Basic Characterization Techniques

Introduction to Profilometry (40 points)

Objective: The objective of this online lab is to demonstrate and learn the fundamental principles of profilometry as well as the operating principles and components of a typical profilometer. This lab also serves as an instruction manual for the operation of an example profilometer, the Veeco Dektak 6M Profilometer. Figure I is a picture of the Dektak 6M.

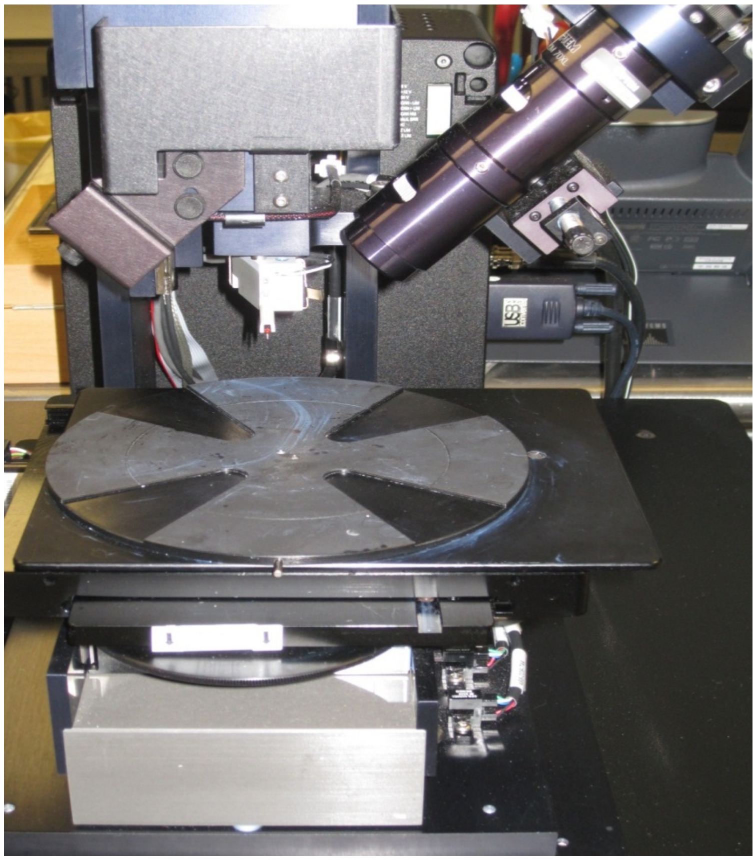

Figure I, Veeco Dektak 6M Profilometer

Background: A Profilometer is a very common tool used to measure step heights of thin films, and the morphology of a relatively flat surface. Profilometers allow us to see and measure micro and nanoscale features by “feeling” the surface with a probe tip. Profilometers work by using a small probe, known as a stylus, typically diamond tipped to make physical contact with a sample. These tips vary in size, angle, and geometry, but a typical profilometer tip will be in the 10 μm radius range. Profilometers are capable of measuring a large range of feature sizes, from less than a nanometer to several microns, making them very versatile characterization tools. The stylus moves up and down, corresponding to changes in feature height, as the stylus is rastered across the sample, in the y direction. The vertical (z) and horizontal (y) displacement is recorded by the tool so that various measurements can be made after completing a scan as shown in Figure II.

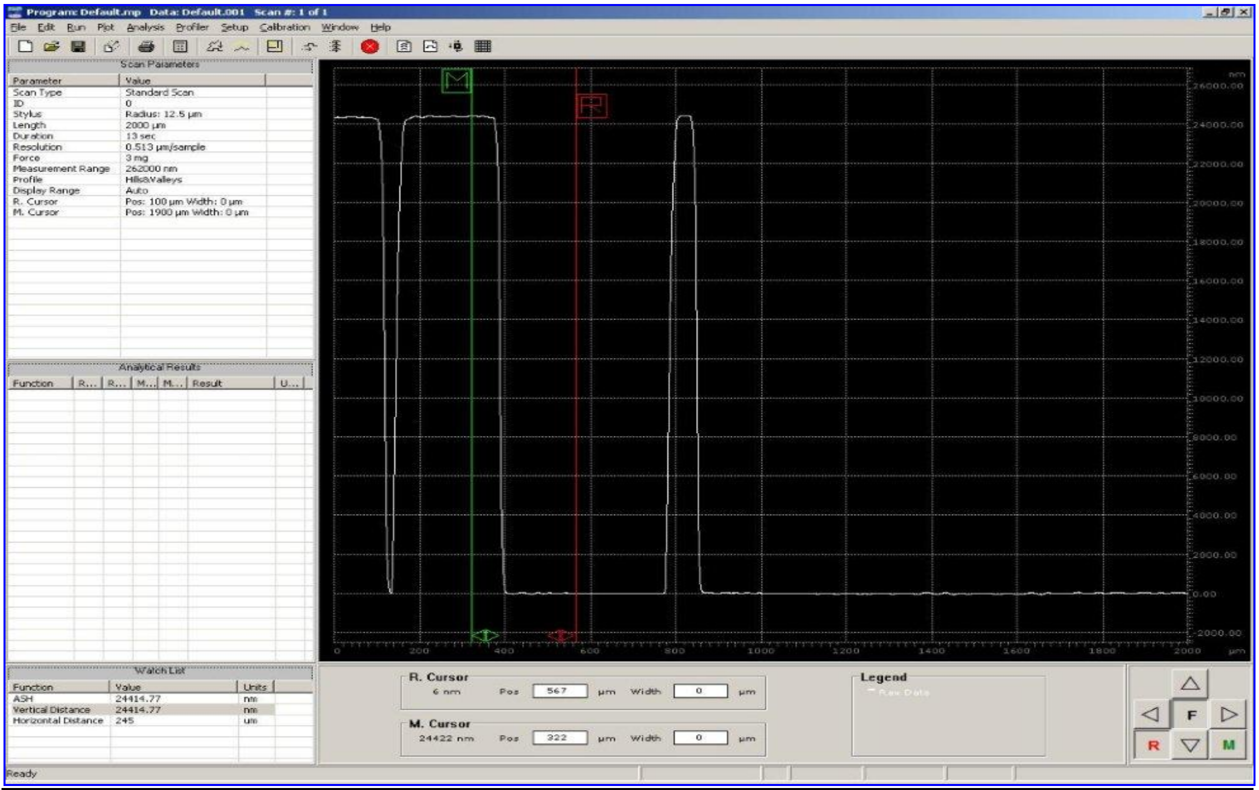

Figure II, typical scan

Some common functions of profilometers include determining surface topography, roughness, feature height (step height), and surface curvature. Surface topography is simply a trace of the topographic features of a sample. Surface roughness can be measured by calculating average roughness of the sample surface after several sample locations have been characterized. Feature height is the most basic type of function which simply involves measuring the distance between average low and average high values of a line scan. This is commonly used for determining the height of features in patterned thin films.

It is important to remember that the hard tip makes contact with the sample and therefore the features being investigated. Since the stylus contacts the surface, the profilometer is considered a destructive test method. Naturally soft materials can be easily damaged during a scan. This potential sample damage typically leads to tip contamination which can cause false information and distortions to appear in the acquired line scan image.

Component Overview and Operating a Profilometer

The video linked below will make use of diagrams, video screen captures, and narration in order to explain the operation of the Dektak 6M. The next series of pictures shows the controls and features of the Dektak 6M, these should be used as a reference while you watch the video.

Please watch the associated video linked on Angel.
http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=1a0e3d1f-d8f2-4993-be6b-a

Figure III is a frontal view of the system. The tower is raised and lowered to contact the sample. The stylus in the system features a 12.5 micron diameter probe tip that has a balance of good resolution, and good durability. As the probe tip diameter is decreased, resolution is increased, but generally durability suffers. The camera is shown with the relationship to the stage where the sample is measured.

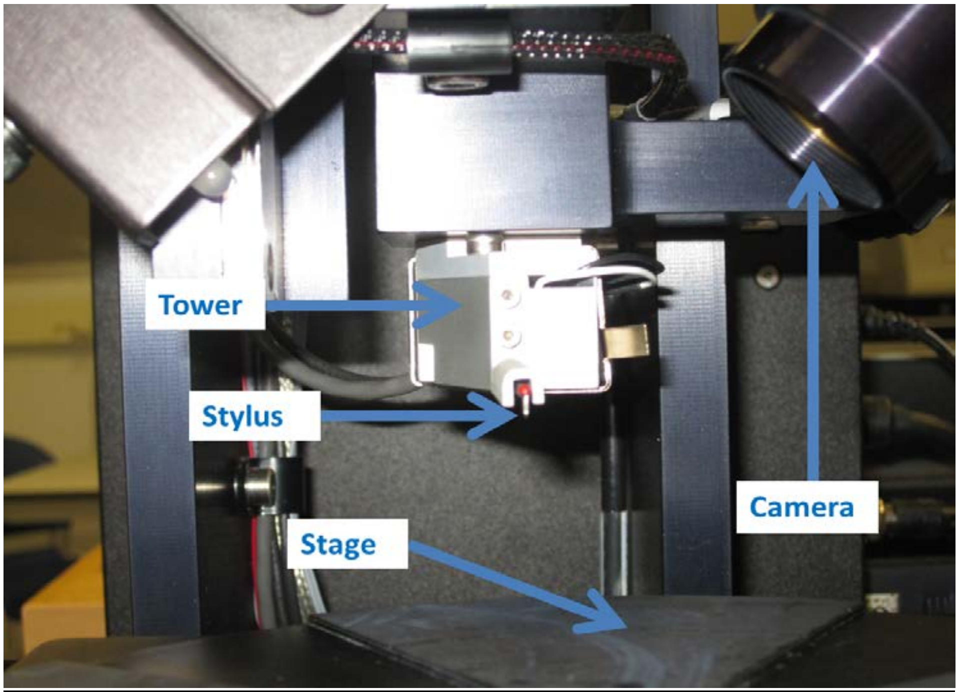

Figure III, Frontal View

Figure IV shows the focus and zoom control on the camera used to align the stylus trace with the area of interest on the sample. The stage rotation pin can be moved to rotate the position of the stage in relation to the stylus.

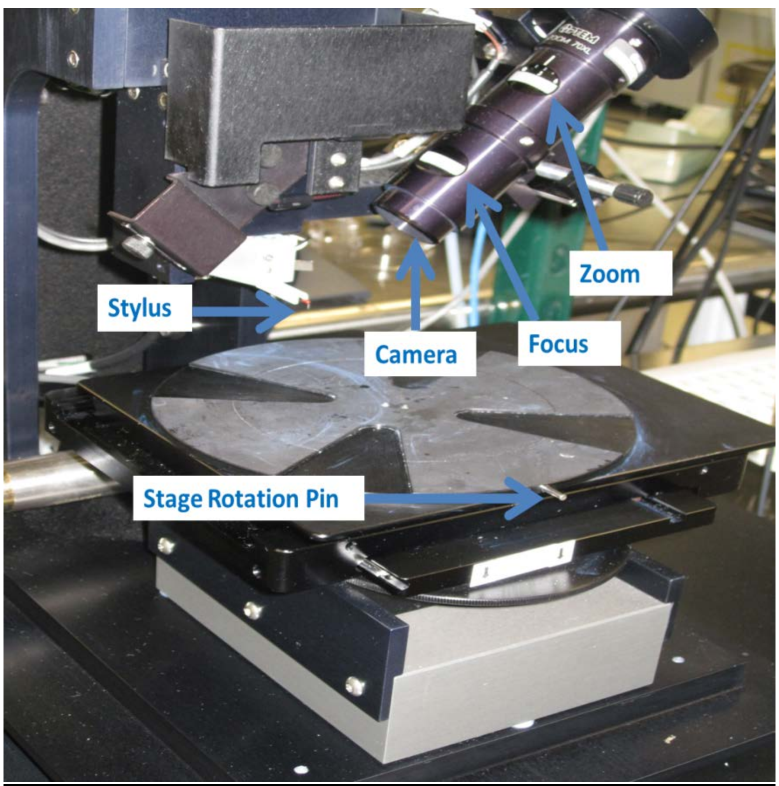

Figure IV, Camera Detail

Figure V is the view from the positioning camera. The dark triangular shape at the top of the picture is the probe tip as it approached the sample under test.

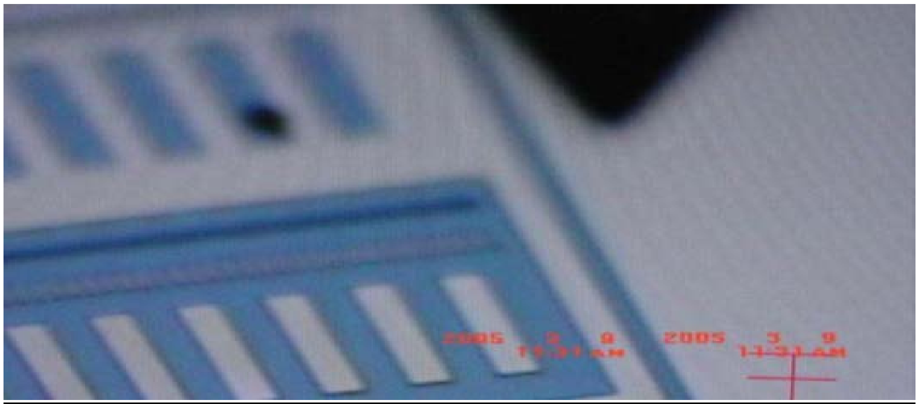

Figure V, Probe Approaching the Sample

Figure VI shows the lower right hand side of the system where some of the stage controls are located. The two rubber knobs can be turned to shift the stage in the X and Y axis. The stage leveling control can also be used to position the sample.

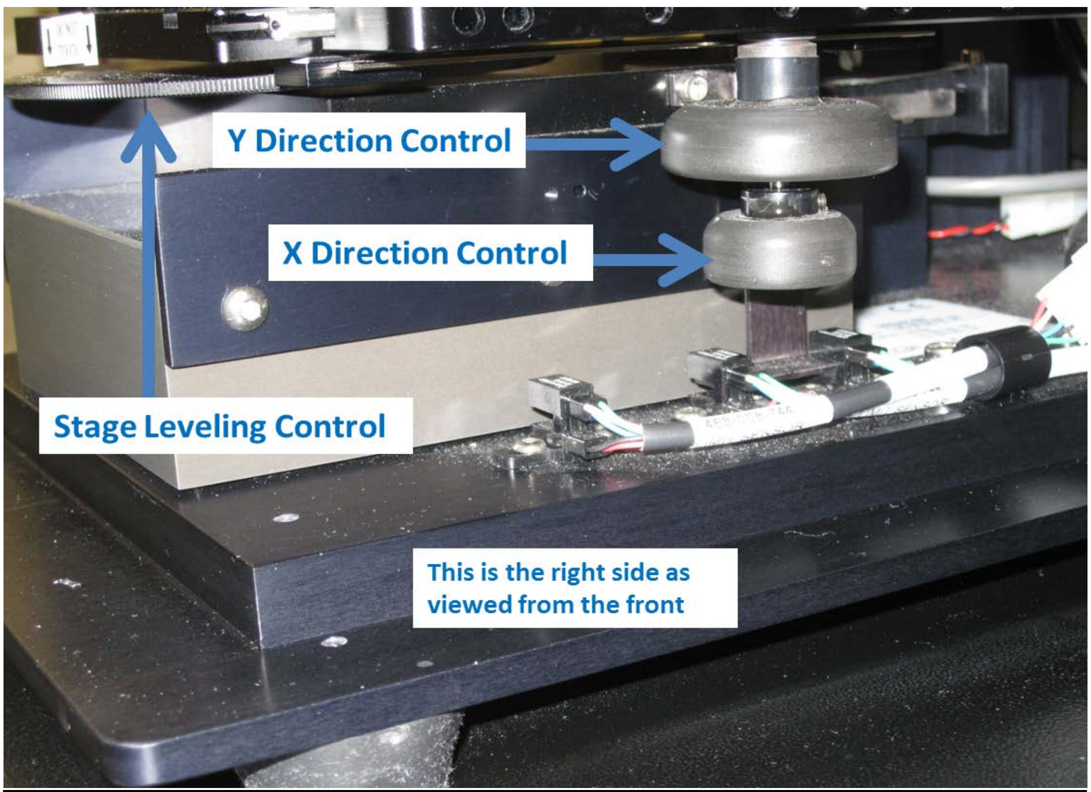

Figure VI, Stage Controls

Technical specifications are listed on the next page in Figure VII, and typical user defined control parameters are shown in Figure VIII.

Detek 6M Technical Specifications		
Specification Standard Option	Vertical Range 50 Å to 2,620 kÅ (0.1 microinch to 10 mils) 1 mm maximum	Vertical Resolution (at various
Scan ranges	1 Å/65 kÅ, 10 Å/655 kÅ, 40 Å/2620 kÅ 160 Å 1 mm	Scan Length Range 50 µm to 30 µm (2 mils to 1.18 in)
Scan Speed Ranges 3 seconds to 100 seconds	Software Leveling Two-point programmable or cursor leveling	Stage Leveling Manual
Stylus (standard) Diamond, 12.5 µm radius 0.2 µm, 0.7 µm, 2.5 µm, 5 µm,	25 µm	Stylus Tracking Force Programmable, 1-15 mg
Maximum Sample Thickness 31.75 mm (1.25")	Sample Stage Diameter 6" for 150 mm and smaller samples	Manual Stage Position
Translation	X Axis, 20 mm	Y Axis, 77mm
Sample Stage Rotation Manual Theta, 360º	Maximum Sample Weight 1.5 lbs	Power Requirements
Current Phase	100-120~ or 220-240~, 50/60 Hz	5A@100-120~ or 3A @ 220-240~ (+/-10%)
Single Phase	Warm-up Time 15 min. for maximum stability	Operating Temperature 21º C +/-3ºC (70º F +/-5ºF)
Environmental Humidity 40%, +/-20%	Camera Field of View 2.6 mm horizontal field of view. 1.1- 4.6 mm zoom	Color Camera 45º side view
Sample Illumination Variable intensity white light LED	Dimensions L= 20" (508 mm), W= 12" (304.8 mm),	H= 17.25" (438.15 mm)
Specification Standard Option	Vertical Range 50 Å to 2,620 kÅ (0.1 microinch to 10 mils) 1 mm maximum	Vertical Resolution (at various
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Figure VII, Technical Specifications

Control Parameters	
Parameter	**Value**
Scan Type	Standard Scan
ID	0
Stylus	Radius 12.5 microns
Length	500 microns
Duration	13 seconds
Resolution	0.128 um/sample
Force	3 mg
Measurement Range	2620000 nm
Profile	Hills and valleys
Display Range	Auto
R. Cursor	Pos: 100 um Width 0 um
M. Cursor	Pos: 500 um Width 0 um

Figure VIII, Control Parameters

QUESTIONS FROM VIDEO – Introduction and Operation of a Profilometer

1. How do profilometers allow us to measure topographic features? (3pts)

   Use a probe, around 10 um, to make physical contact and raster across a sample. By plotting the lateral and vertical probe movement, we can take linescan measurements.

   Use a laser to measure the surface in a non-destructive mode.

   Use a vibrating probe, around 10 um, to make intermittent physical contact and raster across a sample.

   Use a calibrated camera image.

2. What is the purpose of the microscope? (3pts)

   Used to help a user align the probe tip with a particular feature of interest.

   Magnify the collected trace data.

   Mount the stylus to the tower

   Capture step weight information

3. Why should the stage not be moved when the tip is in contact with a sample? (3pts)

   Could result in sample damage, tip contamination, and a broken tip and stylus.

   Image data will be wrong in the Y direction

   Alignment will be out of camera focus

   Resets the calibration factor in the software table.

4. What icon is “clicked” to bring the probe near the sample surface? (3pts)

   Tower down to null position – stylus up.

Tower up to null position – stylus up.

Tower up to null position – stylus down.

Scan left to right after contact.

5. How do we increase the resolution of a scan? (3pts)

   Increase the scan duration and decrease the scan length.

   Decrease the scan duration and decrease the scan length

   Decrease the scan duration and increase the scan length.

   Increase the scan duration and increase the scan length.

6. What is the first thing to do after running the active scan? (3pts)

   Level the scan OR level the trace.

   Record he data.

   Level the stage height with the stage leveling control knob.

   Reset the stage length function.

7. Why would we open the scan routines window? (3pts)

   If we wanted to adjust some of the scan parameters.

   Modify the trace for leveling.

   Replace the stylus.

   Level the stage.

<u>QUESTIONS FROM LAB DOCUMENT</u>

1. What is the typical range over which profilometers can characterize a sample? (2 pts)

   From less than a nm to several microns.

   From 1 micron to 10 microns.

   From 10 microns to 100 microns.

   From 100 microns to 1000 microns.

2. What function is not possible with the profilometer? (3pts)

    Determining surface topography: a trace of topographic features of a sample

    Determining surface roughness: found by averaging roughness after several sample locations have been measured

    Determining feature or step height: found by measuring distance between average low and average high values of a line or profile scan

    Near surface chemical composition.

3. What are two problems associated with using profilometry on soft samples? (3pts)

    Soft materials are easily damaged during line scans due to tip/sample contact.

    This leads to tip contamination which can distort the acquired line scan image.

    Probe can bend due to lateral force.

    A+B

4. Is profilometry a destructive or non-destructive technique? (2pts)

    Destructive

    Non-destructive

5. For the Dektac6M, what diameter stylus would give the highest detail in topography with treanches.? (3pts)

    0.2 µm

    0.7 µm

    12.5 µm

    5 µm

6. For the Dektac6M, what diameter stylus would you suspect would be the most durable measuring topography with treanches.? (3pts)

0.2 µm

0.7 µm

12.5 µm

5 µm

7. What is the speed scan range? (3pts)

    1-500 seconds
    3-100 seconds
    1-50 seconds
    3-50 seconds