

Introduction to Metrology (30 points)

Objective: The objective of this online lab is to provide an introduction to the operation of the ellipsometer, profilometer, and optical microscope. These tools will be used repeatedly throughout the semester.

The student will watch videos on the operation of the profilometer, ellipsometer, and optical microscope. These videos will provide detailed insight onto the operation of each piece of equipment. After watching the videos the student will be required to answer review questions on ANGEL.

Background: Having the ability to create features on the micro and nanoscale is only useful if there is some way to verify your results. Therefore, characterization is an integral part of the fabrication process. A wide variety of characterization tools and techniques are used to ensure reproducible results in every manufacturing process. The nature of the sample and the information to be extracted from the sample dictate which techniques are used. This lab explores three common characterization tools/techniques for analyzing thin films: ellipsometry, profilometry, and optical microscopy. Each technique has its advantages and limitations which will be discussed in detail.

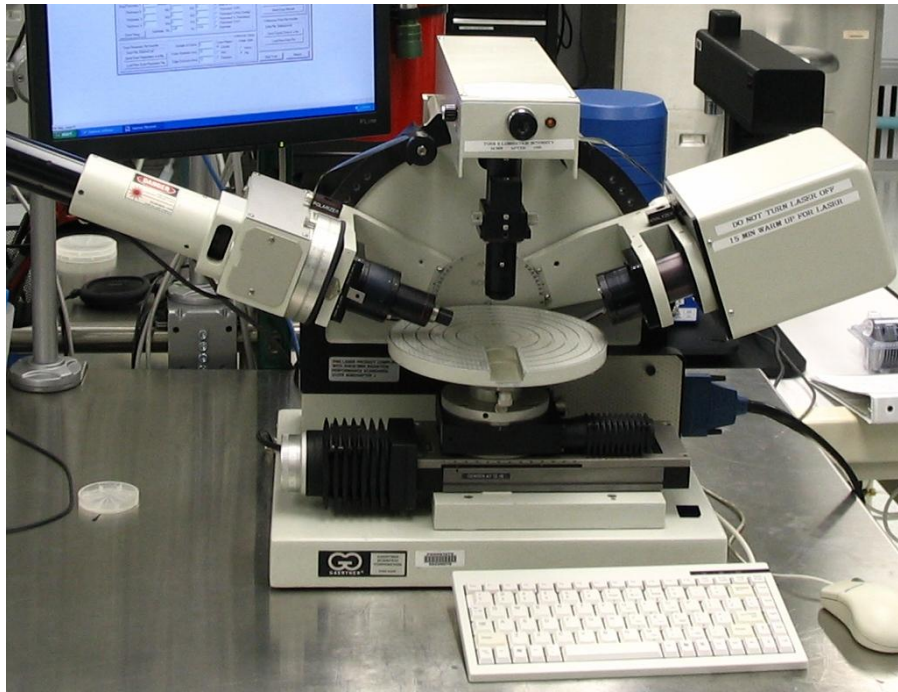


Figure I: Gaertner Scientific L115S-8 Ellipsometer

Ellipsometer: The Gaertner Scientific L115S-8 Ellipsometer (Figure I) is capable of measuring the index of refraction and material thickness for transparent thin films (0-6000nm) deposited on a reflective substrate. Many types of thin films can be analyzed with this instrument; polysilicon, different types of oxides and nitrides, etc. There are

some types of materials that cannot be analyzed: organic films such as photoresist, small features, and opaque films like metals. All films to be analyzed have to be partially transparent.

Ellipsometry is based on the measurement of the light polarization change upon reflection from a sample surface or interface. This very sensitive measurement technique provides unequalled capabilities for thin film metrology. As a non-contact optical technique, spectroscopic ellipsometry is non-destructive and offers excellent accuracy. This includes film thickness for single layer or complex multilayer stacks, ranging from a few angstroms to several microns. Other film properties can be determined, like the index of refraction of a material.

The shape of the reflected ellipse is measured and film thickness is determined based on information from software integrated within the instrument. A linearly polarized input beam from the source is converted to an elliptically polarized reflected beam, which is analyzed by the detector to give a readout of the index of refraction, angle of incidence, and film thickness, watch the video at the link below which shows how to operate the ellipsometer.

<http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=409bbc03-1c3a-4107-bc2e-5>



Figure II: Veeco Dektak 6M Profilometer

Profilometer: The Veeco Dektak 6M surface profiler (Figure II) is capable of performing the following functions:

Surface Roughness: Using software, the tool is capable of measuring the average roughness of the surface of the sample.

Feature Height: One common mode of operation involves using the stylus to measure the height of features in patterned thin films.

Film Stress: Based on sample curvature, the profilometer can be used to measure the stress (tensile or compressive) in solid thin films.

The profilometer is capable of measuring a large feature range (1\AA to $6.5\mu\text{m}$), making it a versatile tool. Since the stylus is in contact with the sample surface, it is important that the profilometer only be used to measure relatively rigid films. The stylus will damage soft films and cause a distorted image. The stylus on the profilometer scans across the sample surface in the y-direction. As it moves across the surface, the stylus moves up and down tracking surface features. This vertical displacement is recorded by the tool for measurement purposes, watch the video at the link below which outlines the operation of the profilometer.

<http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=1a0e3d1f-d8f2-4993-be6b-a>

Optical Microscope: The Leitz Ergolux optical microscope is a reflective microscope capable of viewing samples in both bright and dark field mode.

Bright Field: A traditional light source is used to illuminate the sample and the reflection yields the image.

Dark Field: light scattered off irregularities on the sample surface making features visible through the microscope.

An optical microscope can be used to image many different samples with relatively large feature sizes. Light reflects off the surface of the sample, allowing an optical image to be obtained through a series of lenses. An interchangeable objective lens allows the magnification of the microscope to be altered. Watch the video which shows the operation of the optical microscope.

<http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=3b1e5e03-4231-4664-9902-5>

Once you have watched all 3 videos answer the multiple choice questions on ANGEL.

Questions-2 points each (TO BE ANSWERED ON ANGEL, NO HARD COPY REQUIRED)

1. For a pattern of photoresist on SiO₂, which tool from this lab, would you select to measure the depth of the photoresist?
2. Which tool(s) are non-destructive?
3. What is not a limitation of the ellipsometer?
4. How many total knobs must be turned to center the table and adjust the table height?
5. What two angles are always used for the 2 angle ellipsometer measurement?
6. Based on the color chart for oxides, how thick would we predict an orange to melon colored SiO₂ sample to be?
7. How do we estimate the oxide thickness for the single angle ellipsometer measurement?
8. What is not a limitation of the profilometer?
9. Roughly how large is the probe radius of the profilometer?
10. What icon is clicked to switch to the optical microscope view of the sample?
11. What parameters can be changed in the Scan Parameters window?
12. What dimension are microscopes limited in measuring?
13. When is dark field most commonly used on the optical microscope?
14. Lamp intensities above ____ can damage the light source.
15. What must we do to get an image using darkfield?