Apex Data Analysis Software - General Use With KLA-Tencor Surface Profilers

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Introduction

KLA-Tencor offers Apex as a data analysis software package that is used in addition to the profiler data acquisition software to add software analysis capabilities to its surface profilers. Apex was specifically developed for KLA-Tencor and it contains a range of software analysis features most commonly used in surface profiling. The Apex data analysis software package is an advanced data analysis package that includes algorithms developed to fully characterize surfaces. It includes features, like step height and waviness/roughness, Fast Fourier Transform (FFT) and Spatial Filtering. Many ISO parameters are available for a wide range of surface measurements across a multitude of applications.

Functionality

Apex is integrated into the native profiler software and can be accessed by pressing the icon. Alternatively scans can be exported as Simple Binary (.map format) and analyzed in Apex.

The Apex data analysis software uses the Operators tab to analyze the data and the Studies tab to display and take measurements on data sets.

This applications note elaborates on the most commonly used Apex Operators:

- Zoom
- Symmetries
- Leveling
- Line correction
- Roughness and Waviness
- Profile extraction
- Convert surface into a series of profiles
- Form Removal
- Line Removal

and Studies:

- 3D View
- Step Height 2D and 3D
- Distance measurements
- Abbott-Firestone Curve

Zoom

The Zoom operator enables the user to select an area in # of data points, µm or in percentile. The resulting surface will be the zoomed in surface included in the user selected area.

An example of the Zoom operator is shown in Figure 1 with the initial surface on the left side and the Zoomed in surface on the right.
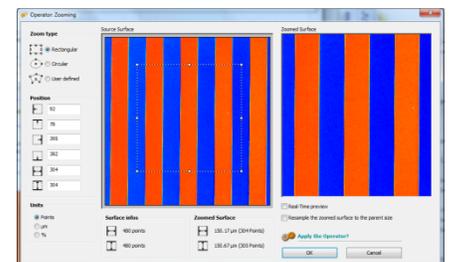
Figure 1 Zoom In Operator

The initial 237 x 237 µm surface is shown in Figure 2 with the selected Zoom area showing.
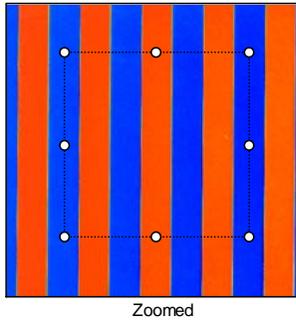
Figure 2 Initial 237 x 237 µm Surface

In Figure 3 the resulting Zoomed In 150 x 150 µm surface is shown.
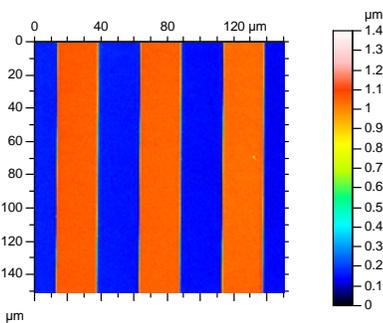

Figure 3 Zoomed in surface

Symmetries

The symmetries operator mirrors a profile along the X, Y and Z axis.

In Figure 4, the profile was mirrored along the X axis. The part of the profile that was a step height was changed to a trench. The same can be done along the Y and Z axis.
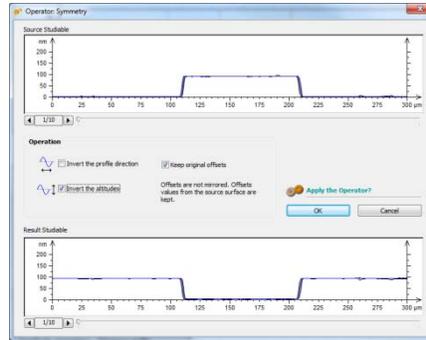

Figure 4 Symmetries Operator

Leveling

The leveling operator is used to level traces and surfaces using the software. Due to the vacuum stage and other sample effects, the scan traces or surfaces, most of the time, are not leveled and measuring the unleveled trace would yield incorrect results. Software leveling allows the user to level the data without any hardware adjustments.

The Apex 2D data analysis package offers multiple leveling methods that can be applied to best match the data. Besides the traditional two bars leveling method, Apex uses the Least Square Line and Minimum Zone leveling methods as shown below in Figure 5.
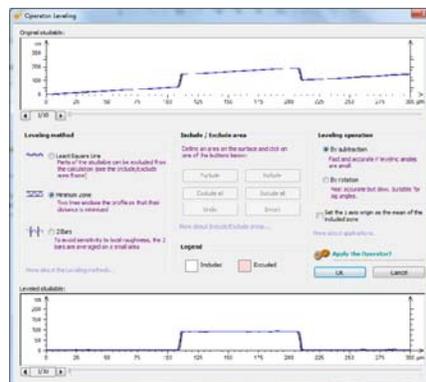

Figure 5 Single Leveled Scan

In Figure 6 a surface is leveled using the Least Plane Square. The layout displays the surface before and after the leveling operator has been applied.
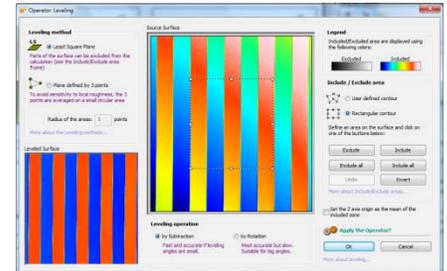

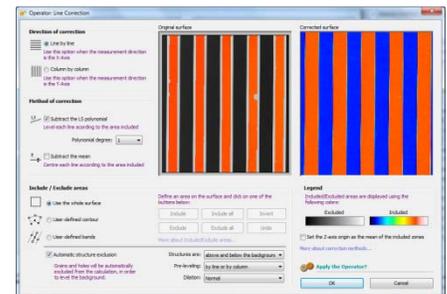**Figure 6** Surface Level

Line Correction

Figure 7 Line Correction Operator

The Line Correction operator is capable of correcting surfaces that show artifacts introduced by environmental or other factors. The operator levels the surface line by line or column by column where the user can exclude areas using an Automatic Structure Exclusion feature. Figure 7 shows an example of the Line by Line correction method.

Roughness and Waviness Filtering (2D and 3D)

When measuring roughness the user has to separate the waviness (low frequency) component from the roughness (high frequency component) in the trace. This

allows the roughness and waviness to be correctly measured using the roughness parameters (R) and the waviness parameters (W). To remove the waviness from the data the user will select the proper Gaussian filter at which point the data will be separated into roughness and waviness. The filter selection will depend on the scan length as well as on the surface topography and stylus used.

To properly demonstrate the Roughness/Waviness operator, different data sets are shown for the 2D and 3D examples.

In Figure 8, an 8 µm Gaussian filter was used to separate the waviness from the roughness component of the 2D data set. After the filter is applied, the high frequency component is considered to be the roughness while the low frequency component (red trace) is considered to be the waviness.

Figure 8 2D Roughness/Waviness Operator

In the case of a 3D roughness measurement the user can apply the appropriate filter and then measure the roughness on the filtered surface. In the event that the user does not know which filter to use to remove the

waviness, the Profile Extraction operator can be used to select a profile from the surface and do a 2D test that will help with the filter selection. In Figure 9 an 8 µm Gaussian filter was also used to separate the roughness and waviness. The starting surface and the two output surfaces (roughness and waviness) are shown to allow the user to select the appropriate filter.
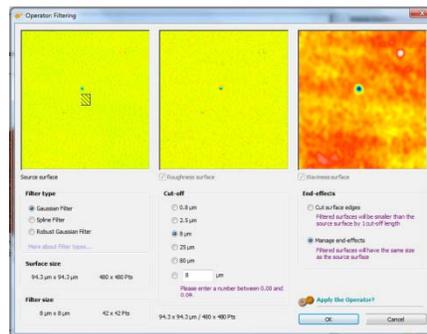
Figure 9 3D Roughness/Waviness Operator

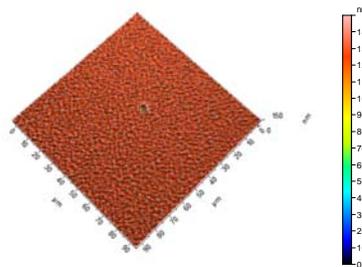Figures 10 and 11 show the roughness and waviness surfaces in 3D view.
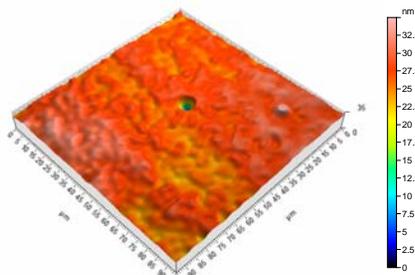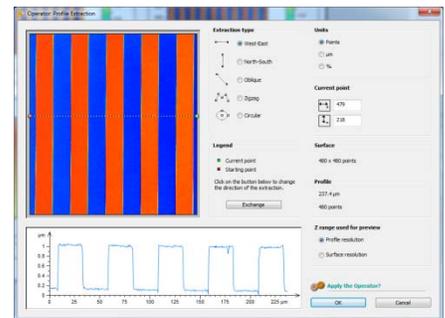
Figure 10 Roughness Alone

Figure 11 Waviness Alone

Profile Extraction

The Profile Extraction operator extracts a profile from a surface. The user can choose to extract the profile in the North-South, East-West, Oblique, Zig-Zag or User Selected way. The feature is used mostly to illustrate the profile of the surface at a certain location.

Screen Shot 8 Profile Extraction Operator

Convert Into A Series Of Profiles

The Convert Into A Series Of Profiles operator is using all the profiles comprising the surface to create an average profile and an envelope of all the profiles. This method of converting the surface into a series of profiles is an accurate method of measuring a surface height because it includes the entire surface by using all the profiles comprising it. In contrast by using one extracted profile, the user is focused on a specific location which is not always indicative of the entire surface.

Figure 12 shows the layout of the Convert Into A Series Of Profiles operator.
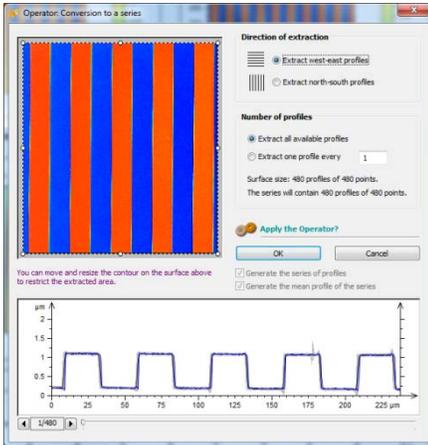
Figure 12 Convert Into A Series Of Profiles Operator

Form Removal

The Form Removal Operator removes polynomials up to the 13th order from a profile or surface. The user has the option of removing cylindrical and spherical shapes out of the data as well.

The operator has the ability to remove shapes from the surface which are induced by the environment or are tool related. Figure 13 shows the layout of the Form Removal operator.
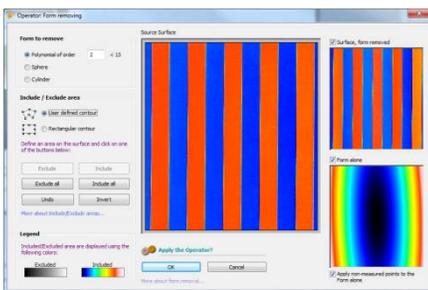
Figure 13 Form Removal Operator

Line Removal

The Line Removal allows for the correction of a surface by removing one or multiple unwanted scan lines. For example, due to environmental disturbances that are outside the operator's control, some bad scan lines could creep into the data being collected. The benefit of removing these unwanted scan lines from a data set is that the measurement does not have to be retaken because of one bad data line. Instead, the bad line is removed using the software and the statistics are not affected. Figure 14 shows the operator layout with the surface at the left, the line removal area in the center and the focus tool at the right. The user has the option of using Small, Medium or Large lines to represent the surface.


Figure 14 Line Removal Operator

3D View

The 3D viewer looks at the data from different angles. It enables the user to change the material, lighting condition, height amplification, zoom in distance, and others. The advantage of the 3D viewer is that the user can enhance features that are visible from other angles other than the top view.

Figure 15 show a surface using the Apex 3D viewer.
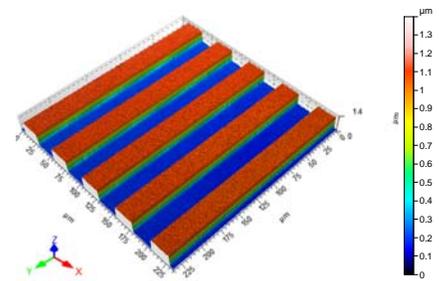
Figure 15 3D View Studies

Step height Measurement (2D and 3D)

The 2D Step Height measurement measures the height of features in a profile. The software has three measurement methods:

- Automatic (allows for multiple features to be measured and the results averaged)
- ISO (uses an ISO defined method of leveling and step height measurement)
- Manual (uses manually placed cursors to measure the features – up to 3 pairs of cursors.)
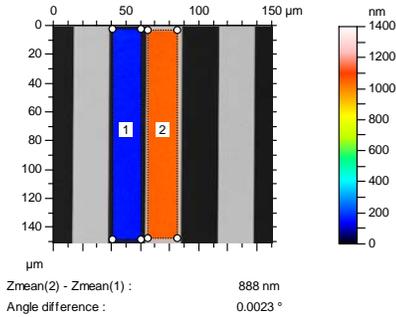
Figure 15 show a step height measurement using the automatic method on a single profile.
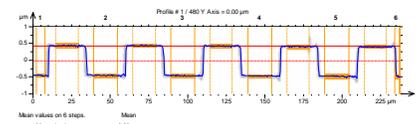
Figure 15 2D Step Height Measurement – Automatic Method

The 3D Step Height measurement measures the height of the features in a surface by manually selecting areas (Area 1 and Area 2). The 3D Step Height measurement is done

based on the difference in height between Area 2 and Area 1. Figure 16 show the 3D Step Height Measurement layout.
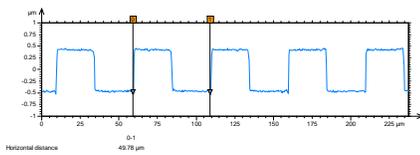

Zmean(2) - Zmean(1) :   888 nm
Angle difference :   0.0023 °

Figure 16 3D Step Height Measurement
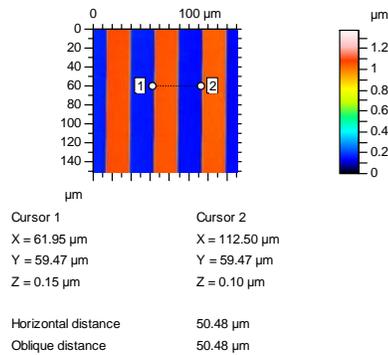
Distance Measurements

The distance measurement tool measures the length between features in a profile or in a surface.

Figure 17 shows the Distance Measurement on a profile.

Figure 17 Distance Measurement Studies

Figure 18 shows the Distance Measurement tool on a surface.

Cursor 1   Cursor 2
X = 61.95 µm   X = 112.50 µm
Y = 59.47 µm   Y = 59.47 µm
Z = 0.15 µm   Z = 0.10 µm

Horizontal distance   50.48 µm
Oblique distance   50.48 µm

Figure 18 3D Distance Measurement

Abbott-Firestone Curve

The Abbot-Firestone curve shows the data distribution of points over a curve. It is similar to a histogram type of data representation where the user can find out what percentage of the data lies at what height in the surface.

Figure 19 shows an Abbott-Firestone curve representation of a step height surface.
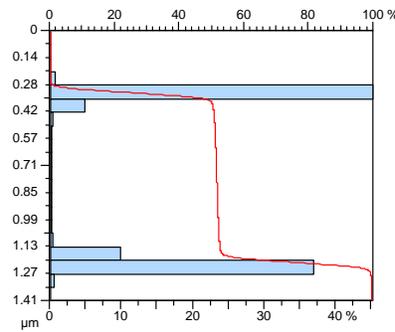
Figure 19 Abbott-Firestone Studies

Conclusion

The Apex data analysis software package offers additional tools and features to the ones already existent on the acquisition software on the system.

The Operator and Studies tabs presented in this apps note are only a few of the many offered.

The full set of analysis tools and the easy to use features of the software make it a great tool for any level of users from research to production environments.