EE213. NANO-CHARACTERIZATION OF MATERIALS
Spring 2012
Tues/Thurs 12:00-1:45pm: Baskin 156/Silicon Valley Campus, 303
Instructor: M. Isaacson, msi@soe.ucsc.edu
EE213. Microscopic Nanocharacterization of Materials
Spring 2012

Miscellaneous Information

Tuesdays/Thursdays 12:00 -1:45 pm
Baskin 156/UCSC Silicon Valley Campus 303, Santa Clara

The aim of this course is to familiarize you with many of the modern methods used to characterize materials on a scale of nanometers to micrometers. We want you to learn some of the physical principles of the methods as well as to understand their regions of applicability and their limitations. Moreover, at the end of the quarter, it is the hope that you will be able to understand how to use these methods in as quantitative a fashion as possible.
Because of the wide variety of methods being discussed here, there is not one book that suffices. The “text” you will be using will be the lecture notes, which will be available after each lecture. The text will be published sometime in 2013 by Cambridge University Press. In this course I will be referring to articles in the literature, many more than you could ever hope to read in one quarter, and will expect you to do some literature searching on your own. When possible I will try to refer to the original article, since often that is more comprehensible than those that come after.

There will not be an exam in this course, but rather a series of short homework sets and a final short paper at the end of the quarter (the topic to be assigned later). The homework is aimed at giving you some inkling of how to use the techniques studied and give you an idea of what can be involved in proper quantitation.
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Miscellaneous Information

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Class Web page:
https://courses.soe.ucsc.edu/courses/ee213/Spring12/01/pages/ee213
Microscopic Nano-Characterization of Materials:
The Physics and Methodology of Materials Characterization from Volumes Less than a Cubic Micrometer
Tentative Course Outline/ Spring 2012

Week 1: Introduction: What is Micro/Nano Characterization?

Week 2: Electron Beam Induced Excitation Methods
A. Reflection Scanning Electron Microscopy
B. Auger Electron Microscopy/Spectroscopy
C. Electron Beam Induced X-Ray Analysis
D. Electron Energy Loss Spectroscopy
E. Transmission Electron Microscopy
   a. Scanning Transmission Electron Microscopy (STEM)
   b. Conventional Transmission Electron Microscopy (TEM)
   c. Energy Filtered Electron Microscopy
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Week 4: Ion Beam Induced Excitation Methods
A. Particle Induced X-Ray Emission (PIXE)
B. Rutherford Backscattering Spectroscopy (RBS)
C. Secondary Ion Mass Spectrometry (SIMS)
D. Ion Induced Secondary Emission Microscopy
E. Helium Ion Microscopy

Week 6: X-Ray and Photon Beam Induced Excitation Methods
A. X-Ray Microscopy/Microprobe
B. Photoelectron Emission Microscopy/Spectroscopy
C. Confocal Optical Microscopy
D. Super Resolution Optical Microscopy
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Week 8: Lenseless Microscopy/Spectroscopy Methods
A. Point Projection Microscopies
   a. X-Rays
   b. Field Emission/Field Ionization
   c. Atom Probe Techniques
B. Scanned Tip Microscopies
   a. Scanning Tunneling Microscopy
   b. Atomic Force Microscopy
   c. Near Field Optical Microscopy
   d. Scanning Conductance Microscopy

Week 10: Comparison of the Various Characterization Methods
There is nothing more deceiving than an image unless you know the rules of translation.

Penrose triangle

Kanizsa Triangle
Surface of Moon Rock from Apollo 11 Mission
Using Field Emission SEM, (SE image)

M. Isaacson, D. Johnson and A.V. Crewe, 1969
What does the secondary electron image in the SEM mean?"
HOW WE VIEW THE WORLD?

<table>
<thead>
<tr>
<th>SENSE</th>
<th>PROBE</th>
<th>MICROSCOPE</th>
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<tbody>
<tr>
<td><em>sight</em></td>
<td>electromagnetic radiation</td>
<td>light, X-ray, ion, STM</td>
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<td><em>sound</em></td>
<td>acoustical radiation</td>
<td>acoustical, stethoscope</td>
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<td><em>touch</em></td>
<td>mechanical, atomic forces</td>
<td>Stylus, AFM</td>
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<td><em>smell</em></td>
<td>chemical</td>
<td>Ion conductance, Nano chemical sensor</td>
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MICROGRAPHIA:
OR SOME
Physiological Descriptions
OF
MINUTE BODIES
MADE BY
MAGNIFYING GLASSES.
WITH
Observations and Inquiries thereupon.

By R. HOOKE, Fellow of the Royal Society.

Non possum oculo quantum contendere Lineas,

LONDON, Printed by J. Martyn, and J. Allestry, Printers to the
Royal Society, and are to be sold at their Shop at the Bell in
S. Paul's Church-yard. M DC LXV.
Microscopy Through the Centuries

\[ d = \text{constant} \cdot \frac{\lambda}{n \sin \Theta} \]

To get better resolution:

1) Reduce \( \lambda \)
   \( \text{electrons, xrays} \)
2) Increase \( n \sin \Theta \)
   \( \text{better lenses, “oil”} \)
3) Decrease constant
   \( \text{confocal} \)
4) Take away lenses
   \( \text{near field} \)
   \( \text{scanned tip} \)
“Camera Obscura”

History:
Aristotle about 350 BC, used to view the image of the eclipse of the sun.

First built and illucidated the correct mechanism of light for visualization around 1000AD by Persian scientist, Abu Ali Ibn al Haitham.

The Greeks believed that the eyes sent out “streamers” that would interrogate objects.

The Camera Obscura in San Francisco is a model of one built by Leonardo DaVinci in the 1500’s.
Principles of the Camera Obscura


Expanded drawing from Al-Haytham

From: www.islamic-study.org/optics.htm
**Imaging Without Lenses**

\[ \frac{H_i}{H_o} = -\frac{v}{u} \]

\[ \frac{H_i}{H_o} = \frac{v}{u} = M \]

**Blurring** / penumbral, \( d_p = sv/u \) / diffraction, \( d_d = (\lambda(v-u))^{1/2} \)

\( s = \) pinhole size or source size
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<td>SOUND</td>
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<td>TOUCH</td>
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<td>STYLUS, AFM, STM</td>
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Nanostructure characterization

wide variety of techniques:

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