



CHEM 455

Chemical Nanotechnology

Units: 4

Term—Day—Time: Spring—MWF—12:00-12:50

Location: Zoom, link through Blackboard

Start date: January 15, 2021

End date: May 12, 2021

Instructor: Prof. Michael S. Inkpen

Office: Zoom (normally LJS 250)

Office Hours: By appointment.

Contact Info: inkpen@usc.edu, +1 (213) 821-1910. Please expect a response to emails/calls within 2 working days.

Teaching Assistant: N/A

IT Help: N/A, use Blackboard.

Catalogue Description: Studies in the fundamental principles governing nanoscale materials. Structure and chemical bonding, preparative methods, and electrical, optical and magnetic properties of nanoscale materials and applications.

Course Description

CHEM 455 is an upper-division undergraduate course in Chemical Nanotechnology. The intent of this course is to describe how properties change when reducing the size of solids to the nanoscale, and explain, using concepts of solid-state chemistry and physics, why these changes occur. Representative properties that may be covered include optoelectronic properties, magnetic properties, dielectric properties, and superconductivity.

Learning Objectives

By the end of this course you should be able to:

- Explain why the properties of solids change upon reducing in size to the nanometer scale.
- Evaluate the significance of recently published research focused at the nanoscale.

By demonstrating that you can:

- Define and contrast common solid-state structure types.
- Apply your knowledge of these structures, their defects, and how these change with temperature and composition, to interpret the physiochemical properties of different compounds.
- Use theories of electrical conduction to interpret the optoelectronic properties of model and real-world materials, and evaluate their utility in different technological applications.

Please note that these lists are not comprehensive and subject to change.

Prerequisite(s): CHEM 322aL or CHEM 325aL

Co-Requisite(s): N/A

Concurrent Enrollment: N/A

Recommended Preparation: N/A

Course Notes

Letter Grades will be assigned based on the assignments described below. Copies of lecture slides will be emailed to all registered participants. Poll Everywhere will be used, for example, to test understanding of key class concepts. Note that Poll Everywhere questions are not graded on right or wrong answers, only participation.

Technological Proficiency and Hardware/Software Required

N/A

Required Readings and Supplementary Materials

Required Texts: West, Solid State Chemistry and its Applications (2nd Ed.)

Supplemental Materials: Supplemental reading materials will be drawn from various sources, including the following textbooks:

Owens & Poole, The Physics and Chemistry of Nanosolids

Kittel, Introduction to Solid State Physics

Description and Assessment of Assignments

Problem Sets comprise 5-6 questions to be completed independently outside of class time. They will be posted approximately 10 days ahead of the submission deadline.

The Solid-State Structure Report is normally based on a Field Trip to the Natural History Museum during the regular class time. This year, we will conduct a virtual version of this by browsing Mineral and Gem exhibitions online (e.g., at the Smithsonian, <https://www.si.edu/spotlight/geogallery>). Every student will independently pick 3 minerals and answer questions on them outside of class time. Questions and additional parameters for this assignment will be posted 2 weeks ahead of the submission deadline.

The Critical Review is an independently written scientific essay that will test your understanding of course material and critical writing skills. Additional parameters for this assignment will be posted 4 weeks ahead of the submission deadline.

Final Exam: This is a two-hour closed book written examination where you will be expected to answer questions based on the class material and reading assignments.

Pop Quizzes will be periodically assigned for completion during class. These comprise approximately 10 short answer questions based on recent class material and reading assignments.

As noted above, Poll Anywhere Questions will be used periodically to encourage discussion and test understanding of key class concepts. Polls are graded only on participation, not on right or wrong answers.

Grading Breakdown

| Assessment Tool (assignments) | Due | % of Grade |
|-------------------------------|--|------------|
| 3 x Problem Sets | Tentatively due February 10, March 10, April 9 | 10 |
| Solid-State Structure Report* | February 24 | 10 |
| Critical Review | May 5 | 30 |
| Final Exam | May 12, 11 am-1 pm | 35 |
| Pop Quizzes | Given periodically throughout semester | 10 |
| Poll Anywhere Questions | Given periodically throughout semester | 5 |
| TOTAL | | 100 |

* Based on a virtual tour of Mineral and Gem exhibitions online.

Assignment Submission Policy

Assignments should be submitted electronically (through email/Blackboard/TurnItIn as directed) by 5 pm on the specified date.

Grading Timeline

Grading and feedback for all assessments will be provided within one week of submission.

Additional Policies

There will be absolutely no make ups, extra time, or special arrangements given for any exams, problem sets, or projects. Students are expected to attend all lectures and participate in class discussions, unless an pre-arranged agreement has been made due to unusual circumstances (e.g., course conflict). The use of laptops and other electronic devices in class for class-related web searches or calculations is encouraged.

University Holidays (no classes)

January 18th – Martin Luther King Day (Monday)

February 15th – President's Day (Monday)

March 12th – Wellness Day (Friday)

April 7th – Wellness Day (Wednesday)

April 30th – Wellness Day (Friday)

Course Schedule: A Weekly Breakdown

| | Topics/Daily Activities | Readings/Preparation | Deliverables |
|--------------------------------|--|--|------------------------------|
| Week 1-2 (3 classes) | <u>Nano 101</u> What is it, what is so special about it, benefits and applications, timeline. | [1] Finish watching 'There's Plenty of Room at the Bottom' speech by Richard Feynman. [2] "Introduction to Nanoscience", Chapter 1 from Stuart Lindsay | |
| Week 3 (3 classes) | <u>Crystal Structures and Crystal Chemistry</u> Description of crystal systems, close packed structures, tetrahedral and octahedral sites. | West, pages 1-3, 18-30 (sections 1.1, 1.9 to 1.15.3.4) | |
| Week 4 (3 classes) | <u>Crystal Structures and Crystal Chemistry (cont.)</u> Space filling polyhedra, important structure types. | West, pages 33-70 (sections 1.16-1.17.9) | |
| Week 5 (3 classes) | <u>Ionic Bonding</u> Trends, rules to interpret structure and properties, thermodynamic considerations, nanoparticles and surfaces. | [1] West, pages 126-143 (sections 3.2.1-3.2.7) [2] <i>Crystal/Ligand Field Theory</i> , Atkins Extract [3] <i>Nanocrystals and Surfaces</i> , Owens and Poole Extract | |
| Week 6 (3 classes) | <u>Crystal Defects</u> Point defects, solid solutions, extended defects, effect of nanosizing. | [1] West, pages 83-104 (sections 2.1-2.3.3) [2] <i>Cohesive Energy of NanoSolids</i> , Owens and Poole Extract [3] <i>Nanocrystals and Defects</i> , Owens and Poole Extract | Problem Set 1 |
| Week 7 (2 classes) | <u>Phase diagrams</u> Gibbs phase rule, the system Fe-C, interpreting phase diagrams. | West, pages 325-340 (sections 7.1-7.3.2) | |
| Week 8 (3 classes) | <u>Phase diagrams (cont.)</u> Different types of phase transition, metastability, ferroelectrics. | | Solid-State Structure Report |
| Week 9 (3 classes) | <u>Covalent, Metallic, Molecular Solids</u> Bonding, introduction of 'band' concept. | West, pages 125-6, 161-173, 173-186, 359-361 (sections 3.1, 3.3, 3.4, 8.1) | |
| Week 10 (2 classes) | <u>Models of electrical conductivity</u> Drude, free electron model, nearly-free electron model. | <i>Drude and Free Electron Model</i> , Turton Extract | Problem Set 2 |
| Week 11 (3 classes) | <u>Band theory</u> K-space, dispersion, density of states, 1D, 2D, 3D systems, band diagrams. | [1] "How Chemistry and Physics Meet in the Solid State", R. Hoffmann, <i>Angew Chem Int. Ed.</i> , 26 , 1987, 846-854. [2] <i>Reciprocal Space</i> , Owens and Poole Extract | |

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| Week 12 (3 classes) | <u>Electrical Conductivity (cont.)</u> Fermi level, important metal, insulator systems. | | |
| Week 13 (2 classes) | <u>Bulk Semiconductors</u> Important systems, doping, applications. | | Problem Set 3 |
| Week 14 (3 classes) | <u>Nanoscale Metals and Semiconductors</u> Band gap estimation, impact of nanomaterial dimensions on density of states, nanoparticles. | | |
| Week 15 (3 classes) | <u>Quantum confinement</u> Excitons, Brus equation, introduction to quantum dots. | <i>Excitons, Owens and Poole Extract</i> | |
| Week 16 (2 classes) | <u>Nanoscale Materials</u> Preparation, properties, applications. | | |
| Week 17-18 (0 classes) | N/A | N/A | Critical Review Final Exam |

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, “Behavior Violating University Standards” policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press “0” after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity | Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

Campus Support & Intervention - (213) 821-4710

campussupport.usc.edu

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101

diversity.usc.edu

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

dps.usc.edu, emergency.usc.edu

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call

dps.usc.edu

Non-emergency assistance or information.