

Dektak 3ST Surface Profilometer

This document is intended to describe the operation of the Dektak 3ST surface Profilometer and its capabilities. In order to gain access on the tool, formal qualification by staff is required.



The Dektak 3ST is a surface profilometer used to measure the vertical profile of samples, thin film thickness, and other topographical features such as film roughness or wafer bowing.

The system takes measurements electromechanically by moving a diamond-tipped stylus over the sample surface according to a user-programmed scan length, speed, and stylus force.

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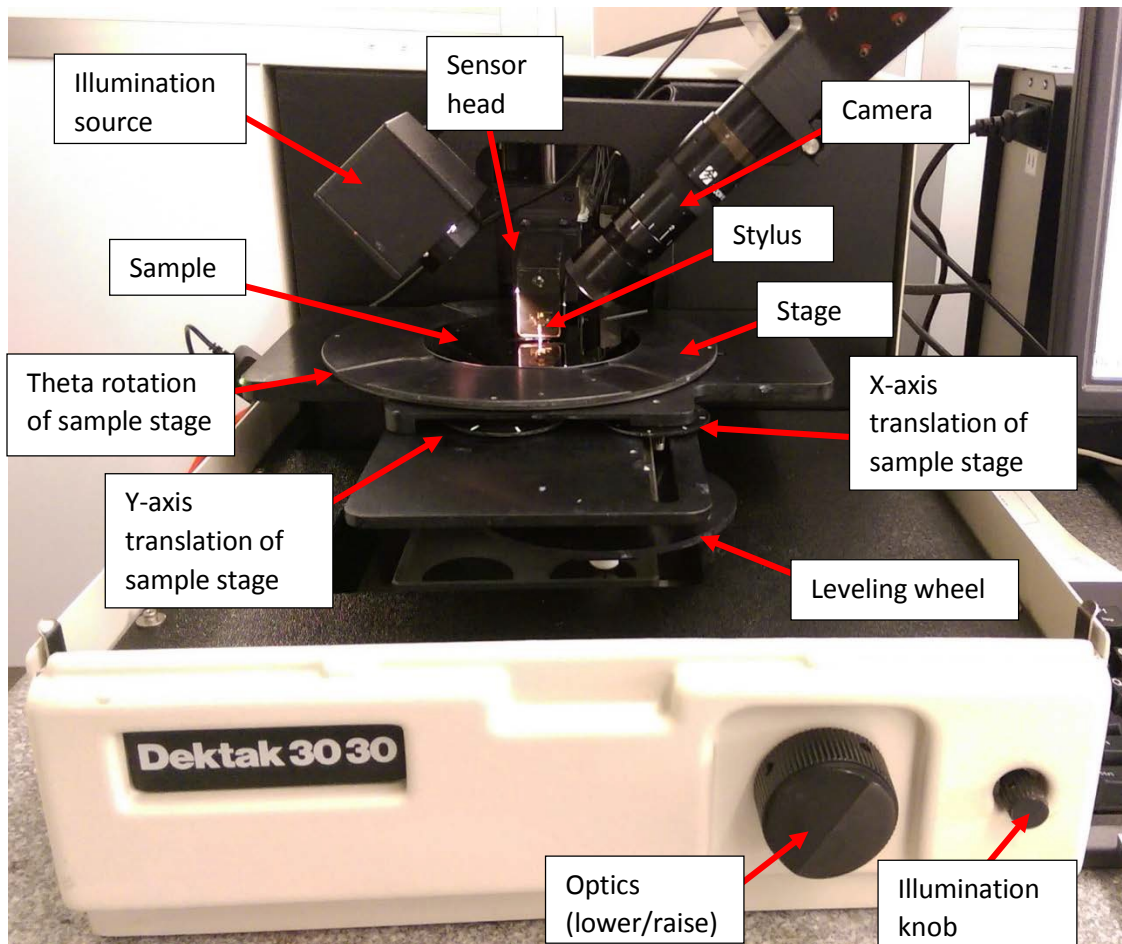
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1. System Configuration

Vertical Range:	100Å to 1,310KÅ (0.4 microinch to 5mils)
Vertical Resolution:	1Å/65KÅ, 10Å/655KÅ, 20Å/1310KÅ
Scan Length Range:	50 microns to 50mm (2 mils to 2 inches)
Scan Speed Ranges:	Low, Medium, High
Scan Time Range:	3 seconds to 50 seconds
Software Leveling:	Two-point programmable or cursor leveling
Stage Leveling:	Manual
Stylus (standard):	Diamond, 2.5 micron radius
Stylus Tracking Force:	Programmable, 1-40mg (0.01-0.4 mN)
Maximum Sample Thickness:	45mm (1.75 inches)
Sample Stage Diameter:	165mm (6.5 inches)
Sample Stage Translation:	X Axis ± 76 mm (± 3 inches)
Maximum Sample Weight:	0.5Kg (1 lb)
Warm-up time:	15min recommended for maximum stability
Zoom Magnification:	35x to 200x
Camera:	Color video image
Sample Illumination:	Variable intensity white light; IR & UV blocked

2. Overview



3. STANDARD OPERATING PROCEDURE

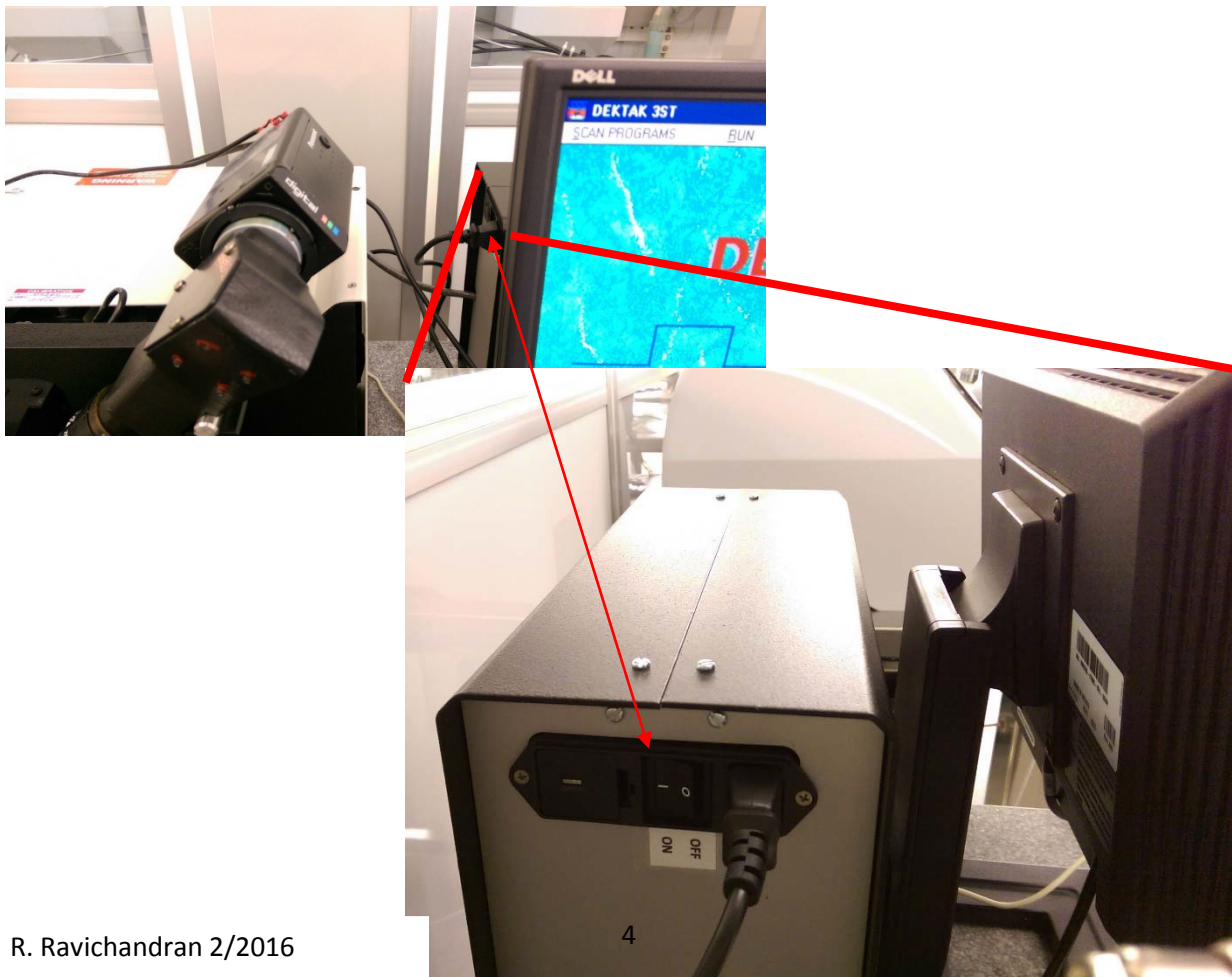
3a) System Startup

Make sure system is enabled on Badger under the Analytical section -> “Dektak 3ST”.

Make sure the system is ON by moving the mouse, and the monitor should display the program.

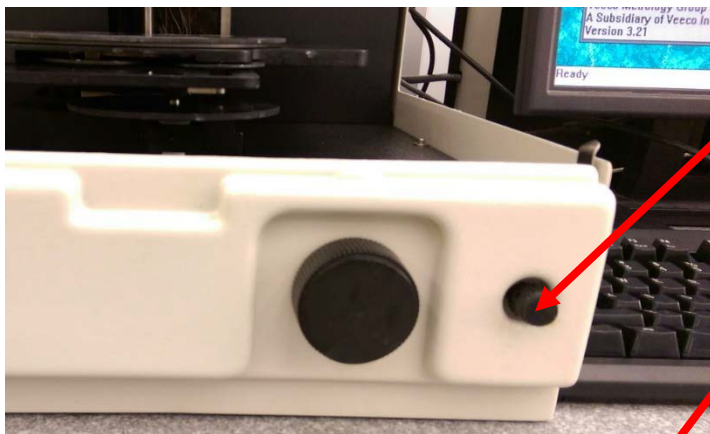


Also, be sure to check the power supply behind the monitor (second picture showing switch). This is the power supply that goes directly to the Dektak unit.

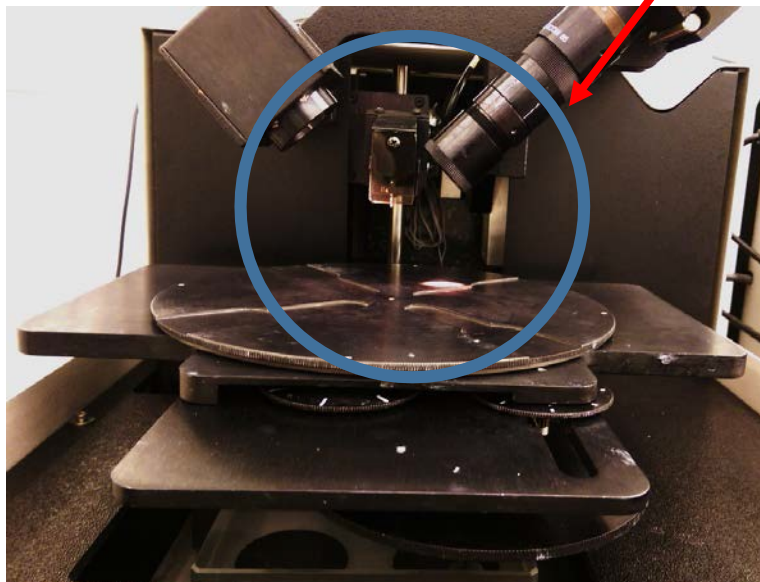




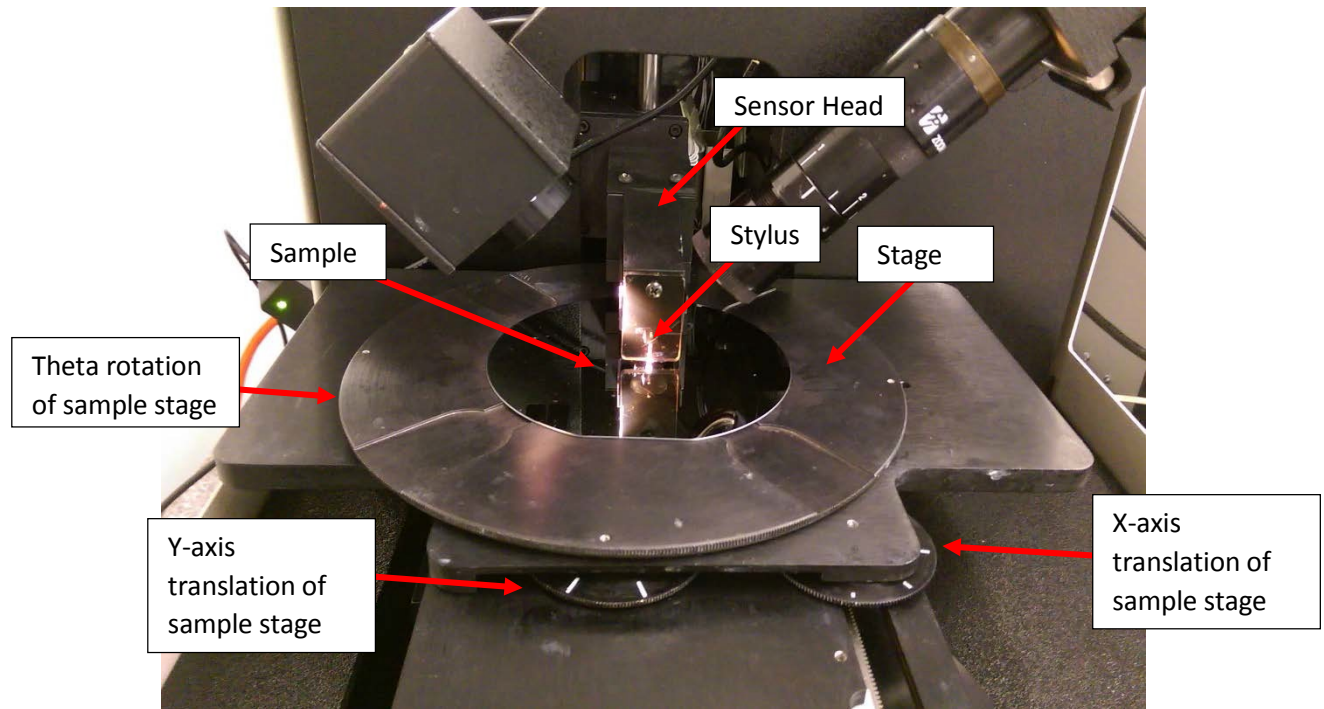
If the monitor does not turn on, then turn on the electronics by pressing the large silver button. The button should turn blue to indicate that the power is on.



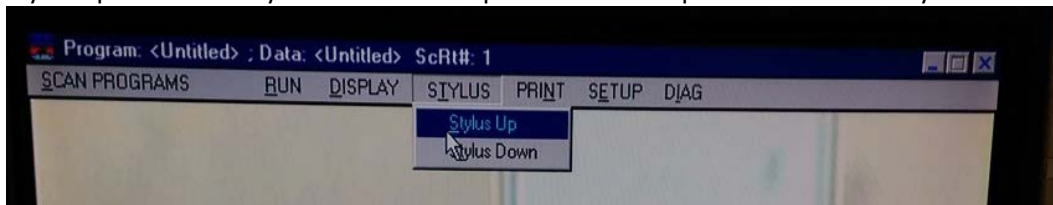
Turn the small illumination knob clockwise to turn on the light to the system. A light should shine onto the stage.



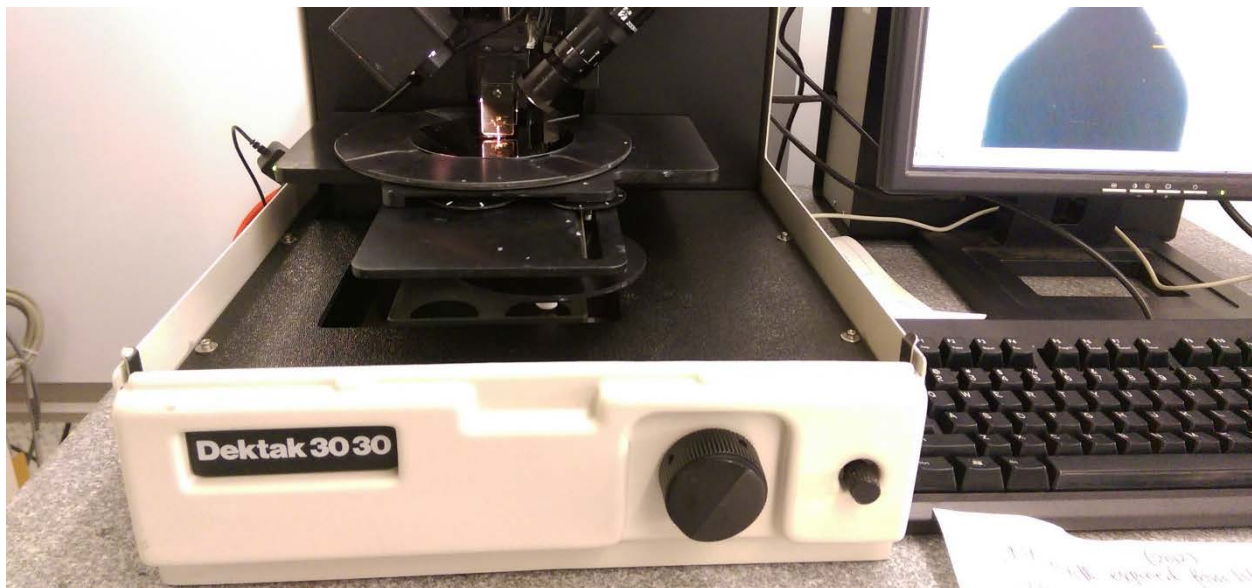
3b) Loading Samples



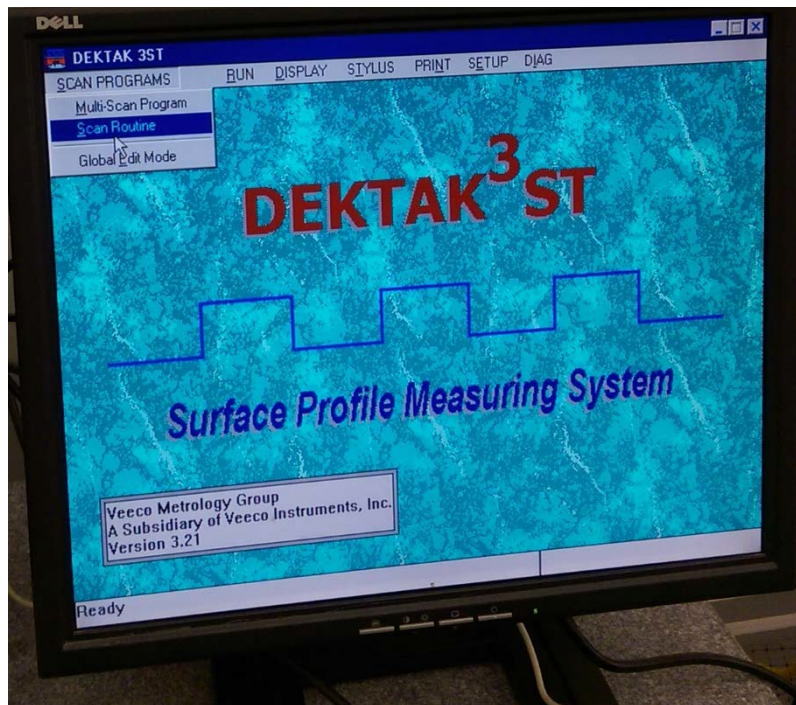
Place the sample under the sensor head as shown. Then from the main menu, go to the stylus menu and select “stylus down” to lower the stylus towards your sample. Use the x, y, and theta wheels to adjust the sample under the stylus, as long as there is enough clearance between the sample and the stylus. Otherwise move the stylus up from the “Stylus” menu and reposition the sample and lower the stylus back towards the surface.



Use the optics knob in front to lower the camera to the surface of the sample so that the sample is reasonably in focus.

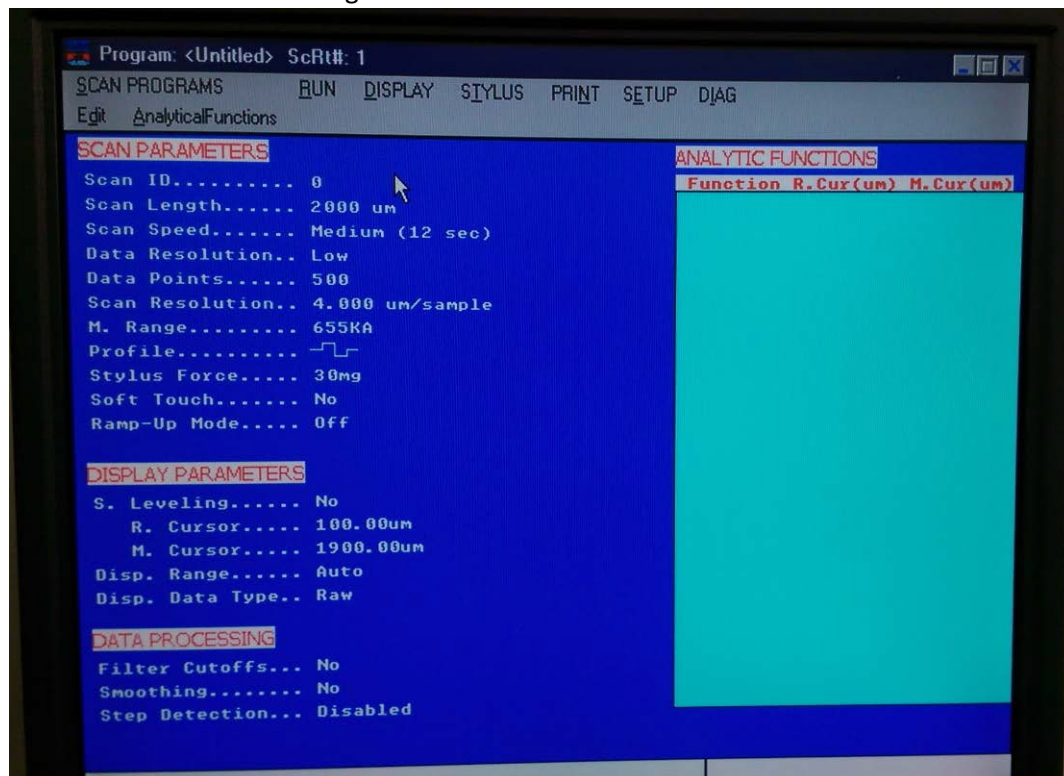


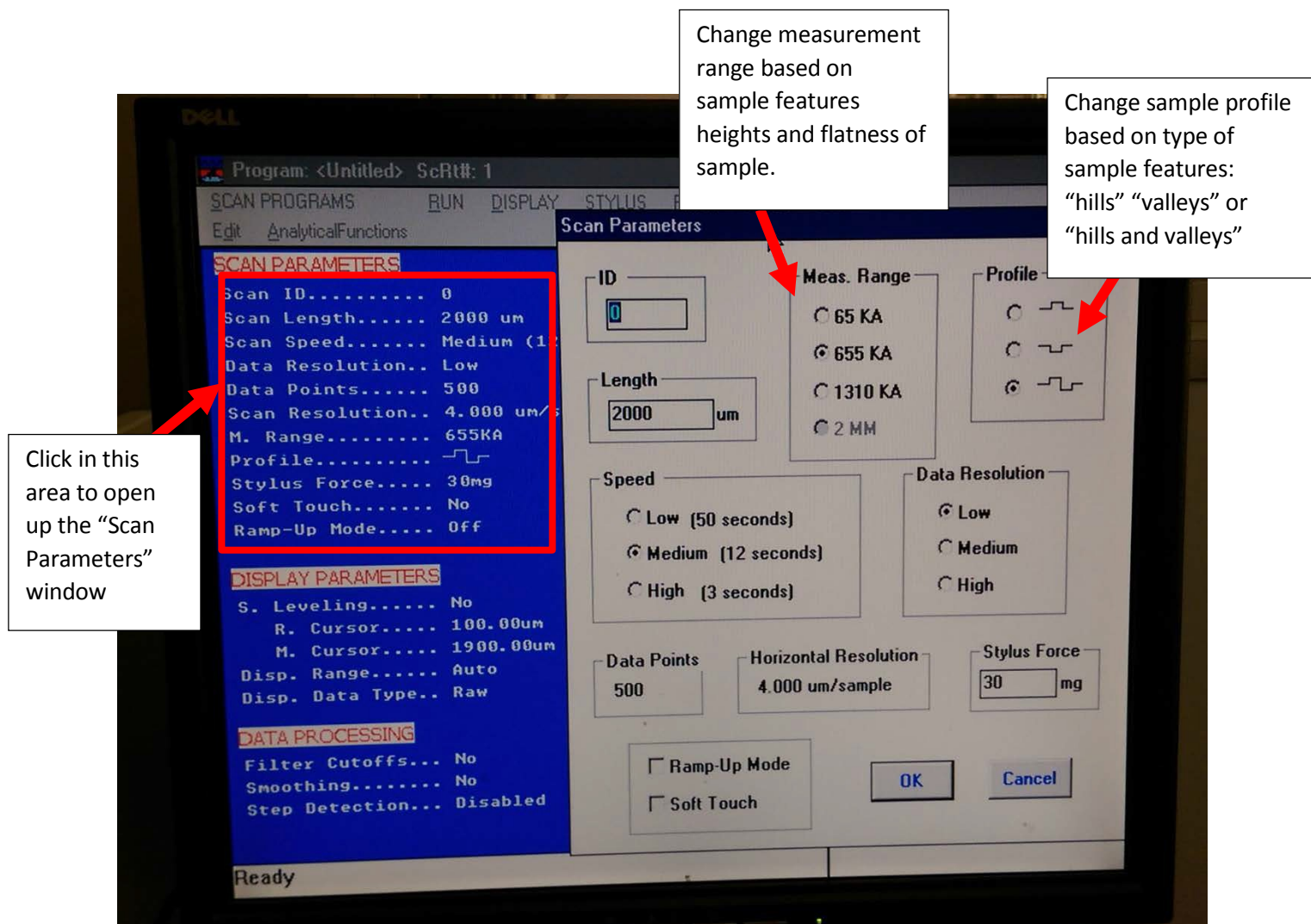
3c) Leveling and Step Height Measurement



From the main menu, select “Scan Routine” to adjust the parameters of the scan.

From the “Scan Routine” menu, you can open 3 windows: Scan Parameters, Display Parameters, Data Processing. Click anywhere on the “Scan Parameters” section to edit and set those parameters. You can program the “Display Parameters” and “Data Processing” functions in a similar fashion by clicking in the area under the white headings.








Measurement Range:

Set the measurement range to 1310kA first, and then after the sample is leveled at 1310kA it can be lowered to 655kA and then down to 65kA (if needed).

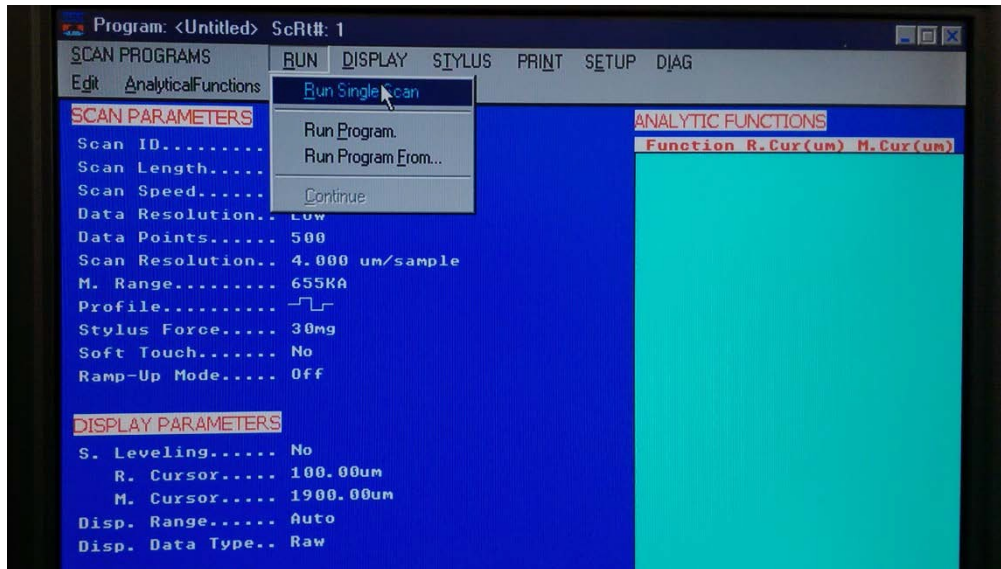
The final range value selected would depend on the wafer geometries and it indicates vertical resolution of the scan. When measuring extremely fine geometries (hills/valleys), the 65kA range provides a vertical bit resolution of 0.1 nm. For general applications, the 1.0 nm vertical resolution of the 655kA range is usually adequate. When measuring thick films or very rough or curved samples, select the 1310kA range with 8.0 nm resolution.

Profile: Select from the following:

- 
 - **Valleys:** Provides 90% of the measurement range below the zero horizontal grid line. This option is used primarily for measuring etch depths.
- 
 - **Hills and Valleys:** Provides 50% of the measurement range above the zero horizontal grid line and 50% below. This option is used in most applications, especially if the surface characteristics of the sample are not well known, or if the sample is out of level.
- 
 - **Hills:** Provides 90% of the measurement range above the horizontal grid line. This option is used primarily for measuring step heights.

Stylus Force: Enter a value between 1 mg and 30 mg. When measuring softer materials (photoresist, pdms, etc) uses the lower values closer to 1mg. When measuring tougher materials a larger force is permissible.

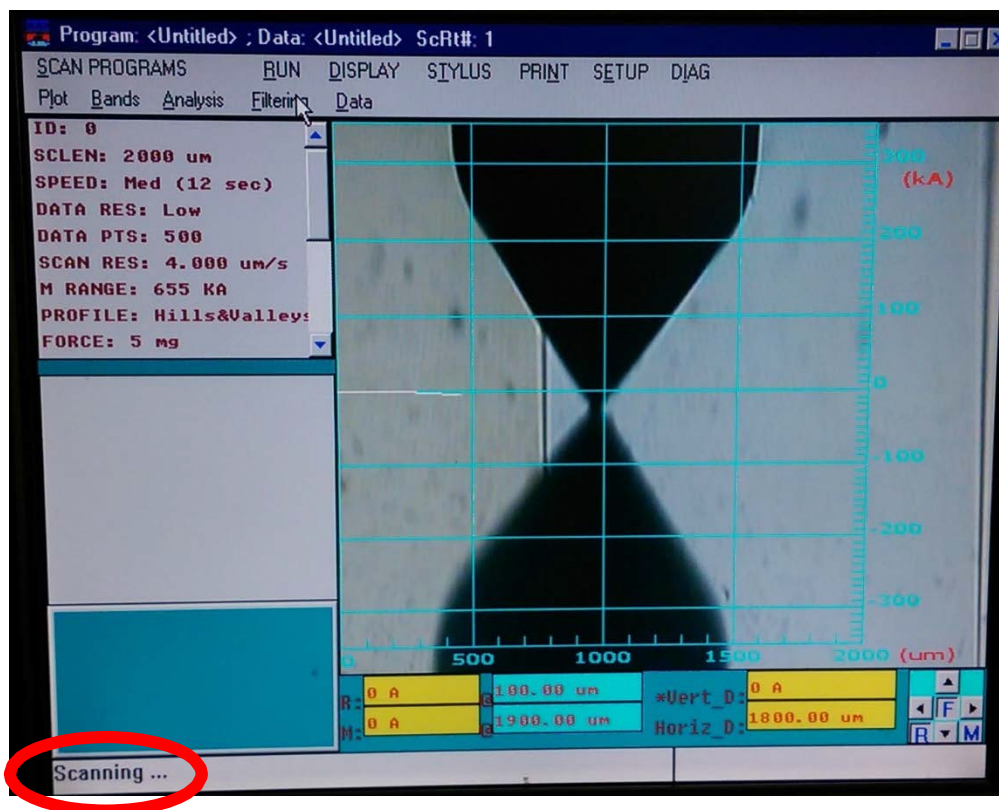
More information about the scan parameters is available in the attached supporting documentation



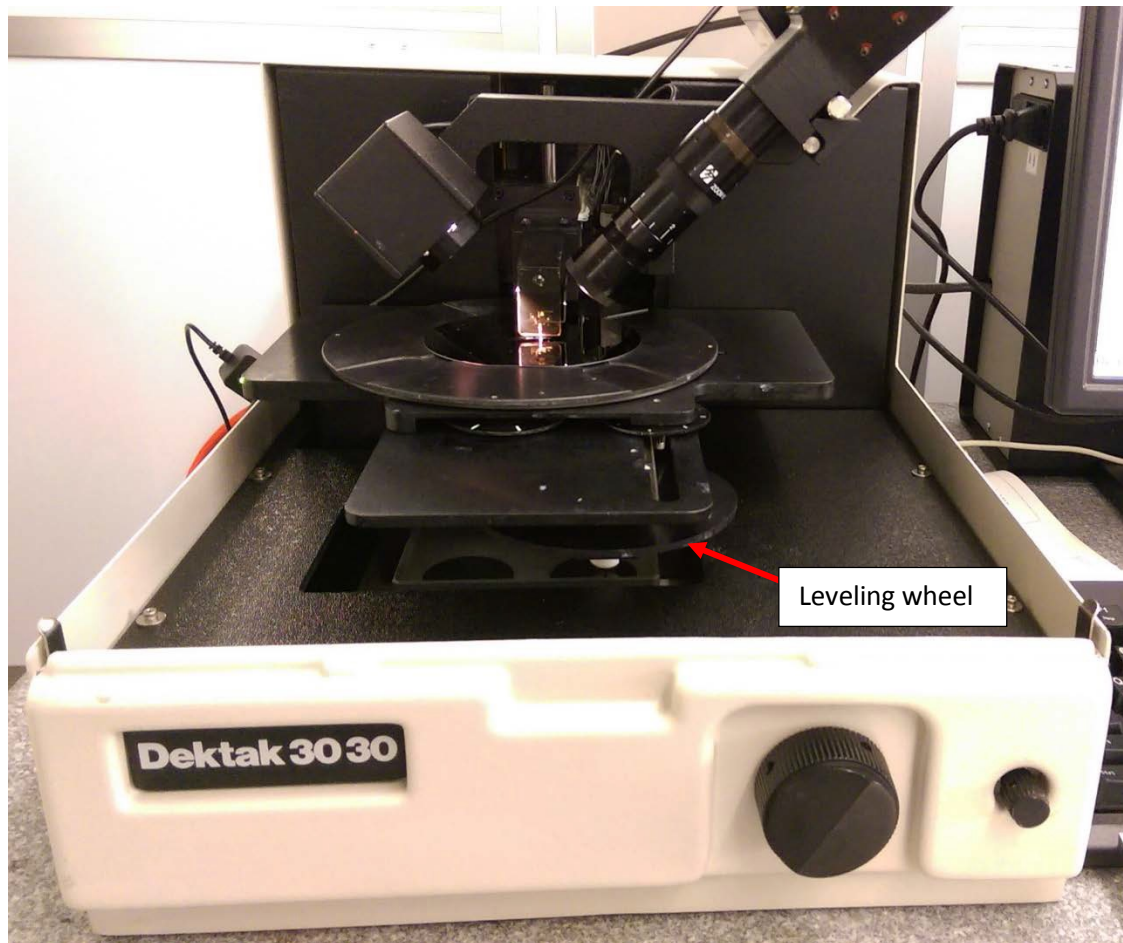
After setting the various scanning parameters. Go to "Run" on the top menu and select "Run single scan"

The stylus should automatically lower to make contact with the sample.

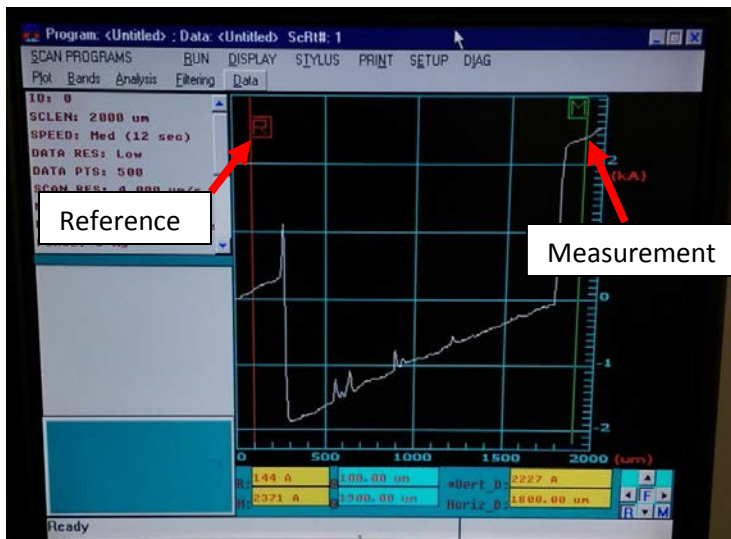
The display will switch to a scanning screen. Your features should appear to be in focus. (2271 A standard sample used in the picture below)



After the scan has been completed, the data analysis window will show up. If the sample is extremely sloped then adjust the stage leveling using the wheel and rerun the scan. The more flat the sample is, the more accurate the measurements. Once the sample has been physically levelled at a larger vertical range, you can decrease the vertical range and level again to get better accuracy. As you decrease the vertical range, the slope of the sample is more apparent. Therefore, you may be able to resolve a finer slope at a smaller range that may be less noticeable at a larger vertical range.



If the sample measurement looks almost flat, then you may resolve the rest of the slope with the software. (2271 A standard sample measured in the picture below).

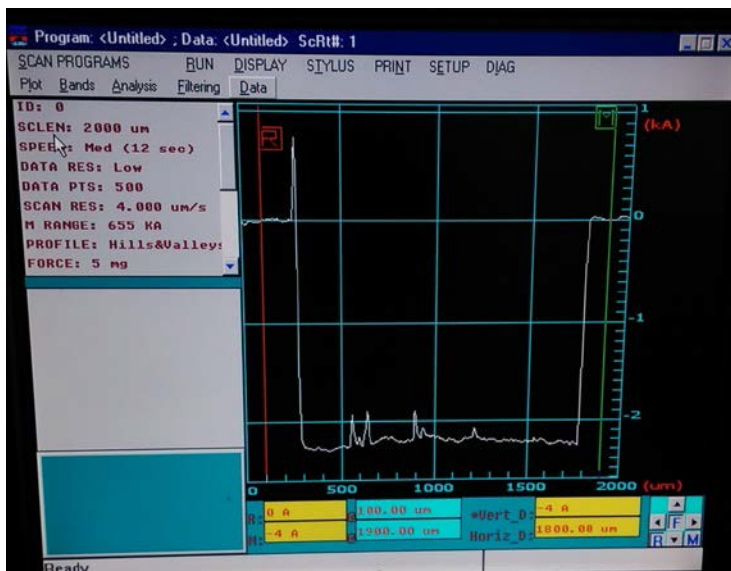


In order to level with the software, click on the reference cursor "R" or the measurement cursor "M" to move them both to areas which you know would be flat on your sample. In this case we are using the surface of a trench that is known to be flat.



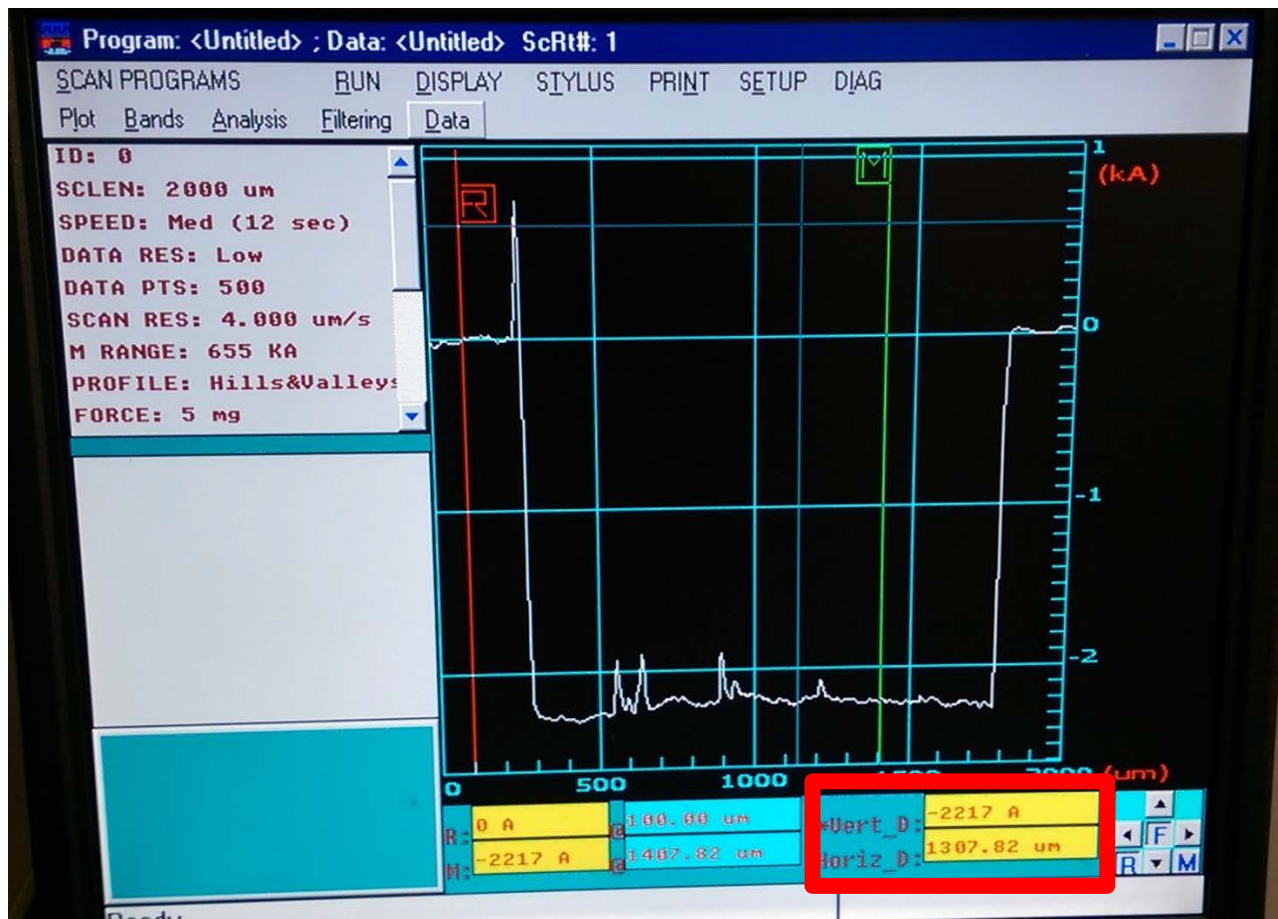
After you have placed the cursors in regions that are flat relative to each other, go to the "Plot" menu on the top tool bar and select "Level".

Before leveling



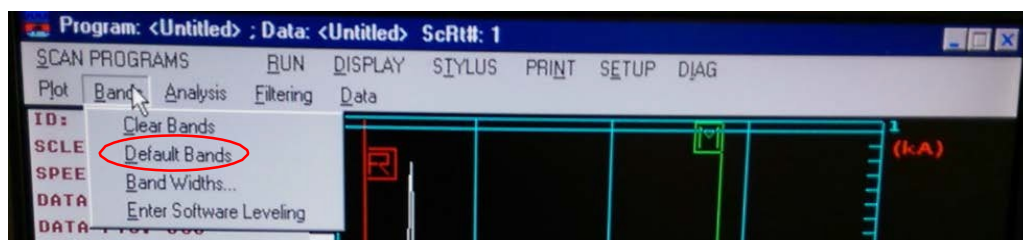
After leveling

After the sample has been levelled through the software, move the “M” (measurement) cursor to the area you want to measure the step height.



At the bottom of the screen, the vertical and horizontal distances are displayed. The vertical distance, “Vert_D” shows the step height (A) from the vertical position of the reference cursor “R”. The horizontal distance, “Horiz_D” shows the width or the distance to the reference cursor.

To get an average step height between two areas, you will need to turn on “bands”. To do so go to the “Bands” menu, select “Default bands” and then move and size them using the 4 arrows at the bottom of the screen.

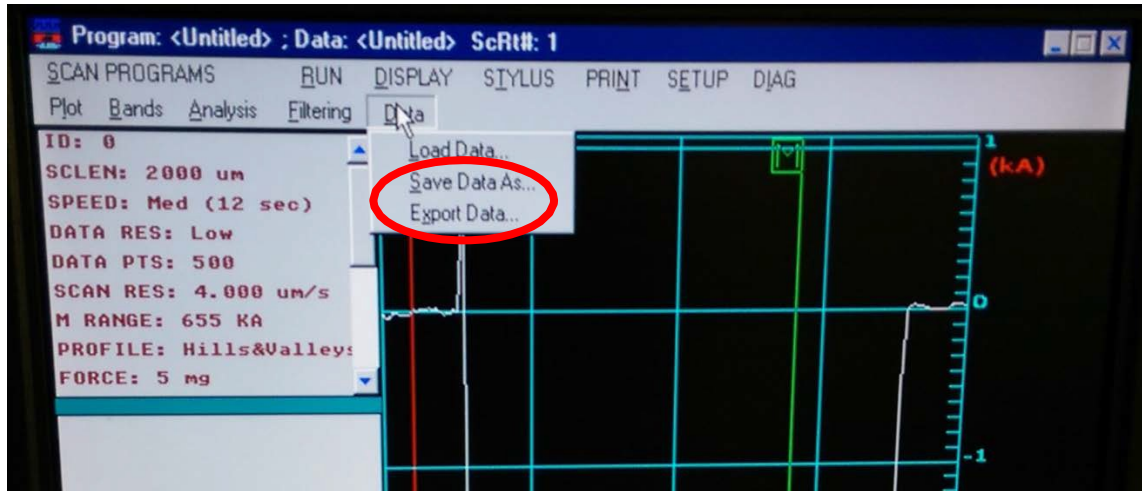


Other analytical functions can be found under the “Analysis” menu.

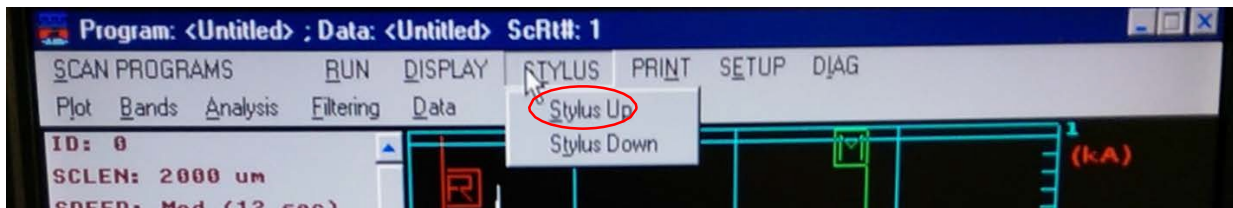


3d) Shutting down

Export data and plots as desired. Go to “Data” menu and select “Save Data As..” Or “Export Data..” to save an excel file on the computer with a folder labelled with your name. **Mislabeled or ambiguous folders with improper names will be deleted by staff at any time.** Copy the files from the computer to a personal USB.



If the stylus is still in contact with the sample, go to the “Stylus” menu and select “Stylus up” to move it a safe distance from the sample.



Safely remove the sample from the stage.

Turn the illumination knob to turn off the light on the stage.

Disable the tool from Badger.

4. SUPPORTING DOCUMENTATION

4a) System Mechanism

The Dektak3ST system takes measurements electromechanically by moving a diamond-tipped stylus over the sample surface according to a user-programmed scan length, speed, and stylus force (Fig 4.1). The stylus is linked to a Linear Variable Differential Transformer (LVDT), which produces and processes electrical signals that correspond to surface variations of the sample. After being converted to a digital format, these surface variations are stored for display and analysis. The factors that affect the resulting measurement data will be discussed in more detail in section 2.

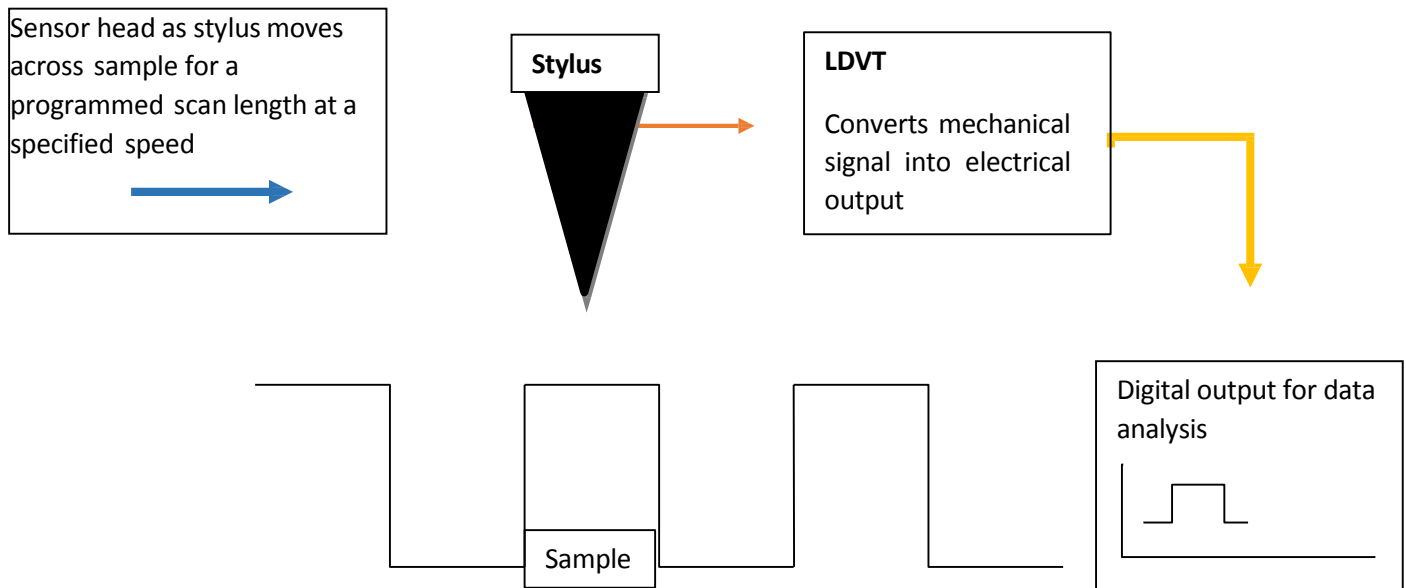


Figure 4.1 Describes an overview of the profilometer measurement mechanism during data acquisition.

The Dektak 3ST application calculates and displays the results of user-selected analytical functions for measuring, step height, surface texture, and other parameters to characterize the profile data. For example, the ASH (Average Step Height) analytical function calculates the step height by taking the difference at two marked points. Other analytical functions are described further in subsequent sections.

4b) Limitations of the Stylus

The stylus shape may have a significant impact on the measurement data as it is the component that makes direct contact with the sample's surface. The following section provides information from **Bruker** about the geometry of the stylus and its limitations. This stylus tip terminates in a 45° cone with an end radius of $12.5\mu\text{m}$, as seen in Figure 4.2. When measuring samples with narrow trenches (Fig 4.3), the stylus is unable to correctly verify the widths or reach the bottom of the trench. This is because the width of the stylus is caught at the opening. If your sample has many narrow trenches, please measure across a larger more open area to get a more accurate reading of the film thickness.

In order to prevent excess wear or damage to the stylus:

- Use the camera to verify that no features on the surface exceed the height of the stylus. Lateral contact between the stylus and the sample is the primary cause of damage.
- When measuring taller features ($> 10\mu\text{m}$), use a slower scan speed to limit sudden forces on the stylus.
- For more information, please refer to Bruker's application notes on Stylus Profilometry: **Dektak Stylus Capabilities: How to Choose the Correct Stylus for Any Application.**

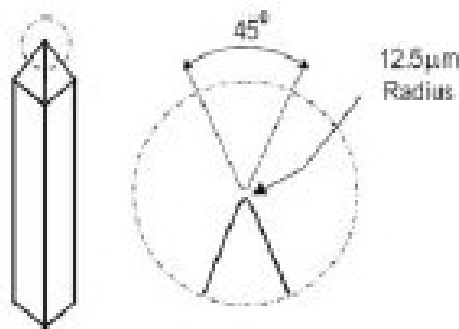


Figure 4.2. Shows the dimensions of the diamond-tipped stylus as it terminates at a 45° cone with $12.5\mu\text{m}$ radius at the end. **Credit: Bruker**

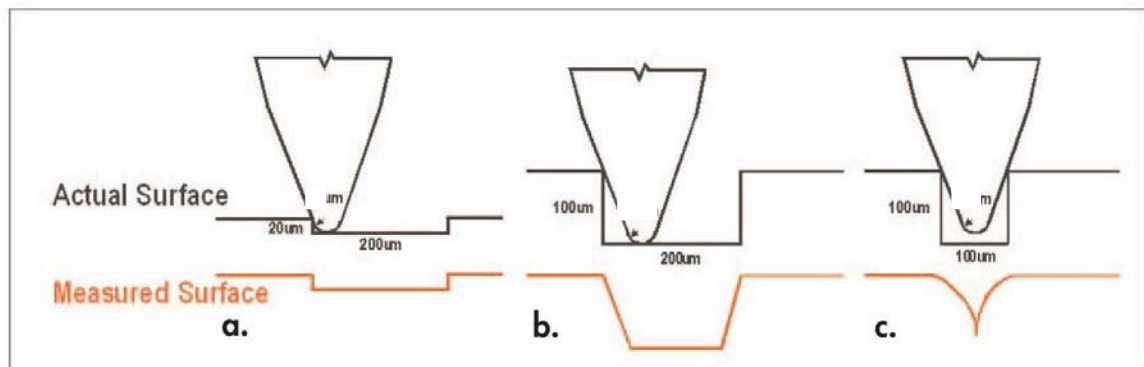


Figure 4.3. The geometry of the stylus must be considered as it creates limitations of the accuracy of the measurements. The $12.5\mu\text{m}$ stylus can easily measure larger trenches (a) but cannot accurately measure the width (b) and height (c) as the trench aspect ratio increases. **Credit: Bruker**

4c) Other Analytical Functions

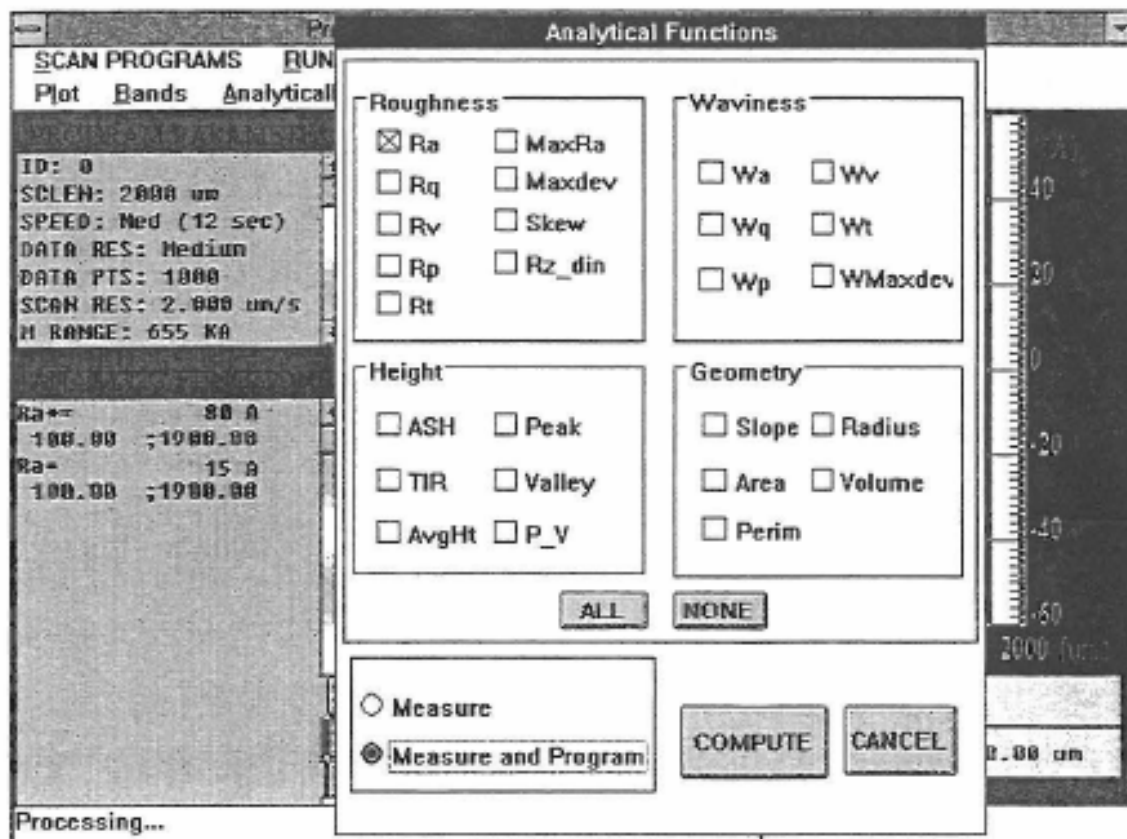
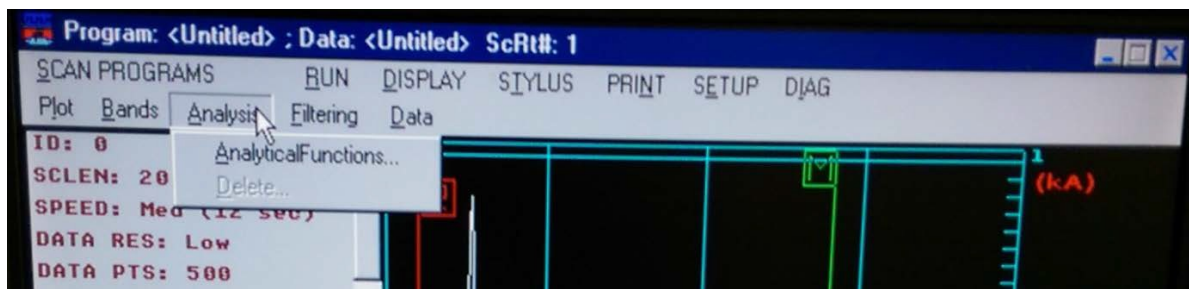


Figure 6 - 6 Analytical Functions/Data Plot Screen Entry

Analytical Functions Description

The Dektak 3ST is equipped with 26 different analytical functions for measuring surface texture. The following pages provide the abbreviation for each function as it appears on the screen, along with a brief description of the parameter.

If extensive surface texture analysis is planned, it is recommended that the ANSI B46.1 specification on surface texture be studied. A copy of this specification can be obtained from the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

Roughness Parameters

When calculating roughness parameters, the R and M cursors are used to define the assessment area of the profile trace. For the best results, the stage should be leveled and the scan trace should be software leveled prior to calculating any analytical function.

Max Dev	Maximum Deviation: Calculates the furthest data point above or below the mean line.
Max Ra	Maximum Ra: Identifies that portion of the assessment length which has the highest Ra. The assessment length, defined by the cursors, is divided into nineteen overlapping segments. Each segment is equal to one-tenth of the assessment length distance. The Ra is calculated for each segment. The R cursor will be positioned in the center of the segment with the highest Ra. Only one MRa is allowed me be programmed into a scan program.
Ra	Arithmetic Average Roughness: Formerly known as AA and CLA, Ra is the universally recognized, and most used, international parameter of roughness. It is the arithmetic average deviation from the mean line.
Rp	Maximum Peak: The maximum height or the highest peak of the profile roughness above the mean line, within the assessment length.
Rq	Root-mean-square (RMS): Determines the root-mean-square value of roughness corresponding to Ra.
Rt	Maximum Peak to Valley: The sum total of Maximum Peak and Maximum Valley measurements of roughness within the assessment length($RRRR = RRRR + RRRR$).
Rv	Maximum Valley: The lowest point, or the maximum depth of the profile roughness below the mean line, within the assessment length.
Rz din	Ten Point Height Average: The average height difference between the five highest peaks and the five lowest valleys in accordance with DIN 4768/1 specifications published by the Deutsche Institut fuer Normung c.v.
Skew	Skewness: The symmetry of the profile about the mean line. It will distinguish between asymmetrical profiles of the same Ra or Rq.

Waviness Parameters

When calculating waviness parameters, the R and M cursors are used to define the assessment area of the profile trace. For the best results, the stage should be leveled and the scan of the profile trace. For the best results, the stage should be leveled and the scan trace should be software leveled prior to calculating any analytical function.

Wa	Arithmetic Average of Waviness: The average deviation of waviness from the mean line (corresponds to Ra).
Wmaxdev	Maximum Deviation of Waviness: Measures the distance of the furthest data point above or below the mean line from the waviness profile (corresponds to Maximum Deviation of roughness).
Wp	Maximum Peak of Waviness: Measures the maximum height of the highest peak of the waviness profile, above the mean line (corresponds to Rp).
Wq	Root-Mean-Square of the Waviness: Determines the root-mean-square (RMS) value of waviness (corresponds to Wa).
Wt	Maximum Peak to Valley of Waviness: The sum total of the maximum peak and maximum valley measurements of waviness ($WWRR = WWRR + WWRR$).
Wv	Maximum Valley of Waviness: The lowest point, or the maximum depth of the waviness profile below the mean line (corresponds to Rv).

Step Height Parameters

When calculating step height parameters, the R and M cursors are used to define the assessment area of the profile trace. For the best results, the stage should be leveled and the scan of the profile trace. For the best results, the stage should be leveled and the scan trace should be software leveled prior to calculating any analytical function.

ASH	Delta Average Step Height: Used to obtain a step height measurement in applications where roughness or noise is present on the profile trace. It computes the differences between two average height measurements.
AVG HT	Average Height: Calculates the average height of a step, with respect to the zero line, using the R and M cursors to define the area of measurement.
PEAK	Maximum Peak: Calculates the maximum height above the baseline, as determined by the cursor/trace intercepts.
PV	Maximum Peak to Valley: Calculates the vertical distance between the maximum peak and maximum valley.
TIR	Total Indicated Reading: Calculates the vertical distance between the highest and lowest data points between the cursors
VALLEY	Maximum Valley: Calculates the maximum depth below the baseline, determined by the cursor/trace intercepts.