Introduction to Surface Physics

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Office Hours: Tuesday-Thursday: 2:00-3:00 pm or just stop by.

Course description

This course will offer a comprehensive introduction to solid surfaces and interfaces focusing mainly on essential concepts. A thorough understanding of the physics and chemistry of surfaces and interfaces is important in fields such as nanoelectronics, catalysis, energy storage and conversion, sensors and corrosion. Topics include:

surface crystallography and structure including reconstruction, band structure and vibrations

experimental techniques: LEED, AFM, AES, XPS, UPS, IR, EELS, STM

chemisorption and physisorption

thermodynamics and kinetics of surface processes

thin film growth and etching

self assembly

plasmonics

Learning Objectives:

After successfully completing this class, you should be able to:

- Understand how surfaces are different from bulk solids

- Understand what are the basic processes and mechanisms for species adsorbing, diffusing and reacting on surfaces.
- Understand the basic physics behind the most common surface characterization techniques.

Textbooks

There is not a single textbook that covers satisfactorily all the material we will explore in this class. I will follow loosely the book "Surface Science: An Introduction" by K Oura. You can purchase a used copy for ~$100 from the bookstore. The library copy has been placed on reserve so it should be available to you. I will post my lecture notes on Blackboard before each class along with research articles when appropriate. Other useful references that will be used in the course of this class are:

- *K. W. Kolasinski "Surface Science: Foundations of Catalysis and Nanoscience" 2nd edition*
- *A. Zangwill, Physics at Surfaces, Cambridge University Press, (1988).*
- *Lueth, Solid Surfaces, interfaces and Thin films, Springer 2001*
- *M. Prutton, Introduction to surface Physics, Oxford Science publication (1994)*
- *G. A. Somojai, Introduction to Surface Chemistry and Catalysis, Wiley Interscience, New York (1994).*
- *Desjonqueres, Spanjaard Concepts of surface science, 2nd edit., Ed. Springer (1996)*
- *D. P. Woodruff and T. A, Delchar, Modern techniques of surface science, Cambridge Univ.(1994)*
- *John C. Vickerman, Surface Analysis-The principal techniques, Wiley (2002)*
- *Elaine M. McCash, Surface Chemistry, Oxford (2004)*
- *C. Kittel, Introduction to Solid State Physics, Wiley (2005)*
- *Butt, Graf, and Kappl Physics and Chemistry of Interfaces 2nd edition Wiley (2006)*

Useful websites:

- *An Introduction to surface Chemistry*
  Dr. Roger Nix, Department of Chemistry, Queen Mary & Westfield College, University of London, UK

  http://www.chem.qmul.ac.uk/surfaces/scc/
- *3D Solid State Crystal models*

  http://www.ibiblio.org/e-notes/Cryst/Cryst.htm
- *SURFACE EXPLORER*

  http://surfexp.fhi-berlin.mpg.de/
- *Richard Feynman "There's Plenty of Room at the Bottom"*

  http://www.its.caltech.edu/~feynman/plenty.html

- *IMB's STM Image Gallery*
  http://researcher.watson.ibm.com/researcher/view_group_subpage.php?id=4253

Course grade

- Graded problem sets (4-6 problem sets) 30%
- One final exam 25% (TBD)
- Final term paper 30%
- Final oral presentation 15%

In principle, everyone can get an A. I will not curve the grades but may change (lower) the limits depending on the difficulty of the exams and homework

score > 90 : A

score > 80: B

score > 70: C

score > 60: D

score < 60 : F

Course management

I will use ***blackboard*** to post course announcements, reading assignments and homework assignments, and post grades. Please do not use the digital dropbox. Send me an email instead.

Course policies

Term Paper and Oral Presentation:

- Term paper suggested length 15 pages, double spaced, with a minimum of 15 references. The paper should include a description of the problem, its scientific significance and its current state.
- Oral Presentation: 30 minutes, using viewgraphs and figures, followed by questions from other students, typically 5-10 minutes.

Topic for term paper and oral (same topic for both):

A list of possible topics will be within the first three weeks of the class. You should not pick a topic directly related to your research.

Evaluation criteria for the paper and presentation

1. The selected topic is relevant to the class
2. Enough background materials was covered
3. The significance of the topic was clear
4. The sequence of the material was logical
5. Adequate references
6. Good examples were used to illustrate key points
7. The material was of appropriate depth/level The quality of the overheads was high
8. The speaker spoke clearly, was well-paced and used appropriate volume
9. The speaker understood the subject material presented
10. The speaker was able to answer the questions thoroughly

Timeline:

by Mar 1: Email instructor topics of choice ranked 1-3

Mar 3: Topics discussed in class. Possible revisions discussed.

Mar 31: First draft of paper to instructor

April 5: Instructor will give feedback on drafts, with suggested modifications

May 7: Final draft to instructor

May 9-16: In-class presentations

Homework

Homework should be turned in at the beginning of the class period on the due date. Late homework will not be accepted under any circumstances. You should turn in well organized and neat solutions not your scrap paper. **Equations and results that are subsequently used and/or referred to should be numbered. Final result should be placed in a box. I WILL NOT GRADE MESSY HOMEWORK.**

I will assign about 6-8 homework sets in the course of the semester. It is to your advantage to do all the homework problems and though tempting **not to use** the solutions that are available through various sources. This is the only way to develop your problem solving skills and be successful in the class. You can drop the lowest homework score. This should take care of any illness, job and family related emergencies or hangover issues.

I will grade homework for completeness and accuracy. In general, each part of a problem will be worth 3 points and the points will be assigned as follows:

3: complete solution and correct results is reached

2: mostly correct solution: start with the correct assumption but did not reach the correct result;

1: Valiant efforts but there are issues with the logic and understanding

0: had no clue but thought I should write anything related even tangentially

I will not provide complete solutions to the homework as I would like to use the same problems in the future iterations of the course.

Cell phone use:

Please turn off your cell phone as soon as you get in class and keep your phone in your pocket. You are welcome not to come to class; I will not hold it against you. But when in class you are not to check email, text or post on Facebook.

Exams

There is going to be one cumulative final exam. Exam solutions should be neat and organized, including explanations of what and why you are doing things (think **partial credit**!!!). Equations and results that are subsequently used and/or referred to should be numbered. **I will not grade sloppy solutions.**

All the exams are closed book. You will be given a formula sheet for each exam. You can only use a standard non-programmable calculator. The use of PDA's, portable CD players, ipod devices etc. is not allowed. Using such a device will be treated as cheating. Do not use any scrap paper of your own. You must turn off your cell phone during class and the exams. If you are caught using a cell phone during an exam you will asked to turn in your paper.

Incompletes

Please read carefully the catalog statement on acceptable grounds for incompletes. In this course, incompletes are given only if you miss the final exam due to a documented medical or legal problem or for a death in your immediate family. According to the catalog you must be doing "qualitatively satisfactory" work in order to qualify for an incomplete. For this course it means that your class averages is at least a B.

Academic Integrity

By enrolling in this course, each student assumes the responsibilities of an active participant in UMBC's scholarly community in which everyone's academic work and behavior are held to the highest standards of honesty. Cheating, fabrication, plagiarism, and helping others to commit these

acts are all forms of academic dishonesty, and they are wrong. Academic misconduct could result in disciplinary action that may include, but is not limited to, suspension or dismissal. To read the full Student Academic Conduct Policy, consult the UMBC Student Handbook, the Faculty Handbook, or the UMBC Policies section of the UMBC Director.

A list of possible topics:

1. Silica nanoformulations for biomedical applications
2. Water splitting reactions and their applications
3. Ion exchange membranes: New developments and applications Dye sensitized solar cells
4. Graphene formation, structure and surface properties
5. MoS_2 formation, structure and properties
6. Electronic properties of carbon nanotubes and their use in devices
7. Chemoresistive Gas Sensors
8. Surface science studies of fuel cell electrocatalysts
9. Inorganic nanotubes and their applications
10. Organic semiconductors and their use in OTFTs and OLEDs
11. Surface physics of semiconducting nanowires
12. Surface science of micro- and nano-device fabrication and technology.
13. Photonic crystals and inverse opal structures
14. Template based formation of nanostructures
15. Use of plasmas in thin film formation
16. SiC: deposition, properties and applications
17. TiO_2 photocatalysis and related surface phenomena
18. Directed growth and assembly of nanotubes/nanowires
19. Surface Science and the Atomic-Scale Origins of Friction
20. Organic/inorganic hybrid materials
21. Current state of knowledge in Li-ion batteries
22. Thermoelectric or the Peltier–Seebeck effect
23. Metamaterials and their applications
24. Supercritical fluids and their use in thin film deposition
25. Applications of surface analytical techniques in Earth Sciences
26. Nanocatalysis: size- and shape-dependent chemisorption and catalytic reactivity