Summary (~2 pages). You should try to answer the following questions: What nanomaterials were used? How were the nanomaterials synthesized or assembled? Which characterization techniques were used? What was the application? How was it tested? What was the performance?

Review and future research (~2 pages). You should try to answer the following questions: Can we use other materials? Can we improve the synthesis or assembly methods? Were the nanomaterials characterized properly? What other characterization techniques we can use? Were the experiments well designed? Were the results correctly reported and reasonably explained? How can we improve the performance? What other studies can be done in the future? What is your hypothesis? How will you test it?

Discussion (~1 page). You should try to answer the following questions: What are the advantages using the described technology? What are the limitations for practical implementation? How does it compare with the conventional processes? Can you estimate the cost?

White paper (5%): A 1-page introduction of your final paper (not the research article) will be due about 4 weeks before the end of the semester on **October 20, 2021**. Late policy is the same as the homework.

Presentation (15%): Students will present their paper in class during the last two weeks of the semester (not in the reading period). Slides should be prepared in PowerPoint and submitted for grading purposes. The presentations will be graded by both the instructor and class peers.

Final paper (15%): The 5-page final paper should be prepared with 11-12 font size, Arial or Times New Roman, single-spaced, and 1-inch margin. Do not use cover or title page. References do not count for the page limit. The paper may contain figures and tables, but they should not occupy more than 1 page. The final paper is due in class on the last instructional day (**December 6, 2021**). Late submission is not accepted.

No any two students will be allowed to work on the same article. A shared online excel file will be created (**October 18, 2021**) for students to sign up the articles selected. The students who sign up later need to make sure their articles have not been chosen. The same order will be applied for the oral presentation. The students can change the articles they pick afterwards, but the order for presentation will not change.

Honor code: Students in this class are expected to abide by the Georgia Tech Honor Code (http://osi.gatech.edu/content/honor-code) and to avoid any instances of academic misconduct, including but not limited to: 1) Use of cell phones during class, including texting or use of apps. Place cell phones in your bag and turn them off/manner mode; 2) Possessing, using, or exchanging improperly acquired

written or oral information in the preparation of homework, class project, and exams; 3) Use of material that is wholly or substantially identical to that created or written by another individual or group (including Plagiarizing); and 4) False claims of performance or work that have been submitted by a student.

Accommodations for students with disabilities: If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

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. Unless you are too ill to work, you should be able to complete your remote work while in quarantine or isolation. 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.

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Tentative assignment schedule: *Subject to change*. Changes will be announced in class.

Date	Topic	Reading	Assignment
8/23	Introduction of the course		
8/25	Introduction of nanotechnology	1	HW1 Assigned
8/27	**Office hour on BlueJeans 11:00-12:15 pm**		
8/30	Basics of material chemistry (1)		HW1 Due; HW2 Assigned
9/1	Basics of material chemistry (2)		HW2 Due; HW3 Assigned
9/6	No class (Institutional holiday)		
9/8	Classification and properties	2	HW3 Due; HW4 Assigned
9/13	Synthesis and fabrication	3&4	HW4 Due; HW5 Assigned
9/15	Dispersion and manipulation	5	HW5 Due; HW6 Assigned
9/20	Overview & Optical Microscope	6	
9/22	XRD	7	HW6 Due; HW7 Assigned
9/27	TEM	8	HW7 Due; HW8 Assigned
9/29	SEM and FIB	9	HW8 Due; HW9 Assigned
10/4	EDS, XPS, and AES	10	HW9 Due; HW10 Assigned
10/6	XAS, DLS, and SPM	11	HW10 Due
10/11	No class (Fall break)		
10/13	Guest Lecture & IEN Tour		
10/18	**Exam**		
10/20	Overview and Application-Disinfection	12	White paper due; HW11 Assigned
10/25	Application-Nano-adsorbents	13	HW11 Due; HW12 Assigned
10/27	Application-Reductants, oxidants, and catalysts	14	HW12 Due; HW13 Assigned
11/1	Application-Photoactive nanomaterials	15	HW13 Due; HW14 Assigned
11/3	Application-Bioelectrochemical systems	16	HW14 Due
11/8	Application-Air purification and Sensors	17&18	
11/10, 11/15, 11/17, 11/22, 11/29, 12/1: Student presentations			
12/6	Summary		Final paper due

Reading: All reading materials are available online through Georgia Tech library.

1. Richard Feynman - There's Plenty of Room at the Bottom

   Qu, Xiaolei, Pedro JJ Alvarez, and Qilin Li. "Applications of nanotechnology in water and wastewater treatment." Water research 47.12 (2013): 3931-3946.

   Li, Renyuan, Lianbin Zhang, and Peng Wang. "Rational design of nanomaterials for water treatment." Nanoscale 7.41 (2015): 17167-17194.
2. Book 1, Chapter 2.2.
3. Book 1, Chapter 3.1, 3.2.1, 3.2.2, 3.3, 3.4.
4. Book 1, Chapter 4.1, 4.2.1.1, 4.2.2.1, 4.2.2.3; Chapter 5.1, 5.2
5. Book 1, Chapter 2.4.
6. Book 2, Chapter 1.
7. Book 2, Chapter 2.
8. Book 2, Chapter 3.
9. Book 2, Chapter 4.

10. Book 2, Chapter 6 and 7.
11. Book 2, Chapter 5.
12. Nanomaterials for disinfection.

    Li, Qilin, et al. "Antimicrobial nanomaterials for water disinfection and microbial control: potential applications and implications." Water research 42.18 (2008): 4591-4602.

    Loo, Siew-Leng, et al. "Superabsorbent cryogels decorated with silver nanoparticles as a novel water technology for point-of-use disinfection." Environmental science & technology 47.16 (2013): 9363-9371.

    Zhang, Mingliang, et al. "Magnetically ultraresponsive nanoscavengers for next-generation water purification systems." Nature communications 4 (2013): 1866.

    Liu, Chong, et al. "Conducting nanosponge electroporation for affordable and high-efficiency disinfection of bacteria and viruses in water." Nano letters 13.9 (2013): 4288-4293.
13. Nano-adsorbents.

    Kanno, Cynthia M., et al. "Novel apatite-based sorbent for defluoridation: synthesis and sorption characteristics of nano-micro-crystalline hydroxyapatite-coated-limestone." Environmental science & technology 48.10 (2014): 5798-5807.

    Zhang, Qingrui, et al. "Sorption enhancement of lead ions from water by surface charged polystyrene-supported nano-zirconium oxide composites." Environmental science & technology 47.12 (2013): 6536-6544.
14. Nanoparticles as reductants, oxidants, and catalysts.

    Zhuang, Yuan, et al. "Dehalogenation of polybrominated diphenyl ethers and polychlorinated biphenyl by bimetallic, impregnated, and nanoscale zerovalent iron." Environmental science & technology 45.11 (2011): 4896-4903.

    Wang, Yin, et al. "Palladium nanoparticles encapsulated in core–shell silica: A structured hydrogenation catalyst with enhanced activity for reduction of oxyanion water pollutants." ACS Catalysis 4.10 (2014): 3551-3559.

    Ardo, Sandy G., et al. "Oxidative degradation of nalidixic acid by nano-magnetite via Fe2+/O2-mediated reactions." Environmental science & technology 49.7 (2015): 4506-4514.
15. Photoactive nanomaterials.

    Lee, Siew Siang, et al. "Novel-structured electrospun TiO 2/CuO composite nanofibers for high efficient photocatalytic cogeneration of clean water and energy from dye wastewater." Water research 47.12 (2013): 4059-4073.

    Liu, Chong, et al. "Rapid water disinfection using vertically aligned MoS2 nanofilms and visible light." Nature nanotechnology 11.12 (2016): 1098-1104.
16. Nano-enhanced bioelectrochemical systems.

    Xie, Xing, et al. "Three-dimensional carbon nanotube− textile anode for high-performance microbial fuel cells." Nano Letters 11.1 (2010): 291-296.

    Xie, Xing, et al. "Enhancing the nanomaterial bio-interface by addition of mesoscale secondary features: crinkling of carbon nanotube films to create subcellular ridges." ACS Nano 8.12 (2014): 11958-11965.
17. Air purification.

    Liu, Chong, et al. "Transparent air filter for high-efficiency PM2. 5 capture." Nature communications 6 (2015): 6205.

    Valverde, J. M., A. Perejon, and L. A. Perez-Maqueda. "Enhancement of fast CO_2 capture by a nano-SiO2/CaO composite at Ca-looping conditions." Environmental science & technology 46.11 (2012): 6401-6408.

    Li, Hailong, et al. "Development of nano-sulfide sorbent for efficient removal of elemental mercury from coal combustion fuel gas." Environmental science & technology 50.17 (2016): 9551-9557.

    Zhao, Zaiwang, et al. "Noble metal-free Bi nanoparticles supported on TiO_2 with plasmon-enhanced visible light photocatalytic air purification." Environmental Science: Nano 3.6 (2016): 1306-1317.
18. Sensors. Book 3, Chapter 10.

    Vikesland, Peter J., and Krista R. Wigginton. "Nanomaterial enabled biosensors for pathogen monitoring-a review." Environmental science & technology 44.10 (2010): 3656-3669.

    Ramesh, G. V., and T. P. Radhakrishnan. "A universal sensor for mercury (Hg, HgI, HgII) based on silver nanoparticle-embedded polymer thin film." ACS applied materials & interfaces 3.4 (2011): 988-994.

    Cui, Yi, et al. "Nanowire nanosensors for highly sensitive and selective detection of biological and chemical species." Science 293.5533 (2001): 1289-1292.

    Xie, Xing, et al. "“Nanofiltration” Enabled by Super-Absorbent Polymer Beads for Concentrating Microorganisms in Water Samples." Scientific reports 6 (2016): 20516.