Physics 9826: Surface Science

Winter 2013
Lectures: Monday, 10:30 am – 12:30 pm P&A B 26
Wednesday, 10:30am-11:30am P&A B 26

Office hours: by appointment, PAB 231

Web-site: http://www.physics.uwo.ca/~lgonchar/courses/p9826/index.shtml
Marks: https://owl.uwo.ca

Course Instructor
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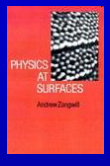
Guest Lectures:
Dr. François Lagugné-Labarthet (vibrational spectroscopies)
and others (TBC)

Textbooks



Several textbooks will be used plus additional reading will be posted on the web-site

First three books are on 2 hours reserve in the library:

1. A. Zangwill, *Physics at Surfaces*. Cambridge University Press: New York, 1988; 472 p.

2. Kurt W. Kolasinski, *Surface Science: Foundations of Catalysis and Nanoscience* 2nd ed.; Wiley & Sons: Hoboken, NJ, 2008; 500 p.

3. D.P. Woodruff, T.A. Delchar, *Modern Techniques of Surface Science*. 2nd ed.; Cambridge University Press: New York, 1994.

4. John C. Vickerman, *Surface Analysis - The Principal Techniques*. John Wiley: New York, 1997; 474 p.

Additional Resources

Reference Books and Materials :

5. John T. Yates, *Experimental innovations in surface science : a guide to practical laboratory methods and instruments*. Springer: New York, 1998; p 904
6. G. Attard, C. Barnes, *Surfaces* Oxford University Press: 1998; p 96.
7. D. Briggs, M.P. Seah, *Practical Surface Analysis*. 1991; Vol. 1.
8. Harald Ibach, *Physics of Surface and Interfaces*. Springer: Berlin, 2006.
9. Ch. Kittel, *Introduction to Solid State Physics*. John Wiley: New York, 1996.
10. H. Luth, *Solid surfaces, interfaces and thin films* Springer: Berlin ; New York, 2001; p 559.
11. R.I. Masel, *Principles of adsorption and reaction on solid surfaces*. Wiley: New York, 1996.
12. S. Roy Morrison, *The Chemical Physics of Surfaces*. Plenum Press: New York, 1977.
13. G.A. Somorjai, *Chemistry in two dimensions : surfaces*. Cornell Univ. Press: Ithaca 1881; p 575.

Some useful web sites are:

- http://www.phys.au.dk/~philip/q1_05/surflec/surflec.html
- http://venables.asu.edu/grad/lectures.html
- more later…

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Assignments and Marks

- Course requirements will include

2 homework assignments (each of them cares 15% of the grade)

2 presentations/discussion (each - 5% of the grade)

Midterm exam (late February – early March, 25 %)

Final exam (April, 35% of the grade)

Homework assignments, presentation topics and their dates will be posted on the web site and communicated to you in the class

- Assignments must be turned in at the requested day before 6pm

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Timeline…

Part I:

- Thermodynamics of the surfaces, equilibrium crystal shape
- Bulk and surface structure, relaxations, reconstructions
- Introduction to electronic interactions with the surface
- Physics of ultrahigh vacuum
- Work function; electron emission
- Thermodynamics and kinetics for adsorption, diffusion and desorption
- Nucleation and growth of films and nanostructures
- Photoemission spectroscopy

Part II:

Linear and non-linear spectroscopies

Physics of ion-surface interactions; ion scattering, recoiling and sputtering

Scanning probe microscopies

Synchrotron-radiation-based spectroscopies

January

HWA #1

Presentation #1

February

Presentation #1

Midterm Exam

March

Presentation #1

HWA #2

April

Presentation #2

Final Exam

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Presentation #1: review of important concepts

- **Motivation**: discuss some important and/or difficult concepts in the classroom

- **Format**: 5 minute presentation followed by 5-10 minute discussion. Use ≤ 5 slides, you are encouraged to use the board. You will be evaluated based on your presentation and contributions to the discussion (equations, comments, etc.)

- **Examples**:

1. Ewalds construction: how does it work, examples
2. Backbonding: definition, examples, when it is important, how it can be evaluated?
3. What determine reactivity of metal?
4. Ostwald ripening: definition, examples
5. Mechanism of silicon etching in HF

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Presentation #2: case study

- **Motivation**: we will try to apply our knowledge of surface characterization techniques to real systems.

- You will be given a hypothetical system to analyze.
- You will need to propose a set of experimental techniques to solve the problem and propose a possible outcome

- **Format**: 5 minute presentation followed by ~5 minute discussion. Use ≤ 2-3 slides, you are encouraged to use the board. You will be evaluated based on your presentation and contributions to the discussion (equations, comments, etc.)

  More details will be provided later…

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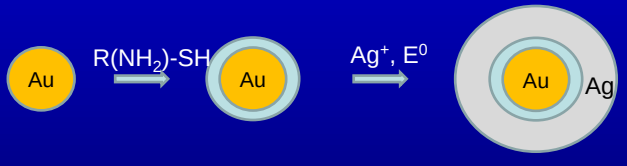
Presentation #2: examples

- **Examples 1:**

Smith and co-workers used selective adsorption and electrochemistry to build core-shell structures with gold nanoparticles (Au-NP). They started with ~ 5nm in diameter Au nanoparticles, functionalized them with thiol molecules ($R(NH_2)$-SH, $R=C_{10}$-C_{14}) followed by reduction in Ag^+ solution to form continuous Ag shell



Assuming that both thiol-covered Au-NP and Ag-thiol-Ag core-shell particles can be deposited on the surface by spin coating, suggest a set of surface sensitive characterization techniques

(1) to prove that core-shell system was formed;

(2) to estimate the thickness of Ag layer

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Presentation #2: examples

- **Examples 2**:

Postdoctoral fellow Bob oxidizes Al film (~ 1μm thick) deposited on top ITO/glass for optical sensor applications.

First he tries Al oxidation in oxygen (O_2) at high temperature (~300°C), than he decides to compare it with electrochemical oxidation in solution of H_2SO_4.

(1) Propose several (at least 3) characterization techniques to compare oxidation rate in oxygen to the electrochemical one.

(2) What oxidation route is referable, assuming that Al_2O_3 layer at least 200nm thick need to be produced?

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Historical Sketch

•"The essence of a thing is hidden in its interior, while the (misleading) sensate qualities are caused by the surface"
- Democritos

1833 – Michael Faradey, reaction of H_2+O_2 in presence of Pt below combustion temperature ⇒ catalytic effects

1874 – Karl Braun, derivation from Ohm's law in the conduction through a sandwich of Cu and FeS ⇒ thin layer at the interface, rectification

1877 – J.W. Gibbs ⇒ thermodynamics of the surfaces

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Historical Sketch – 20th century

1906 – Irving Langmuir, dissociation of various gases on Pt; later: adsorption chemical bind, accommodation coefficient and adsorption precursors

1920th – Langmuir and Kate Blodgett explored 2D monomolecular films

1932 – I. Langmuir receives NP for "outstanding discoveries and inventions within the field of surface chemistry"

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Historical Sketch

- "God made solids, but surfaces were the work of the devil!"
  - Wolfgang Pauli

1921 - Einstein, NP fro his explanation of photoelectric effect

1937 – C. Davisson and L. Germer receive NP for "outstanding electron diffraction phenomena"

1956 – Shockley, Bardeen, Brattain for invention of a transistor

1965 – Grover and Goldstein marked a distinction between " real" surface and "clean" surface

1960th – electron spectroscopy and Auger spectroscopy

1986 - G. Binnig, H. Rohrer (IBM), Scanning Tunneling Microscopy

2007 - Gerhard Ertl, NP in Chemistry, Fritz-Haber-Institut, Berlin, Germany "*for his studies of chemical processes on solid surfaces*"

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Aspects of Solid Surfaces

- Course objectives: to be introduced to the "science" part of surface related structures and phenomena

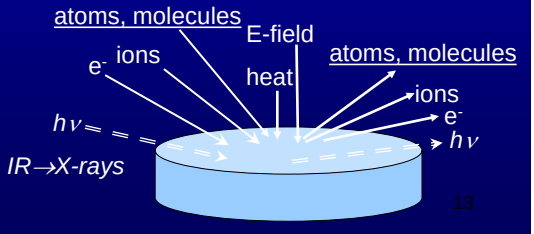
Surface Properties

- Structure
- Chemical composition
- Bonding properties
- Kinetics (adsorption, diffusion, desorption)
- Dynamics of surface processes

Applications

- Semiconductor devices
- Catalysis
- Friction and lubrication (tribology)
- Sensors
- Electrochemistry

Probing Surface Properties



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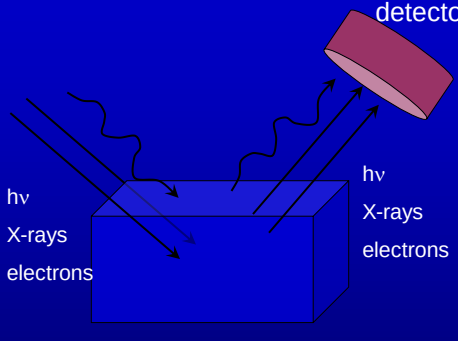
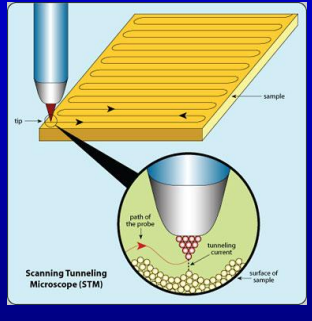
Probes of materials structure and properties





- information about **bulk** (*average*)
- X-ray diffraction (X-rays in and out)
- Optical microscopy (light in and out)
- *local* information about **surface**
- Scanning tunneling microscopy (STM)
- Atomic Force microscopy (AFM)
- Low energy electron microscopy (LEEM)

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