CEE 8813 Environmental Nanotechnology

Semester: Spring, 2018 **Time:** MWF 10:10 – 11:00 AM **Location:** Molecular Sciences & Engr. 1222

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

Office hour: F 11:00 AM – noon; or by appointment. After class is often 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/

Required textbook: None. Currently, no single textbook adequately covers the material in this course.

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.

Grading: Quizzes, 5% (Bonus); Homework, 20%; Exams, 40%; Final project, 40%.

Grading Scale: A, 90-100%; B, 80-89%; C, 70-79%; D, 60-69%.

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

Course Guidelines & Policies:

Quizzes (5%): Two in-class closed book/notes quizzes (5-min) will be given on *unannounced* dates in the beginning of the class. Each quiz accounts for 2.5 bonus points towards final grades.

Homework (20%): Four homework sets (5 points each) will be assigned. The homework should be handed in before the class starts on the day they are due unless specified otherwise. For late submissions, 1 out of 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.

Exams (40%): Two in-class closed book/notes exams will be given. Each exam accounts for 20 points towards final grades. The instructor may provide necessary equations. You may need a calculator. Calculators must not have any communication capability: you cannot use a mobile phone as a calculator during exams. 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 (40%): 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 March 26th, 2017 and March 26th, 2018); 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 **March 26, 2018**. 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). The presentation will be 15 min long (12 min of presentation + 3 min for questions). Slides should be prepared in PowerPoint and submitted for grading purposes. The presentations will be graded by both the instructor and class peers. To reduce the transitional time between presentations, the presentation file must be uploaded to the course website at least 60 min before the class begins.

Final paper (20%): 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 (**April 23, 2018**). 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 (around March 1st, 2018) 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.

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

Date	Lecture	Reading	Assignment
1/10	Introduction	1	
1/12	Basics of material chemistry (1)		HW1 Assigned
1/15	No class		
1/17	No class		
1/19	Basics of material chemistry (2)		
1/22	Classification and properties (1)		
1/24	Classification and properties (2)	2	
1/26	Classification and properties (3)		
1/29	Synthesis and fabrication (1)	3,4	HW1 Due; HW2 Assigned
1/31	Synthesis and fabrication (2)	5	
2/2	Dispersion and manipulation	6	
2/5	Overview and Optical microscope	7	HW2 Due
2/7	XRD	8	HW3 Assigned
2/9	TEM	9	
2/12	**Exam 1**		
2/14	SEM and FIB	10	
2/16	EDS, XPS, and AES	11,12	
2/19	XAS and DLS		HW3 Due; HW4 Assigned
2/21	SPM and Summary	13	
2/23	**IEN Tour**		
2/26	Overview and Application-Nano-adsorbents (1)	14	HW4 Due
2/28	Application-Nano-adsorbents (2)	15	
3/2	Application-Nano-adsorbents (Guest)		
3/5	**Exam 2**		
3/7	Application-Nano-structured membranes (Guest)		
3/9	Application-Disinfection (1)	16	
3/12	Application-Disinfection (2)		
3/14	Application-Reductants, oxidants, and catalysts	17	
3/16	Application-Photoactive nanomaterials		
3/19, 3/21, 3/23: Spring break			
3/26	Application-Electroactive nanomaterials (Guest)	18	**White Paper Due**
3/28	Application-Bioelectrochemical systems	19	
3/30	Application-Air purification	20	
4/2	Application-Environmental sensors (1)	21	
4/4	Application-Environmental sensors (2)		
4/4, 4/6, 4/9, 4/11, 4/13, 4/15, 4/18, 4/20: Student presentations (3 students each time, 24 students in total)			
4/23	Implication and Summary	22	**Final Paper Due**

Reading:

1. Richard Feynman - There's Plenty of Room at the Bottom
2. Surface energy. Book 1, Chapter 2.2.
3. Synthesis and fabrication, 0D nanomaterials. Book1, Chapter 3.1, 3.2.1, 3.2.2, 3.3, 3.4.
4. Synthesis and fabrication, 1D nanomaterials. Book1, Chapter 4.1, 4.2.1.1, 4.2.2.1, 4.2.2.3
5. Synthesis and fabrication, 2D nanomaterials. Book1, Chapter 5.1, 5.2
6. Dispersion of nanomaterials. Book 1, Chapter 2.4.
7. Optical microscope. Book 2, Chapter 1.
8. X-ray diffraction. Book 2, Chapter 2.
9. TEM. Book 2, Chapter 3.
10. SEM. Book 2, Chapter 4.
11. EDS. Book 2, Chapter 6.
12. XPS and AES. Book 2, Chapter 7.
13. SPM. Book 2, Chapter 5.
14. Applications overview.

    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.
15. 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.
16. 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.
17. 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.

18. 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.

19. 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. "Nano-structured textiles as high-performance aqueous cathodes for microbial fuel cells." Energy & Environmental Science 4.4 (2011): 1293-1297.

    Xie, Xing, et al. "Microbial battery for efficient energy recovery." Proceedings of the National Academy of Sciences 110.40 (2013): 15925-15930.

20. 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.

21. 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.

22. Implication.

    Brame, Jonathon A., et al. "EHS Testing of Products Containing Nanomaterials: What is Nano Release?." (2015): 11245-11246.

    Auffan, Mélanie, et al. "Towards a definition of inorganic nanoparticles from an environmental, health and safety perspective." *Nature nanotechnology* 4.10 (2009): 634-641.

    Lowry, Gregory V., et al. "Transformations of nanomaterials in the environment." (2012): 6893-6899.