

Zeta-20 Optical Profiler

OPERATION MANUAL



ZETA
ZETA INSTRUMENTS

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For software versions 1.6 or later

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Safety

Compliance

The Zeta-20 system complies with the following international regulations:

EN 61326-1: 2006

IEC 61326-1: 2005

EN 61000-3-2: 2006

EN 61000-3-3: 2008

Safety

The Zeta-20 is safe when operated as instructed. Observe the following guidelines:

- Keep fingers away from moving parts.

24V power supply

The Zeta-20 is powered by a 24V power supply that can provide different voltage levels.

Before powering up the system, check the switch on the power supply to make sure that the switch is at the 24V output. The switch should be in the far right position, as shown in Fig. 1.



Fig. 1. Configurable power supply

AC power supply

By configuring the computer's AC input select switch, the Zeta-20 can operate with AC voltage of either 100-120V or 200-230V. The 24V power supply and the monitor can accept the different AC voltages without any change, but the computer must be configured correctly.



Caution

Before powering up the system, check the computer's AC select switch before plugging in the AC power cord. The computer will be damaged if the switch is not set correctly.

For 100V to 120V AC power (nominal 115V):

With a tool such as a flat blade screwdriver, move the horizontal bar to the bottom position. You will see "115" in the top opening (see Fig. 2).

For 200V to 230V AC power (nominal 230V):

Move the horizontal bar to the top position. You will see "230" in the bottom opening (see Fig. 2).

115V position

230V position



Fig. 2. Computer AC select switch

CHAPTER 1 **Introduction**

The Zeta-20 Optical Microscope is a fully integrated microscope based system that provides 3D imaging and metrology capability in a small, robust and cost effective package. Based on proprietary technology, the Zeta-20 enables imaging of surfaces with very low reflectivity and very high roughness.

Topics in this chapter:

- 1.1 Principle of operation
- 1.2 System description

1.1 Principle of operation

Conventional microscopes have a very limited depth of focus. Test surfaces and features are clearly visible only when they are within the focal depth. The Zeta system scans a sample over a user specified vertical (or Z) range. At each Z position, it records the XY location and the precise Z height of the pixels using the Zeta Optics Module. This information is used to create a true color 3D image and a 2D composite image. The resulting image has an extended depth of focus so the entire surface is seen clearly. The Zeta 3D software can be used to ascertain dimensional and roughness information. An optional film thickness module allows calculation of transparent layer thicknesses on the surface.

Fig. 3 shows a comparison between a conventional microscope image and Zeta images. The microscope image is in focus for only part of the image, while the Zeta 2D image is in focus for the entire image.

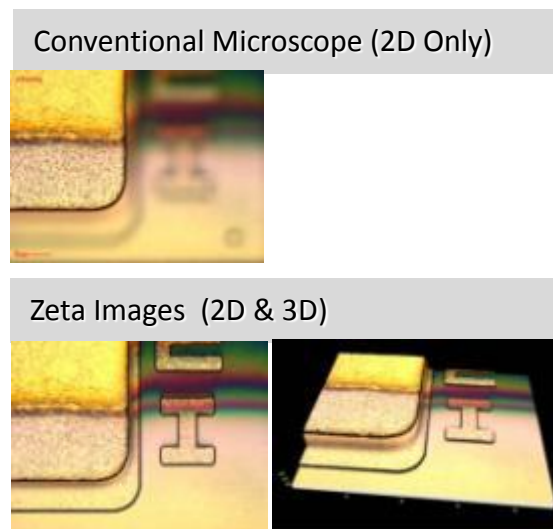


Fig. 3. Comparison between microscope and Zeta images

1.2 System description

Overview

The Zeta-20 Optical Microscope system is shown in Fig. 4. It consists of:

- A microscope unit with proprietary Zeta hardware modifications
- A Windows-based computer and high-resolution monitor
- Zeta 3D imaging and analysis software



Fig. 4. Zeta-20 system

Parts of the system

Fig. 5 shows the parts of the Zeta-20 measurement station. They are:

1. CCD Color Camera to capture sample images and focus map data
2. Zeta Optics Module, containing the focus map signal generator, a high intensity white light LED to preserve sample color, and a high efficiency optics design to optimize illumination
3. Precision Z-drive mechanism for sub-micron vertical resolution
4. Zeta Control Box, containing the controller for the Z-drive and optics module electronics

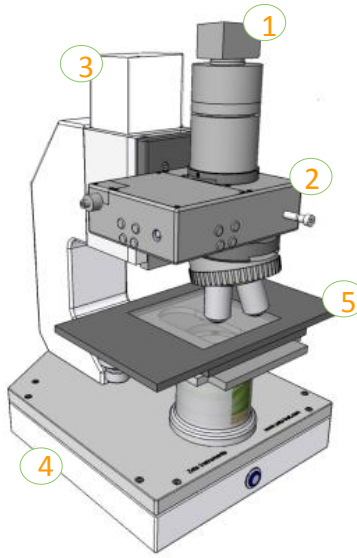


Fig. 5. Schematic view of Zeta-20 measurement system

Objective specifications

Imaging can be performed with different magnifications depending on the requirements for resolution and field of view. Table 1 provides specifications for standard objectives.

Table 1. Specifications for common objectives

	NA	Working distance (mm)	Z resolution (μm)	XY resolution (μm)	Optical resolution (μm)	FOV with 0.35X coupler		FOV with 0.5X coupler	
						1/3" camera	2/3" camera	1/3" camera	2/3" camera
2.5X	0.08	10.7	22	3.60	4.20	5364 × 4024	9394 × 7044	3788 × 2840	6614 × 4960
5X	0.15	20.0	5.9	1.80	2.20	2682 × 2012	4697 × 3522	1894 × 1420	3307 × 2480
10X	0.30	11.0	1.5	0.90	1.10	1335 × 1000	2327 × 1745	944 × 708	1644 × 1233
20X	0.45	3.1	0.5	0.45	0.75	668 × 500	1169 × 877	468 × 351	822 × 616
50X	0.8	1.0	0.1	0.18	0.42	267 × 200	466 × 349	189 × 142	328 × 246
100X	0.9	1.0	0.01	0.09	0.37	133 × 100	234 × 175	93 × 70	164 × 123
150X	0.9	1.0	0.01	0.06	0.37	88 × 66	156 × 116	62 × 46	109 × 82

CHAPTER 2 **System startup and Zeta 3D software**

Zeta 3D software is an essential part of the Zeta-20 system. It runs the hardware, analyzes the results, and provides ways to customize system operation.

Topics in this chapter:

- 2.1 System startup
- 2.2 The initialization file
- 2.3 Software appearance and organization
- 2.4 Image and analysis file operations
- 2.5 Recipe file operations

2.1 System startup

Before you start

Do not place a sample on the platform until the system has been initialized.

If the auto-turret option is not installed, rotate the turret to place the lowest magnification objective (for example, 5X) into the vertical position for measurement.

If the auto-turret option is installed, the turret will rotate one position during initialization.

Powering up and logging in

1. Power up the computer. The Windows password is set at the factory to "Zeta."
2. Power up the Zeta-20 by pressing the round button on the front of the base. It glows blue when the system is powered up.
3. Wait two minutes for the computer to recognize all serial ports.
4. Double click on the "Zeta 3D" icon in the center of the screen to start the Zeta 3D software.
5. Log in to the Zeta 3D software in the popup window shown in Fig. 6. The user name and password are set to "a" at the factory but you may have other user accounts on your system.

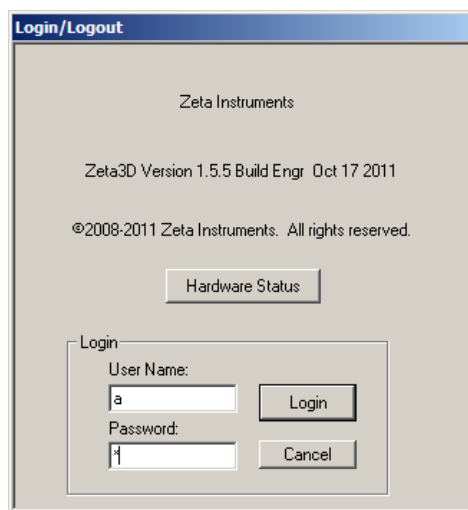


Fig. 6. Zeta3D software login screen

The "Hardware Status" button in the login screen tells you which hardware options are recognized. One example is shown in Fig. 7.

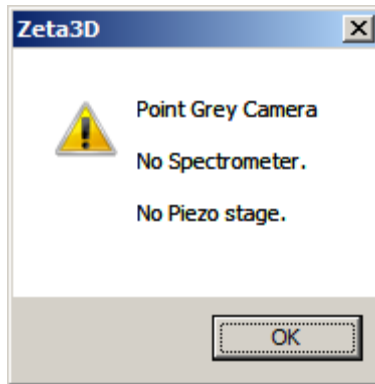


Fig. 7. Hardware status

Initialization

The system next performs initialization, which includes the following operations:

- Verify the initialization file settings
- Initialize moving parts, if installed: the Z stage, the XY stage, the automatic turret, and the cassette handler

Verification of settings in initialization file

If the camera and coupler match the initialization file (*Zeta3D.ini*), the system proceeds directly to Z stage initialization. However, if a mismatch is detected, the message in Fig. 8 appears.



Fig. 8. Camera mismatch notification

To correct the settings, do the following:

1. Press **OK**. The *Optical Setup* popup window shown in Fig. 9 appears. These settings must be correct in order to make accurate measurements.

NOTE: The format of the *Zeta3D.ini* file has changed. If you run Zeta3D software version 1.5.5 (or later) for the first time, or if you use an old *Zeta3D.ini* file, a popup message appears, as shown in Fig. 10. Press **OK** to convert the file into the new format.

2. Choose the correct settings for the camera, coupler, and turret from the pulldown lists at the top of the window.
3. Verify the objective settings. If needed, change any of the objective settings using the pulldown menu for each turret position. Enter the resolution value in microns per pixel for any new objectives. The column for Z calibration is used only for special purposes.

4. Press **OK**. Another popup window asks whether to save the settings into the *Zeta3D.ini* file.
5. Choose whether to save the new settings in the *Zeta3D.ini* file by clicking **Yes** or **No**. If you choose **No**, the system will operate with the new settings until the next time the system is powered down, but the settings will not be saved.

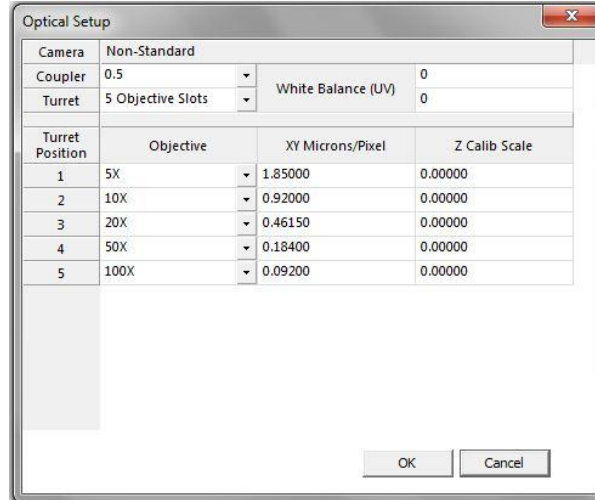


Fig. 9. Optical Setup dialog

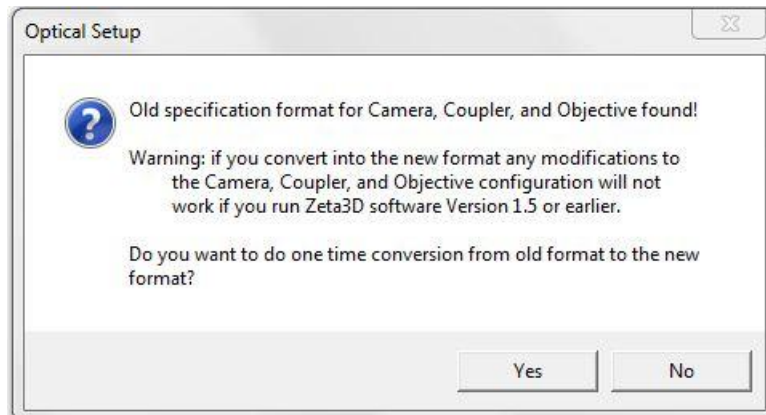


Fig. 10. New file format notification

Initialization of moving parts

To warn you that the system will move during Z stage initialization, the message in Fig. 11 appears.

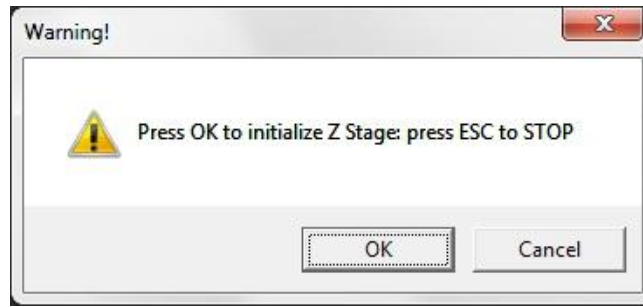


Fig. 11. Z stage initialization warning

Press **OK** to continue. Press the **ESC** key only if there is a problem, for example if the Z stage moves down instead of up.

The optical assembly, including the objectives and optics module, moves up to locate the Home sensor. After the Home sensor is located, the Z stage performs a slower motion for more precise location of its Home position. The Z stage finishes the initialization by moving down to a preset position.

The system next performs initialization of options that include moving parts, such as automatic turret initialization. A warning message appears to inform you that the system will move.

After initialization is complete, the Zeta 3D software starts up on the *Live Video* screen. A pop-up window named *Scan Dialog* also appears, as shown in Fig. 12. Note that the *Scan Dialog* window is a fixed size and may not fill up the screen vertically (as shown here) if a larger monitor is in use.

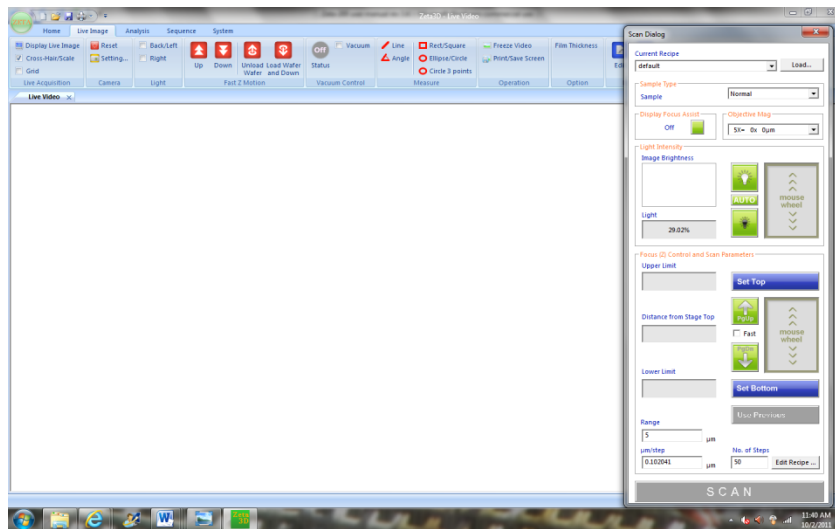


Fig. 12. Initial software screen

Load a recipe by selecting one from the pull-down list at the top of the *Scan Dialog* window. You are now ready to begin using the system.

2.2 The initialization file

Many software and hardware settings are defined in the initialization file. This file is named *Zeta3D.ini* and is located in the *System* folder.

Most of the settings can be edited within the Zeta3D software. If necessary, the file can be edited directly using a text editor. You must have System Administrator privilege to edit the System Setup.

- Keep a backup copy of the initialization file in case of file corruption or improper editing.
- Do not change parameters unless you have instructions for the correct values.

Improper settings in the initialization file will not damage the system. However, improper settings may affect the operation of the system and the validity of the measurements.

To edit the file, select the System tab and the System Setup button from the top left corner of the Zeta3D software screen, as shown in Fig. 13.

The initialization file parameters appear in a popup window with the title *Edit System Parameters*. There are four sets of parameters: *system_spec*, *stage_spec*, *objective_spec*, and camera specifications.

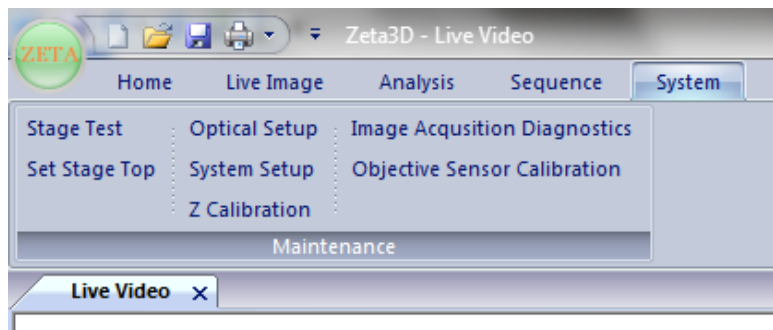


Fig. 13. System setup button

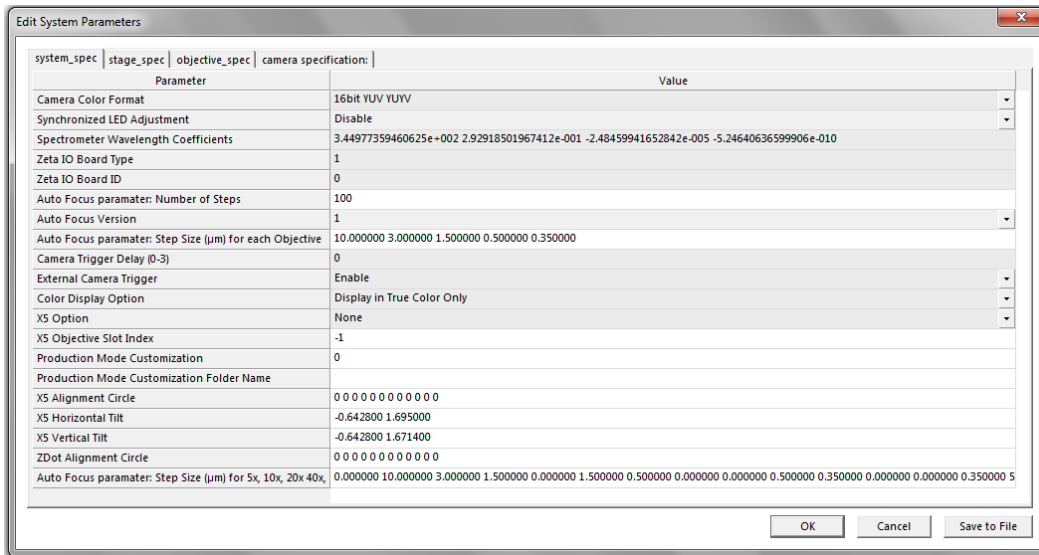


Fig. 14. System parameter editing window

The system_spec parameters are shown in Fig. 14. The other three sets of parameters are similar.

Some parameters have pulldown lists, while others require entering a value into the field. Some changes take effect immediately, but others require that you save the file and restart the software.

After you edit critical parameters, a message pops up to tell you to save the file and restart the software, as shown in Fig. 15.

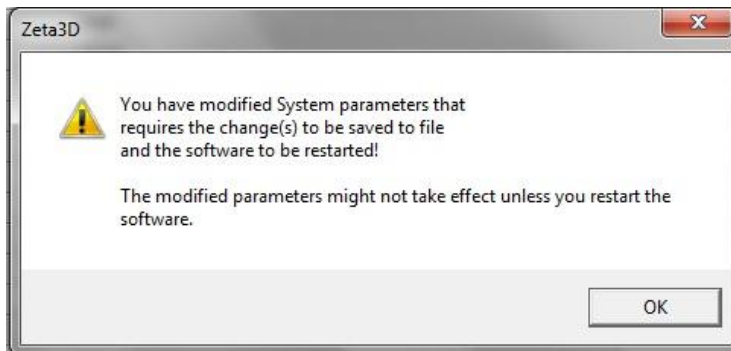


Fig. 15. System parameter change notification

2.3 Software appearance and organization

Zeta 3D software includes many functions. Understanding the software organization and the names of different parts of the software will help you to navigate through it.

Quick access toolbar

The upper left corner of the screen contains a toolbar which contains icons to select frequently used computer operations, as shown in Fig. 16. Customize the toolbar by clicking on the down arrow at the far right side.

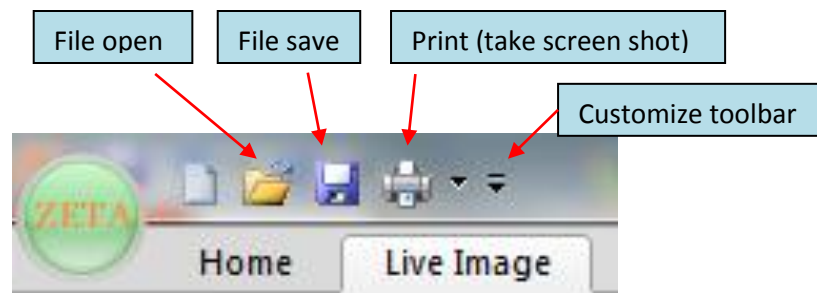


Fig. 16. Quick access toolbar

Tabs, ribbons, and groups

Fig. 17 shows the top left corner of a typical Zeta-20 screen. The top level of organization is a *tab*. Functions within a tab are shown in a *ribbon* of commands. You can choose to hide or display the ribbon by double-clicking on the tab name.

Each tab ribbon contains several *groups* of functions and each group contains active items such as buttons, checkboxes, or fields for data display or data entry.

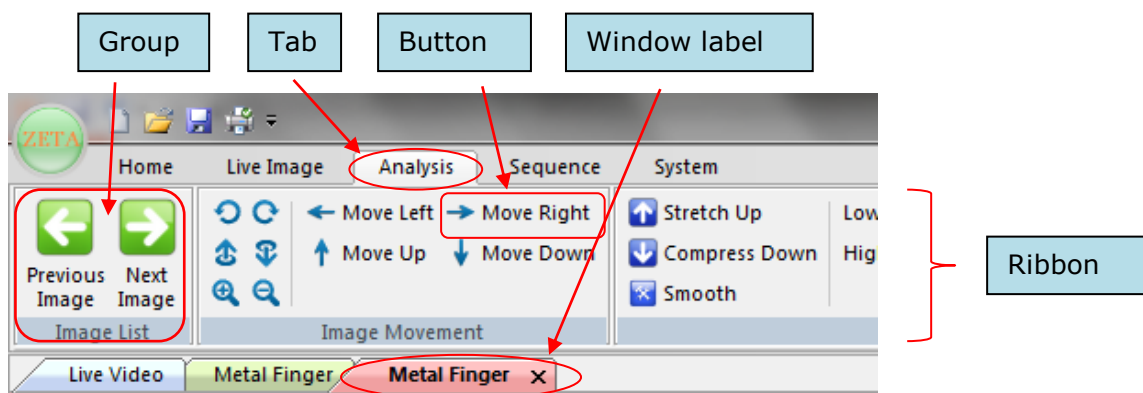


Fig. 17. Zeta3D screen detail with naming conventions

The main part of the screen contains one or more *windows* which contain the measurement results. Fig. 18 shows an example.

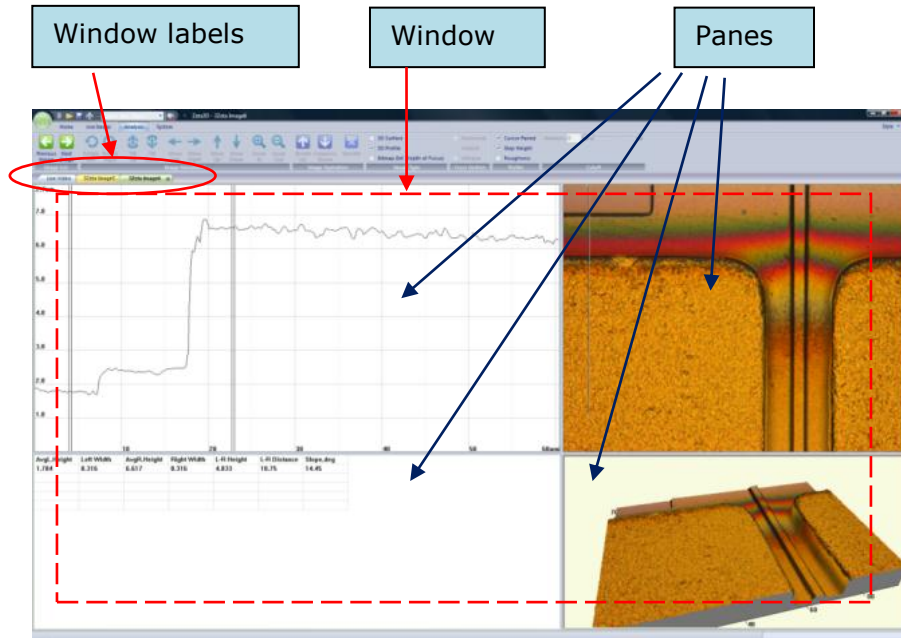


Fig. 18. Example Zeta 3D display screen showing panes in analysis window

Windows and panes

Every window has a colored label at the top. The first window, which is located at the far left side, is usually the live video window and is labeled *Live Video*.

There are three other types of windows: 3D images, 2D composite images, and analysis windows. The maximum number of different windows for each scan is three (one for each of the three types) and all related windows have the same window label. There is no limit (besides computer memory) to the number of windows which can be open at the same time.

Window label colors are used to help separate them but do not have any specific meaning. If a 3D image from a scan has not been saved, the window has a default name such as “3ZetaImage2” with no extension. If the image has been saved, the window name is the file name with the extension of *.zmg*.

If you perform a new scan or open a saved image file, a new 3D image window with a new name appears to the right of the existing windows. Analysis windows for the new image have the new image name.

Operations on windows:

- Select a window to make it active by clicking on its label. Three things happen: the label changes shape to indicate that it is the active window, an X appears to the right of the window label, and the window name is written at the top of the screen.
- Change the order of the windows by dragging the active window to the right or left.
- Show a list of all windows by clicking on the down arrow at the far right of the window labels.
- Compare windows by dragging any window label down into the display area. The display area splits into separate parts, each showing a different window. You may need to use scroll bars to adjust how the window is positioned within the new display area. To return to a single display area, drag all of the window labels to one side.
- Click on the X next to a window label to close it.

Most analysis windows are divided into sections called panes. Every pane has a specific purpose, but different applications may use panes in different ways.

You can drag the pane boundaries to adjust the pane sizes to change the appearance of a screen capture. However, the size adjustment cannot be saved.

The software makes extensive use of situational menus. If you click the right mouse button, a menu appears which contains items that are appropriate for the object under the cursor.

You can change the overall appearance of the screens by choosing different Microsoft Office styles through a pulldown list at the far right of the screen.

2.4 Image and analysis file operations

File types

Zeta 3D software uses several types of computer files to store measurement and analysis results.

(a) Image files (file extension **.zmg*)

An image file contains the raw data from a measurement scan. It can be viewed and analyzed in two-dimensional (2D) and three-dimensional (3D) ways. This is the only file type that can be fully reanalyzed later.

(b) Display files (**.bmp*, **.jpg*, and **.png*)

2D and 3D sample views are very useful for reports.

A bitmap (**.bmp*) file is an uncompressed format with one pixel per measurement pixel, which provides the highest quality picture.

A JPEG (**.jpg*) file is a lossy compressed format which produces the smallest file size with a reasonable quality picture.

A PNG (**.png*) file is a lossless compressed format which is set to have a transparent background. This is useful for capturing 3D objects without the screen background.

(c) TIFF files (**.tif*)

This is a type of 2D display file which is saved with calibration information to preserve accurate lateral dimensions.

(d) Results files (**.txt* and **.csv*)

Numeric results on the screen may be saved as screen shots in JPEG files. However, in order to import the numbers into a spreadsheet or word processing program, other file types are required.

Text files (**.txt*) contain simple text that includes headings, punctuation marks, and spaces. Text files have an appearance similar to the results on the screen and can be printed.

Comma separated value files (**.csv*) contain numbers separated by commas to make it easy to import the values into Microsoft Excel.

How to open a saved file

You can reopen a saved image data file (**.zmg*) within the Zeta software and reanalyze it. You can also reopen a saved TIFF file (**.tif*) in order to use the 2D dimensional analysis tools. You cannot reopen a picture file (**.jpg*, **.bmp*, or **.png*) within the Zeta software.

To open a file:

1. Click on the *File open* icon shown in Fig. 16 to start the Windows file open dialog.
2. Browse to the folder containing the target file.
3. Choose an option from the *Save as Type* list, as shown in Fig. 19. There are three options for opening *.zmg files. These options control the appearance of the screen when the file is opened, but do not change the underlying raw data. "Zeta Image File" displays a 3D image window, "Zeta Image Profile File" displays a default step height analysis window, and "Zeta Image (bitmap) from 3D Surface file" displays a 2D image window.

NOTE: Once the file is open, you can easily change between the 3D, 2D, and analysis windows.

4. Choose a file and double click on the name, or click the **Open** button.

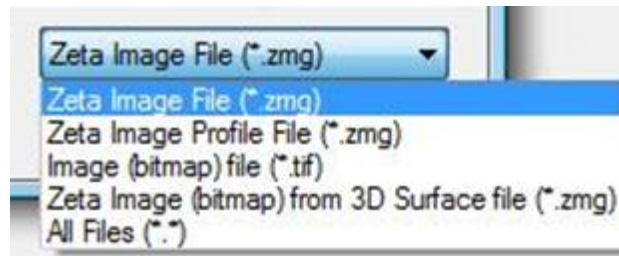


Fig. 19. Options for opening image files

In addition, whenever the Zeta software is running, you can double click on any *.zmg file name within Windows Explorer. The image will open in 3D view mode.

How to save a 3D image data file

Start the file save procedure in either one of these ways:

- Click the *File save* icon in the Quick Access Toolbar when a 3D image is displayed.
- Right click on a 3D image to open a menu, then select *Save as ZMG*.

Both options cause the Windows file save dialog to appear. To save the file:

1. Browse to the desired folder location.
2. Enter a meaningful file name. The *Save as Type* field is set to the only option, which is Zeta Image File (*.zmg).
3. Click the **Save** button.

How to save a 2D image data file

Right click on a 2D image view to see the menu, then select *Export to Bitmap*. The Windows file save dialog appears.

To save the file:

1. Browse to the desired folder location.
2. Choose *Save as Type* *Imgfile (*.tif, *.jpg)*.
3. Enter a meaningful file name and include the extension of the desired file type.
4. Click **Save**.

Both of these options create an image that is a little larger than the 2D view you see on the screen. You may need to crop the edges if you use the file as an illustration in a report.

How to save a screen shot

To capture a screen shot:

1. Click on the *Print* icon in the Quick Access toolbar to start the Windows print dialog shown in Fig. 20.
2. In the printer name pull-down list, select *Microsoft XPS Document Writer*.
3. Check the box labeled *Print to File* and press **OK**. The Windows file browser appears.
4. Select the folder where you would like to save the file.
5. Enter a file name and choose a file type (JPEG, bitmap, or PNG), then click **Save**.

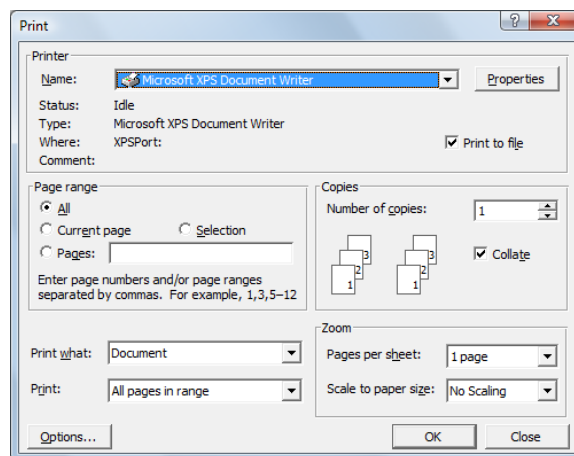


Fig. 20. Print dialog for screen shots

This operation saves the analysis window without the software toolbar. If you want to include the software toolbar or to capture the appearance of a pop-up window, use the **PrntScr** key on the keyboard instead.

How to export analysis results

Analysis data appears in the *Analysis Report* pane in a spreadsheet format. To export the data to another program such as a word processor or spreadsheet program:

1. Right-click within the report pane and select *Save to File*.
2. Choose the desired file type from the pull-down menu labeled *Save as Type*. The choices are "Tab-separated text file (*.txt)" and "Comma-separated text file (*.csv)."
3. Browse to the desired folder location and enter a file name (without an extension).
4. Click the **Save** button.

Export graph data

The data points behind most graphs may be exported in comma separated values (CSV) format. To export the data for one profile:

1. Click on a cross section within the *2D Composite View* pane to make it the current one.
2. Right click within the *2D Line Profile* pane to bring up a menu and select *Export to CSV file*.
3. Browse to the desired folder location and enter a file name (without an extension).

2.5 Recipe file operations

A recipe file contains instructions for performing a scan and analyzing the results.

Find and open a recipe

There are two ways to browse through folders to locate a saved recipe:

- Click the **Load** button in the *Recipe* group of the *Live Image* tab, shown in Fig. 21.
- Press the **Load** button in the *Scan Dialog* window (discussed in Chapter 3).

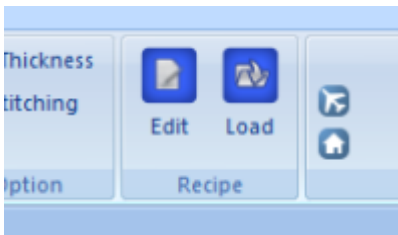


Fig. 21. Recipe buttons in Live Image tab

The *Open* dialog shown in Fig. 22 appears. Recipes may be located at the top level of the browse window or in folders below this level. Recipes in any other folders will not be recognized.

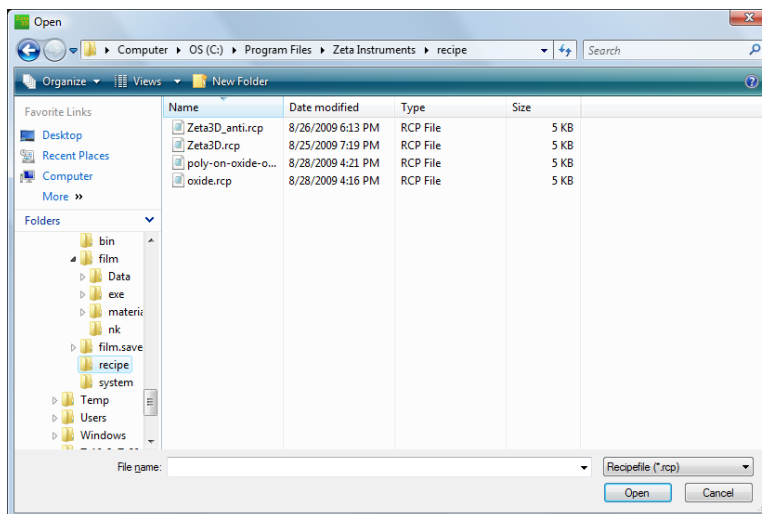


Fig. 22. Recipe Load dialog

Click on a recipe file name to highlight it, then press the **Open** button at the bottom of the window. You may also double-click on the recipe name.

Recipes at the top folder level may also be selected using the pull-down list at the top of the *Scan Dialog* window.

Edit and save a recipe

There are two ways to open a recipe for editing:

- Click the **Edit** button in the *Recipe* group of the *Live Image* tab, as shown in Fig. 21.
- Press the **Edit Recipe** button in the *Scan Dialog* window.

Specific recipe parameters are discussed later in this manual.

After editing the recipe, click on the **SaveToFile** button within the *Recipe Edit* window. The *Save As* window as shown in Fig. 23 appears. In the *File name* input field, type in the recipe name and click **Save**.

You may create folders under the top level of the browse window for recipe organization.

Recipe files must have an extension of **.rcp*. Do not change the file extension.

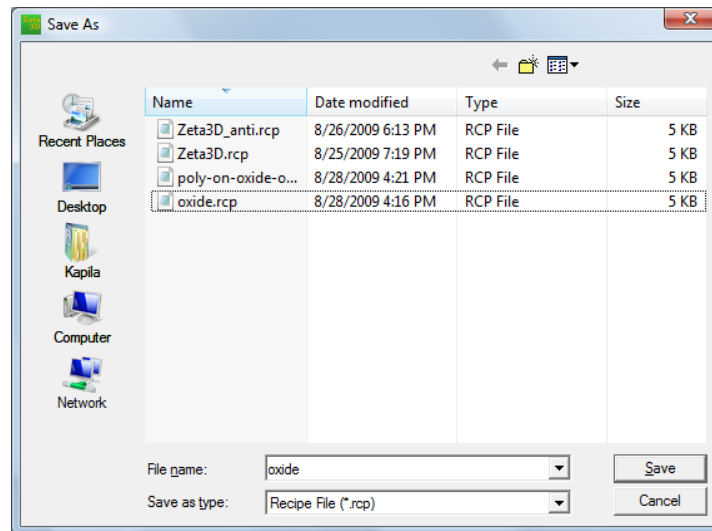


Fig. 23. Recipe save dialog

CHAPTER 3 **Scanning**

The primary goal of the Zeta-20 system is to create high-resolution three-dimensional images that can be used for analysis of step height, roughness and other properties. This chapter tells you how to take manual scans of a sample on a standard Zeta-20 system. Later chapters cover scanning with other hardware configurations (Chapter 4) and analysis of the scans (Chapter 5).

In this chapter, the words "wafer" and "sample" are used interchangeably.

Topics in this chapter:

- 3.1 Taking a single scan
- 3.2 Stitching
- 3.3 Moving and unloading the sample

3.1 Taking a single scan

Before you start

Power up and initialize the system before placing a sample on the stage.

If the auto-turret option is not installed, rotate the turret to place the lowest magnification objective (for example, 5X) into the vertical position for measurement. After initialization, select the lowest power magnification in the *Scan Dialog* window.

If the auto-turret option is installed, the turret will rotate one position during initialization. After initialization, select the lowest power magnification in the *Scan Dialog* window to move it into the measurement position.

Loading the sample

1. Place the sample in the center of the stage.
2. Use the stage control knobs to position the approximate location of interest under the objective.
3. Click the **Down** button in the *Fast Z Motion* group located in the *Live Image* tab, as shown in Fig. 24. Alternatively, press the keyboard **F4** key which is equivalent to the **Down** button.



Fig. 24. *Live Image* tab showing Up and Down buttons

4. When prompted by the on-screen message (shown in Fig. 25), press the keyboard space bar to move the optical head to the default coarse focus position. The head stops when it reaches a preset safe position.

If installed, the stage vacuum turns on before the optical head moves downward. The *Vacuum* checkbox in the *Vacuum Control* group becomes checked and the *Status* indicator turns green.

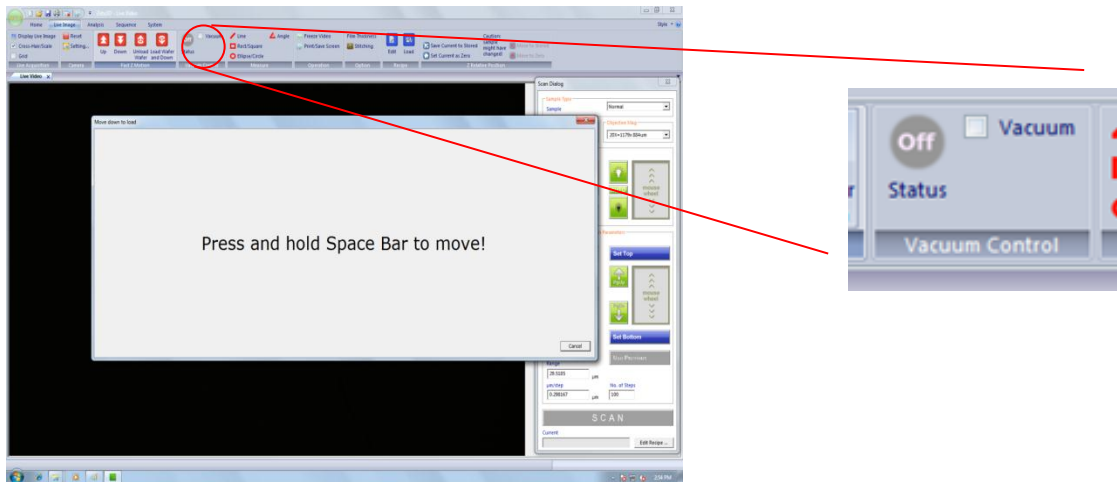


Fig. 25. Message to move to focus position and Vacuum Control group

Focusing on the sample

A live video image window is displayed on the screen. A dialog box titled *Scan Dialog* appears on the right side, as shown in Fig. 26. However, the image is not usually in focus at first.

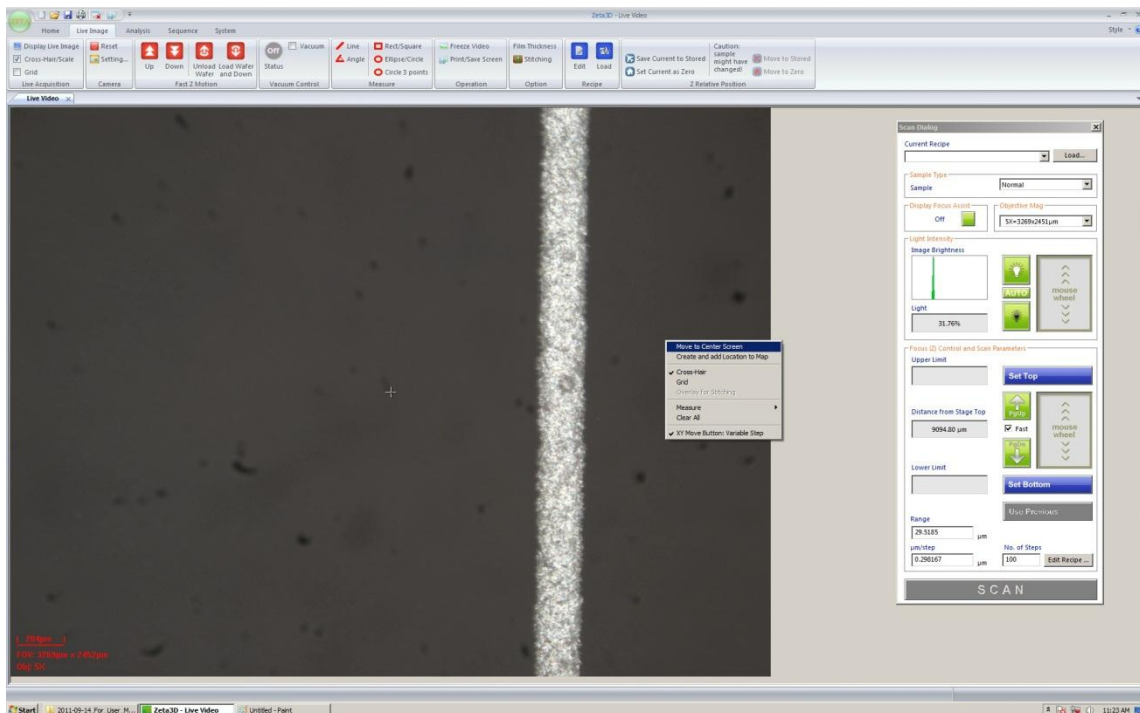


Fig. 26. Live video image window with right-click menu and Scan Dialog window

To find the focus position, follow these steps:

1. Select the sample type in the first frame of the *Scan Dialog* box, as shown in Fig. 27.
 - Choose “Normal” for most samples.
 - Choose “High” for very reflective surfaces such as metal films.
 - Choose “Low” for low reflectivity surfaces such as anti-reflective coatings.
2. If the Auto-Turret option is not installed, verify that the objective magnification in the *Scan Dialog* matches the physical objective setting, which should be at the lowest magnification level to start. If the optional Automatic Objective Sensor is installed, the system recognizes which objective is in place and changes the drop-down menu selection automatically.

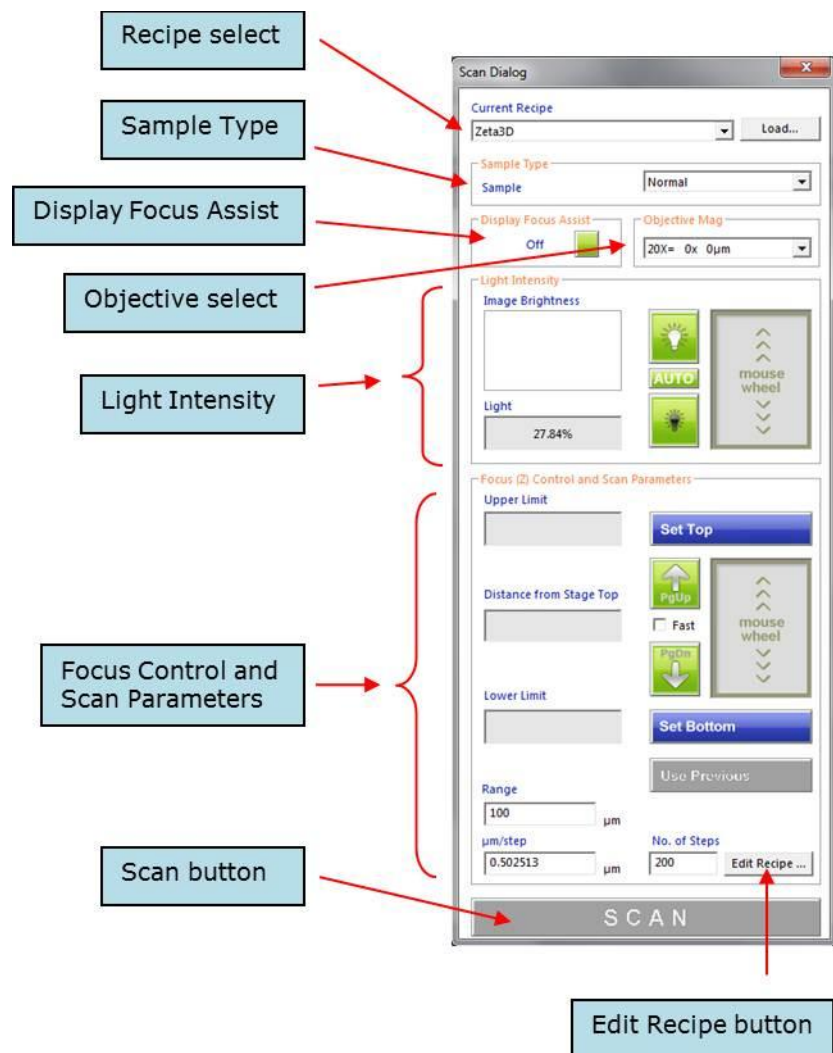


Fig. 27. Detail of frames in Scan Dialog box

3. Find the focus position at low magnification by moving the optical head up and down. Watch the live video image to optimize the image sharpness.

NOTE: Be careful not to crash the optical head into the sample. If you cannot see an image in the live video window, look at the objective to make sure that its height above the sample is approximately the same as the expected working distance.

- To move the head slowly, place the cursor inside the focus mouse wheel box and roll the mouse wheel in either direction.
- To move the head at a medium speed while focusing, click on the **PgUp** or **PgDn** buttons on the screen, or press the corresponding keys on the keyboard.
- To move the head quickly while loading or unloading samples, use the keyboard **F3** key or the **Up** button in the toolbar to move the head up, and the **F4** key or the **Down** button to move the head down.
- When the head is close to the sample, uncheck the checkbox labeled "Fast" in the *Scan Dialog* to reduce the Z movement speed in all mouse and button operations.
- To center a feature in the live video window, right click within the window and select the *Move to Center Screen* option, as shown in Fig. 26.

4. Change the illumination level to improve the image.

- a. Place the cursor inside the mouse wheel box in the *Light Intensity* frame and move the mouse wheel back and forth.
- b. To change the settings more quickly, use the **Home** and **End** keys instead of the mouse wheel.
- c. Stop when the green histogram peak is approximately in the center of the histogram box.

5. If you have trouble finding the focus on a featureless surface such as a clean silicon wafer or mirror surface, use the *Focus Assist* feature.

- a. Click the square green button in the *Display Focus Assist* frame in the *Scan Dialog* box. The status indicator changes to "On."

Focus Assist projects a grid of dots (known as Z-dots) onto any surface located at the focal plane of the objective. If there is a surface in focus in the current field of view, the dots will be visible and in focus. If there is no surface in focus, the dot grid will be out of focus or not visible. An example is shown in Fig. 28.

- b. Use the focus controls to move the optical head up and down, and choose a position that puts the desired surface in focus (in other words, makes the dots visible and in focus on the surface of interest).
- c. If the image appears dark, change the illumination by placing the cursor inside the mouse wheel box in the *Light Intensity* frame and moving the mouse wheel back and

forth. Stop when the green histogram peak is approximately in the center of the histogram box and the dot grid is in focus.

- d. Turn *Focus Assist* off when finished.



Fig. 28. Z-dots produced by Focus Assist

6. Decide if higher magnification is required for the measurement. The decision is largely determined by the Z resolution and the field of view required for the sample. Table 2 lists the Z resolution, working distance, and field of view of five commonly used objective lenses.
7. If higher magnification is needed, do the following, select the new magnification in the *Scan Dialog* box. If Auto-Turret is installed, the physical objective will be changed to match it. If Auto-Turret is not installed, then physically rotate the turret to the new objective.
8. Use the focus controls to find the focus position.

Table 2. Properties of objective lenses

	NA	Working distance (mm)	Z resolution (μm)	XY resolution (μm)	Optical resolution (μm)	FOV with 0.35X coupler		FOV with 0.5X coupler	
						1/3" camera	2/3" camera	1/3" camera	2/3" camera
2.5X	0.08	10.7	22	3.60	4.20	5364 × 4024	9394 × 7044	3788 × 2840	6614 × 4960
5X	0.15	20.0	5.9	1.80	2.20	2682 × 2012	4697 × 3522	1894 × 1420	3307 × 2480
10X	0.30	11.0	1.5	0.90	1.10	1335 × 1000	2327 × 1745	944 × 708	1644 × 1233
20X	0.45	3.1	0.5	0.45	0.75	668 × 500	1169 × 877	468 × 351	822 × 616
50X	0.8	1.0	0.1	0.18	0.42	267 × 200	466 × 349	189 × 142	328 × 246
100X	0.9	1.0	0.01	0.09	0.37	133 × 100	234 × 175	93 × 70	164 × 123
150X	0.9	1.0	0.01	0.06	0.37	88 × 66	156 × 116	62 × 46	109 × 82

Working with the live image

The live image always appears under the window label *Live Video*. The *Live Image* tab in the Zeta 3D software contains several useful functions for working with the live image, as shown in Fig. 29.

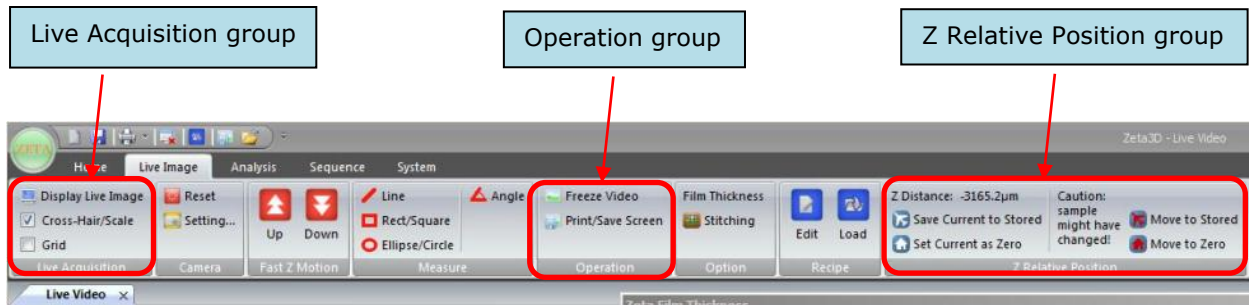


Fig. 29. Function groups in Live Image tab

- The *Live Acquisition* group allows you to change the scale displayed on the image. The default display is *Cross-Hair/Scale*. This option places a cross-hair in the center of the field of view (FOV) and a label in the lower left corner of the image that includes the FOV, the objective in use, and a distance scale. Fig. 30 shows an example.

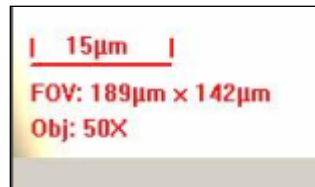


Fig. 30. Scale option for live image

The second scale option is *Grid*. This option draws a square grid over the entire image and places a scale (the length of one division) in the upper left corner. This allows you to estimate feature sizes and distances. A portion of an image with the grid is shown in Fig. 31.



Fig. 31. 3D image with grid and scale

- The *Operation* group provides a way to save the image as a screen shot. Click on **Freeze Video** to take a snapshot of the live image; a new window opens. Click on **Print/Save Screen** to create a screen shot file.

Since you have not yet performed a full scan, there is not enough information for 3D measurements such as step height or roughness. The frozen image is a 2D snapshot of the microscope image.

- The *Z Relative Position* group allows you to save the focus position you found. This is useful when you need to move back and forth between features of different heights. Click on **Save Current to Stored** to save a Z position. Click on **Set Current as Zero** to set the Z position to zero to serve as a reference plane. Click on **Move to Stored** or **Move to Zero** to move the head to either of these positions.

Be very careful when using these commands. If you change the sample, do not use previously stored positions as the surface height may have changed.

Setting the scan range

In a typical scan, the optical head moves over a range of positions that puts all surfaces in focus at some point. Therefore the lowest head position (scan bottom) should have a focal plane below the lowest surface, and the highest head position (scan top) should have a focal plane above the highest surface. During the scan, digital images are captured as the head moves. You can set the scan range manually, or you can use Auto Focus. Switch between the two choices by editing the current recipe as follows:

1. Click the **Edit Recipe** button in the *Scan Dialog*, which opens a new window.
2. In the *Recipe Edit* window, click the checkbox labeled *Auto Focus* (or the label itself), as shown in Fig. 32.
3. Close the recipe window by clicking the **OK** button. It is not necessary to save the recipe.

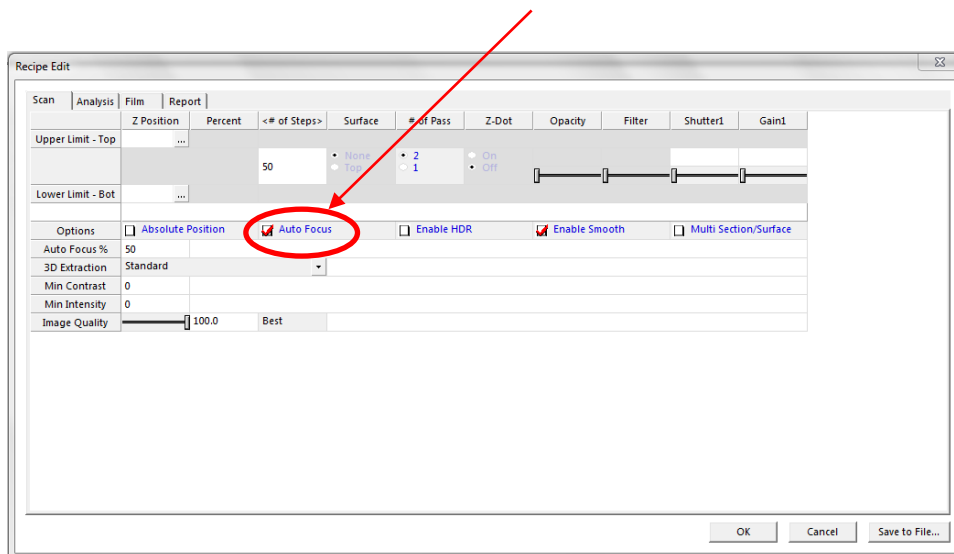


Fig. 32. Recipe Edit window with Auto Focus checkbox

The *Scan Dialog* is different depending on the type of focus. Fig. 33 shows the two options.

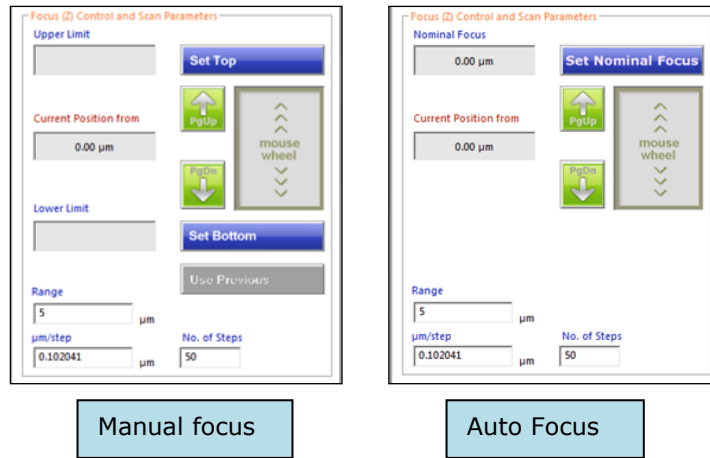


Fig. 33. Appearance of Scan Dialog for two focus options

To set the scan range using manual focus:

1. Focus on the highest surface of the sample using the mouse wheel for fine focus position control.
2. Move the optical head a small amount higher than the highest surface; the image will look a little bit fuzzy.
3. Click **Set Top** to set the top of the scan range. The *Upper Limit* field displays the Z position.
4. Focus on the lowest surface of the sample.
5. Move the optical head a small amount lower than the lowest surface.
6. Click **Set Bottom** to set the bottom of the scan range. The *Lower Limit* field displays the Z position and the *Range* field displays the scan range.
7. Set the number of steps (in the field labeled *No. of Steps*). A value of 100 is a good starting point, but the maximum value is limited only by the computer memory. Increasing the number of steps reduces the Z resolution but increases the measurement time.

The Z resolution is displayed in the field labeled $\mu\text{m}/\text{step}$ and is calculated as the range divided by the number of steps. If the value is below the minimum of $0.013 \mu\text{m}$, you will be prompted to change the range or the number of steps to correct it.

If you edit the *Range* field, the bottom scan position stays fixed and the top position is changed to fit the new range.

If you edit the resolution field, the closest available value is selected and the number of steps is recalculated.

To set the scan range using Auto Focus:

1. Locate the highest and lowest surfaces of the sample using the mouse wheel for fine focus position control.
2. Move the optical head approximately half way between the highest and lowest surfaces.
3. Click **Set Nominal Focus**.
4. Set the number of steps, range, or resolution values. The default behavior is to center the Z range at the final auto focus position, so the range should be large enough to accommodate the known feature sizes.
5. If necessary, change the way the Z range is set relative to the auto focus position by editing the value of *Auto Focus %* in the recipe. This is the percentage of the Z range that is scanned above the final auto focus position.

Taking the scan

Click on the orange **Scan** button to initiate the scan.

During the scan, the head moves from the scan bottom position to the scan top position, taking images at intervals equal to the step size. The Windows rotating circle cursor indicates that the system is busy during the scan and a large red window labeled "Scanning" appears at the top right corner of the screen. You may notice the appearance of the live image change as the head moves.

Press the **Esc** key to abort the scan.

When the scan is complete, the screen changes to display the analysis window.

3.2 Stitching

For each objective, the field of view is fixed. If you would like to scan an area larger than the field of view, an optional feature called *Stitching* is available. This option is separately purchased and requires a license key. In this mode, the system scans adjacent areas, then combines them into one image for analysis.

To use stitching, follow this procedure:

1. Select the objective to be used for scanning.
2. In the *Live Image* tab, *Option* group, click on *Stitching*, as shown in Fig. 34. A new dialog box appears, titled *Stitching Dialog*; it is shown in Fig. 35.

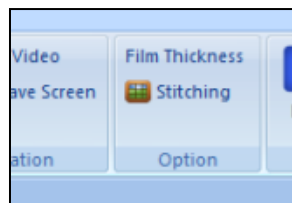


Fig. 34. Stitching option in Live Image tab.

3. Type a file name into the *Sample ID* field or use the default name. This file name will be modified for each of the scans. The default file name is “ZmgYYYYMMDD” where YYYY is the year, MM is the month and DD is the day. For every scan, the system appends the characters “-r-c” to the base name, where r is the row index and c is the column index.
4. Set the scan location and dimensions.
 - a. Move the sample to a position that will be either the center or the corner of the final stitched image and click **Set Origin**. In the dialog box titled *Set Stitching Origin*, choose the desired option (center or upper left corner).
 - b. Click **Set Dimensions**. Enter the width and height of the total scan area in microns (here, "height" means scan area length and not Z height). The software calculates the number of scans needed based on the field of view of the objective and updates the number of rows and columns in the scan matrix in the *Row and Column Configuration* frame.
 - c. Instead of using **Set Dimensions**, you can set the number of rows and columns in the scan matrix (in the *Row and Column Configuration* frame). For 32-bit computers the maximum number of scans is 7 x 8. For 64-bit computers the maximum number is 20 x 20. The software calculates the total height and width of the scan area.
5. Set the amount of overlap and transparency between scans. Overlap helps with alignment of scans. The default values of 10 per cent overlap and 50 per cent transparency are good starting points.
6. Choose whether to save the individual scan images, the stitched scan image, or both. Select the destination folder for the image files.

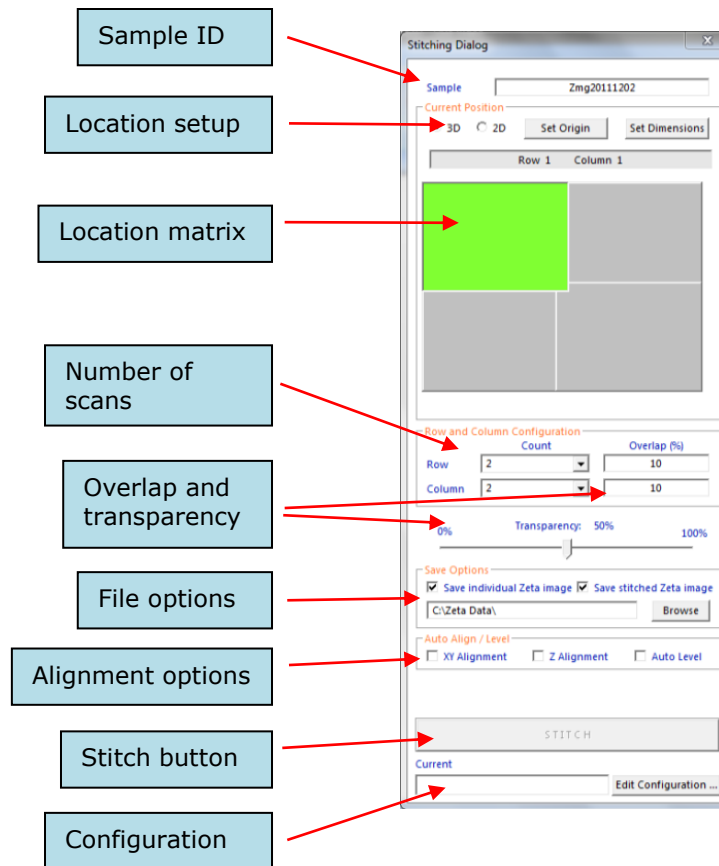


Fig. 35. Stitching dialog box

7. Choose whether to save the individual scan images, the stitched scan image, or both. Select the destination folder for the image files.
8. For most applications, select the checkbox labeled *Z Alignment*.
9. Verify settings in the *Scan Dialog*. All scans must be performed with the same settings. Make sure that the Z range is larger than the height difference between the lowest surface and the highest surface of the entire measurement area. Surface features and sample curvature can both affect the required Z range.
10. Scan the first image, which is always the patch in row 1 column 1, by clicking **Scan** in the *Scan Dialog*.

When the scan is complete, the Zeta-20 saves the file, displays an image in the completed cell then changes the color of the next cell to green.

11. Move the stage to change the scan position to the next cell in the stitching matrix. Refer to the live image which is displayed next to the previous image for comparison. The overlap area helps you to align the sample.

12. When the alignment is satisfactory, press the **Scan** button. Do not change any of the settings in the *Scan Dialog*.
13. Continue moving the stage and taking new scans until all cells have been measured.
14. Adjust image alignment prior to stitching as follows:
 - a. Right click on any cell and select *Load* to display it in the *Live Image* window. Areas of overlap with surrounding cells appear at the image edges, depending on the amount of overlap and transparency selected in the *Stitching Dialog*. After scans are complete, overlap cannot be changed, but transparency can be adjusted.
 - b. Set the transparency to about 50%.
 - c. Use the keyboard arrow keys to move the image up, down, right, or left to improve alignment with neighboring cells.
 - d. Set the transparency to zero to simulate the final image after stitching.
 - e. If you see a discontinuity at the image boundaries, keep moving the active image until the alignment is acceptable.
15. Click **Stitch** in the *Stitching Dialog*. The stitched image appears in a new window.

If you saved the individual image files from each of the matrix locations, you can open them in the Zeta3D software the same as any other image file. You can also open the final stitched image file. Additionally, within the *Stitching Dialog*, you can open all of the individual files scanned together during a stitching operation. To do this, right-click on any location in the stitching matrix and select *Load*, then browse to find and select any of the files.

3.3 Reference images

Optical components and systems sometimes contain minor physical imperfections that cause distortions in the final images. One example is vignetting, or the tendency of an optical image to be darker around the edges of the image compared to the center. The effects are subtle and can be ignored for 5X and 10X objectives and for measurements of large steps. However, for scanning features on the order of a micron in height or less, especially over a large field of view, compensation of the background effects is recommended. To do this, Zeta 3D software employs reference images.

Scan and save reference images

Every combination of objective, camera, and coupler that is used on the system requires a separate reference scan. However, reference scans are not usually required for interferometer objectives.

1. Choose a clean, bare and flat sample to use for reference scans. Silicon is a common and very good choice for the reference sample.
2. Scan the reference sample following standard scanning procedures, with settings similar to those you use for measurement samples.
3. Inspect the scan image. If particles or scratches appear in the field of view, move the sample and take another scan until a very clean region is found.
4. Save the image as a reference image. Choose a folder location and file name that is easy to remember and understand. Including information about the objective, camera, and coupler used for the scan into the file or folder name is strongly recommended.
5. Create reference images for all combinations of objective, camera, and coupler that are used on the system.

Use a reference image to correct a single scan

You can use a reference scan to subtract the optical system effects from any 3D image.

1. Scan the sample using standard scanning procedures, or open a saved 3D image file.
2. After the 3D image appears, press the "V" key on the keyboard. A file browser window appears.
3. Choose the reference image that corresponds to the hardware combination used for the measurement scan. The software performs the correction operation and displays a new 3D image. If any 2D analysis windows were already open, close them, then repeat the 2D analysis to see the corrected results.
4. If desired, save the new 3D image. If you save the corrected image to the same name as the original measurement scan, the original scan cannot be recovered.

Before performing the correction, the software compares the field of view of the measurement scan and the reference image. If they do not match, the error message shown in Fig. 36 appears.

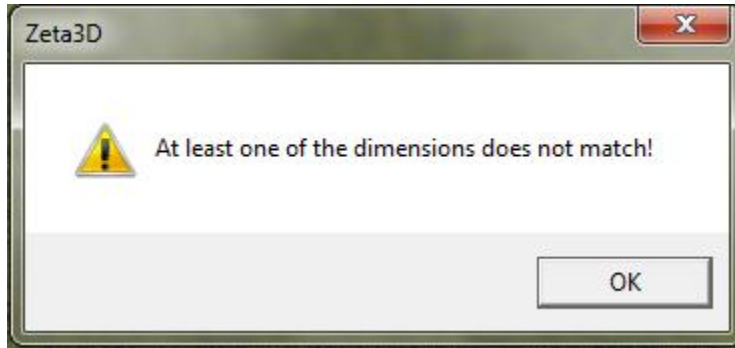


Fig. 36. Error message for incorrect reference image

Use reference images during stitching

Stitching operations involve taking a sequence of measurement scans with the same hardware configuration. Therefore only one reference image is needed to perform corrections.

1. Press the **Edit Configuration** button at the bottom right of the *Stitching Dialog*, as shown in Fig. 35.
2. In the *Stitching Configuration* window (shown in Fig. 37), check the checkbox to enable the use of reference images (labeled *Auto Vignette Correction*).
3. Press the **Select Reference Image** button. Browse for the appropriate reference image file, then click OK.
4. Set up and execute the stitching operation. All image files will be corrected before being saved.

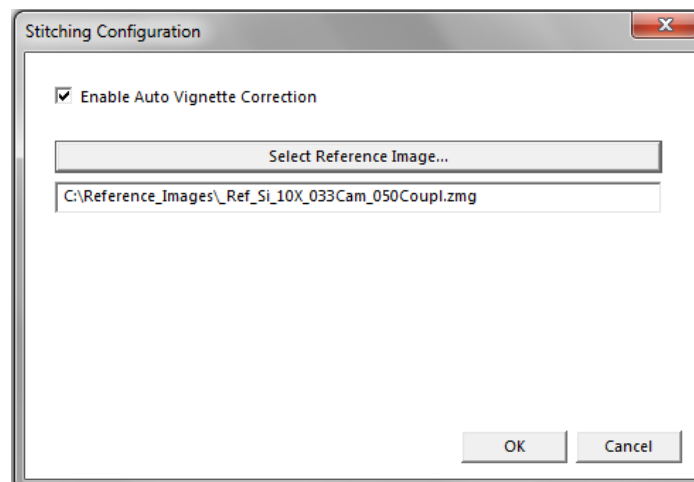


Fig. 37. Reference image selection for stitching

3.4 Moving and unloading the sample

Moving to another measurement location

If you would like to inspect another measurement location without unloading the sample, you can change the sample position using the joystick. If the new location is very close to the old location, the operation is safe. However, if you want to move a large distance, the sample may be too close to the objective if the sample is not flat or if you are using high magnification. Also, you may need to use a lower magnification to find features of interest in the new location.

1. To move a short distance (one or two fields of view), use the joystick to change the sample position. Push the top left joystick button to toggle between fast and slow movement.
2. To move a large distance, then
 - a. Click the **Up** button in the *Live Image* tab or use the **F3** key. The optical head moves up and stops at a preset location.
 - b. Change the objective to a lower magnification.
 - c. Move the XY stage to change the sample position.
 - d. Click the **Down** button or use the **F4** key and press the space bar when prompted.
 - e. Focus on the sample following the procedure described previously.

Unloading the sample

1. Click the **Up** button in the *Live Image* tab or press the **F3** key.
2. Rotate the turret to select the 5X objective.
3. Move the XY stage to the front right corner of the system.
4. If needed, push the sample sideways so that it is not under the objective.
5. Remove the sample.

CHAPTER 4 **Other Scan Configurations**

Several hardware options are available to enhance the capabilities of the Zeta-20 system.

Differential Interference Contrast (qDIC) with the Nomarski interferometer allows measurement of roughness on very smooth surfaces (such as wafers) and very small step heights.

Vertical Scanning Interferometry (VSI) with the X5 white light interferometer allows the imaging of large areas with excellent Z resolution, which is essential for measuring features with small Z height but large XY dimensions.

Topics in this chapter:

- 4.1 The Nomarski interferometer
- 4.2 The X5 interferometer

4.1 The Nomarski interferometer

The Zeta-20 Nomarski interferometer is an option for performing quantitative Differential Interference Contrast (qDIC) microscopy to enhance the contrast of very small features on smooth surfaces such as semiconductor wafers.

DIC works by shearing the illumination beam into two beams with orthogonal polarizations. The two beams travel slightly different optical distances because one is incident on the feature while the other is not. When the beams are recombined, the phase shift in one beam with respect to the other causes interference. The interference is detected and displayed as an image in which the contrast is proportional to the optical path length slope. (The optical path length is the product of the refractive index and the geometric path length.) The software then converts the slope information into a conventional *.zmg image in units of height.

This option includes three components that you install in the optical head: the polarizer, the analyzer, and the DIC prism. They are removed from the system when scanning normally.

Installation

To use the Nomarski option, follow this procedure:

1. Install the polarizer into the slot in the front of the optical head, but leave it in the detent out (partly pulled out) position, as shown in Fig. 38. The dot on the rotating dial should be positioned in front of the arrow on the sleeve.

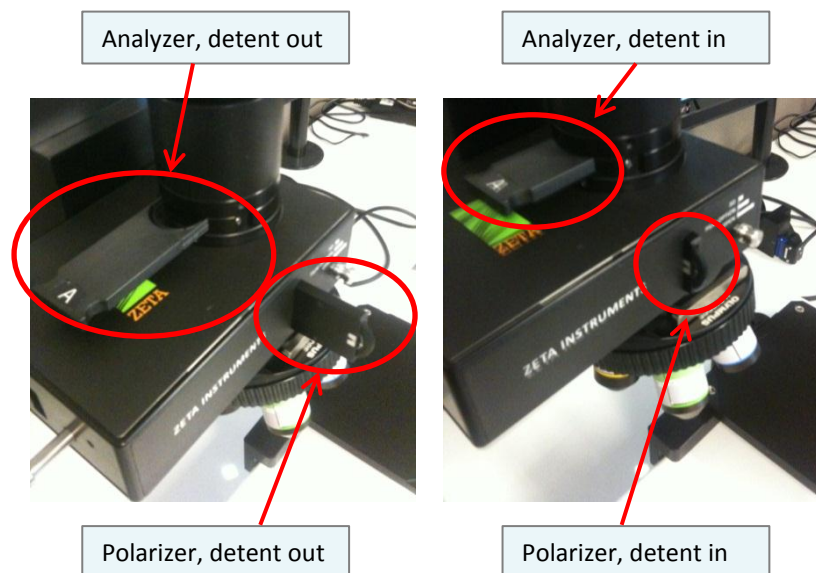


Fig. 38. Analyzer installed into left side of head

2. Install the analyzer into the slot on the left side of the optical column but leave it in the detent out position, as shown in Fig. 38.

Operation

1. Place the sample on the stage.

2. Turn *Focus Assist* on and find the focus position following standard procedures. Turn *Focus Assist* off.
3. Push the polarizer and analyzer fully into their slots. The image turns dark.
4. Install the DIC prism and set the lever to the appropriate position for the objective (out for long working distance objectives and in for standard objectives). The lever positions are shown in Fig. 39.

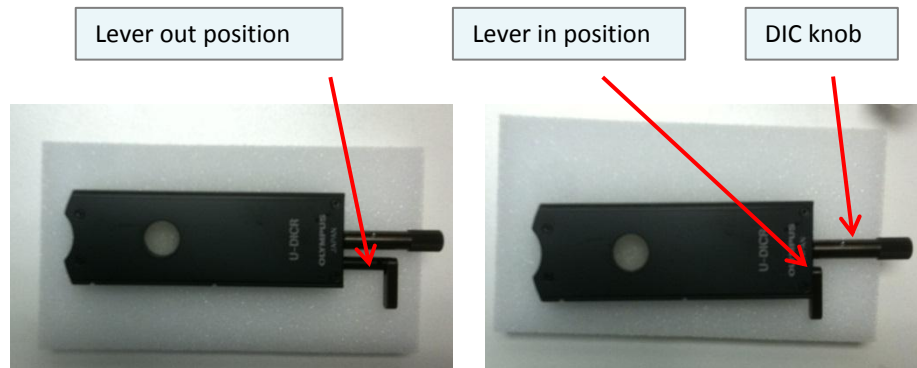


Fig. 39. DIC prism set for long working distance (left) and standard (right)

5. Increase the intensity of the illumination if needed.
6. Turn the DIC knob to improve the image. Check the image at the extremes of the knob travel, then choose the position that maximizes the contrast of features on the surface, such as scratches and pits.
7. Freeze the video.
8. Right click on the image to display the menu in Fig. 40. Select *Test* then select *Display Profile*.

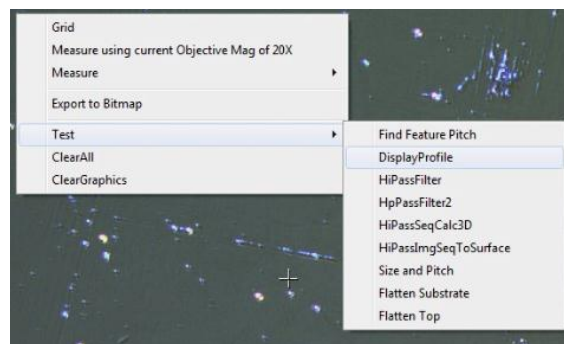


Fig. 40. Right-click menu on Nomarski image

9. A calibration window pops up as shown in Fig. 41. The *Z calibration* field allows you to enter a scale factor to convert the image information to height. Typically this value would be obtained

from comparison to a measurement made on another instrument such as a scanning electron microscope (SEM) or atomic force microscope (AFM).

The *Filter* field takes an integer from 0 to 6. Values from 2 to 6 result in increasing the integration length. For very small features, use 2. For large features (on the order of 10 per cent of the field of view or larger), use 6.

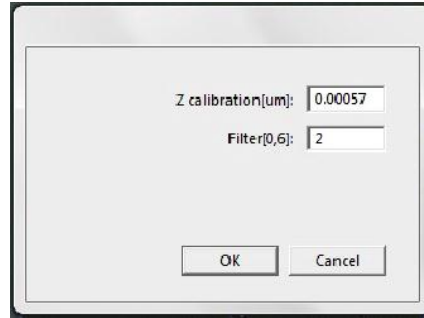


Fig. 41. Calibration window

10. Click **OK**. The image will be converted into a height image and can be stored and analyzed like a conventionally scanned image. An example is shown in Fig. 42. The Z height is approximately 0.2 μm , demonstrating the increased vertical resolution achieved with this technique.

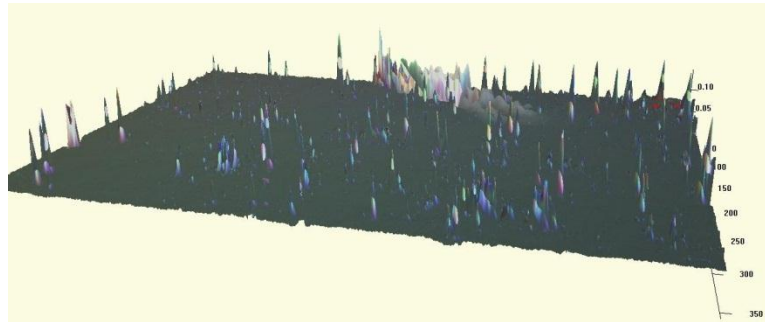


Fig. 42. 3D image of silicon wafer with particles

11. When done, remove the Nomarski components and store them carefully.

4.2 The X5 interferometer

The Zeta-20 X5 interferometer is a hardware option (separately purchased) for performing interferometry to measure small Z height features in a large field of view.

In Vertical Scanning Interferometry (VSI), a single beam of light is split into two beams. The two beams are in phase with each other. One is reflected from a reference surface, while the other is reflected from the sample. When the two beams are recombined, the intensity of the resultant beam is highest if the two component beams are in phase, which happens if the difference in path length is equal to the wavelength of the light or an integral multiple of the wavelength (constructive interference). Conversely, if the path length difference is an odd multiple of the half wavelength, the beam intensity is reduced due to destructive interference. The pattern of high and low intensity across the surface (fringes) provides detailed information about the topography of the surface.

For accurate measurements, it is very important that the surface be as level as possible. Otherwise, the interference fringes from the surface tilt swamp out the fringes from the small features to be measured. Therefore a leveling stage (tip/tilt stage) is almost always used with the X5 interferometer. In addition, active vibration isolation is strongly recommended.

VSI is suitable for fairly smooth reflective or transparent surfaces. Rough surfaces and low reflectivity surfaces are not good candidates because they either scatter or absorb too much of the incident light.

Installation

The interferometer hardware consists of the X5 objective, which is installed in one of the turret positions like any other objective. The final appearance is shown in Fig. 43.

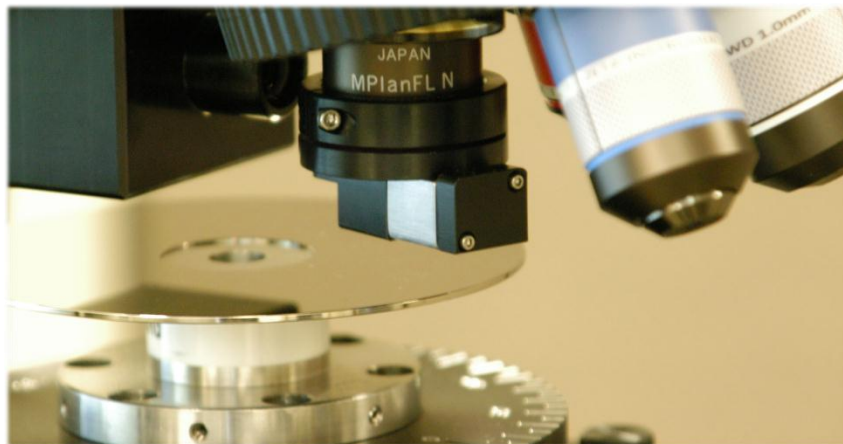


Fig. 43. X5 interferometer objective

In order to recognize and use the new objective, it must be selected in the optical setup file.

A leveling stage is almost always used. Fig. 44 shows a tip/tilt stage installed on the Zeta-20. The stage has knobs for leveling in the front to back and left to right directions.

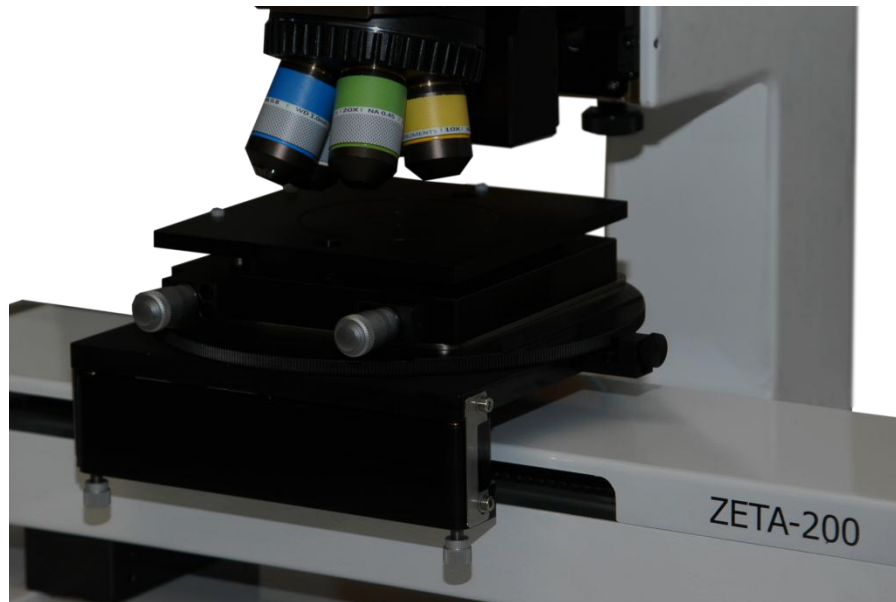


Fig. 44. Leveling stage on Zeta-20

Operation

1. Focus on the surface using a low power objective.
2. In the *Z Relative Position* group of commands in the ribbon, press **Set Current to Zero** to store the low magnification focus position.
3. Adjust the tilt stage to bring the entire surface into equal focus.
4. Change to the X5 objective.
5. Move the objective upward by approximately 3300 μm , using the stored position as a reference. The image may appear grayed out, or you may see colored interference fringes.

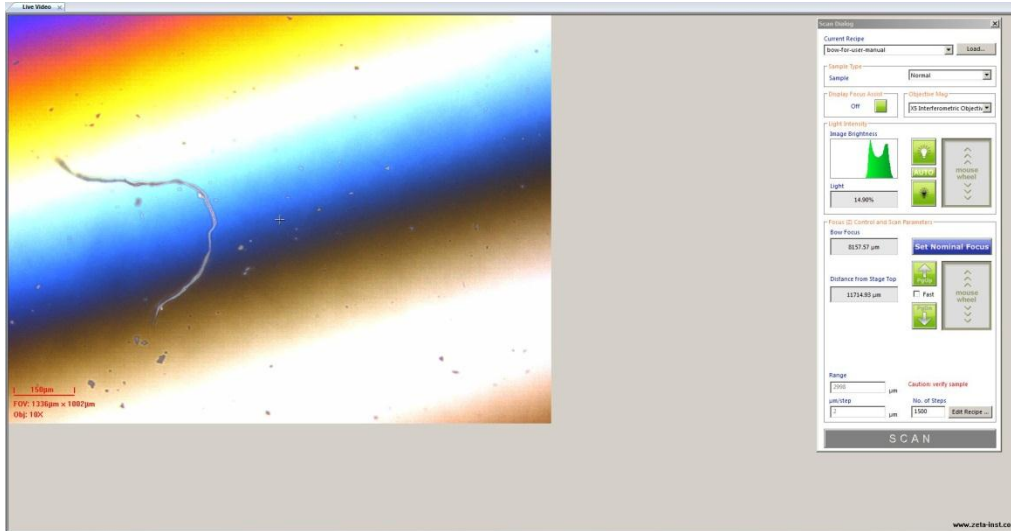


Fig. 45. Interferometer fringes

6. Uncheck the *Fast* checkbox, then move the head slowly in the range of 3000 to 4000 μm above the zero point until colorful interference fringes appear. Fig. 45 shows an example.
7. Adjust the leveling knobs to widen the fringes in the image. This step levels the surface and optimizes the measurement resolution. Try to achieve a position where the surface to be measured exhibits only one or two colors. Fig. 46 shows an example for a hard disk head assembly. One set of features that are at the same plane (same height) is entirely green, while another group of features at a different height are purple or purple-red. The background is very dull and shows no interference fringes because it is much lower in height and out of focus.

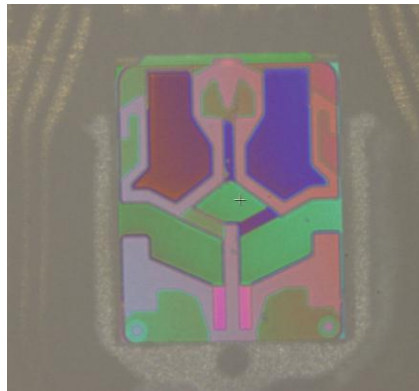


Fig. 46. Target appearance of interferometer fringes

8. Open an interferometer recipe (the factory default recipe is named "X5"). Set the top and bottom scan positions as follows:
 - a. Find a Z position where a white fringe appears on the highest feature in the field of view.

- b. Move the objective upward and observe the color changes on that feature. When the white color fringe disappears, set this position as the scan top.
- c. Move the objective back to the original Z position. Then move it downward until a white fringe appears on the lowest feature in the field of view.
- d. Move the objective downward and observe the color changes on that feature. When the white color fringe disappears, set this position as the scan bottom.

Fig. 47 shows the color changes on a complex surface as the Z height changes.

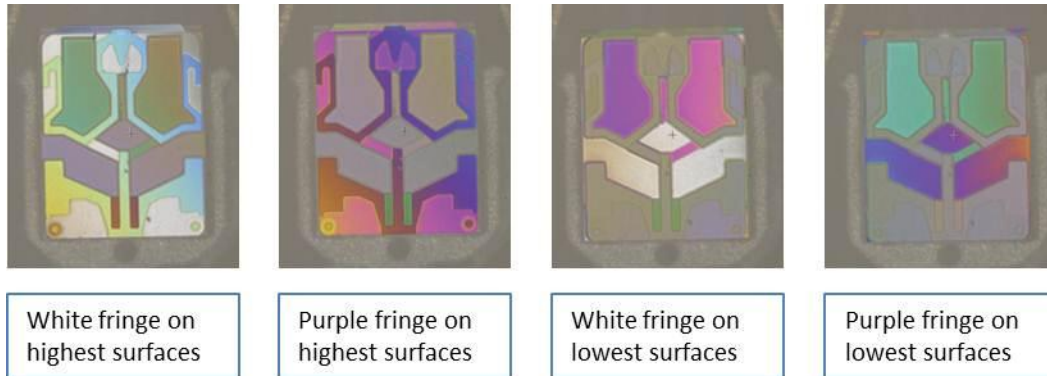


Fig. 47. Changes in fringe colors as Z height changes

9. In the recipe Scan Parameters, set the number of scans to 1 Pass and the Z-Dot setting to OFF, as shown in Fig. 48. For interferometry, the 3D Extraction parameter is set to either "Intensity Peak" or "Intensity Valley." This choice is determined by the specific X5 objective on your system and a default recipe with the correct option is provided by Zeta applications.

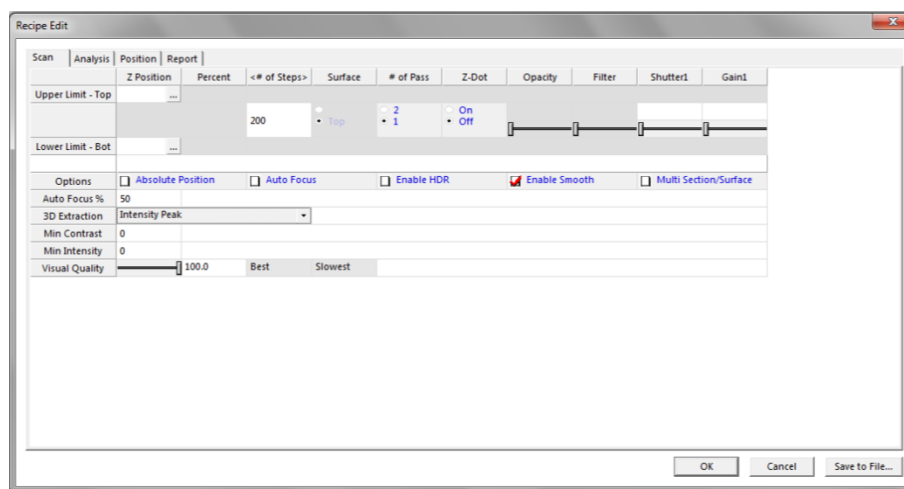


Fig. 48. Recipe settings for interferometer

10. Start the scan. You will see the fringes move in the live video image during the scan. The resulting 3D image can be stored and analyzed like a conventionally scanned image. An example is shown in Fig. 49.

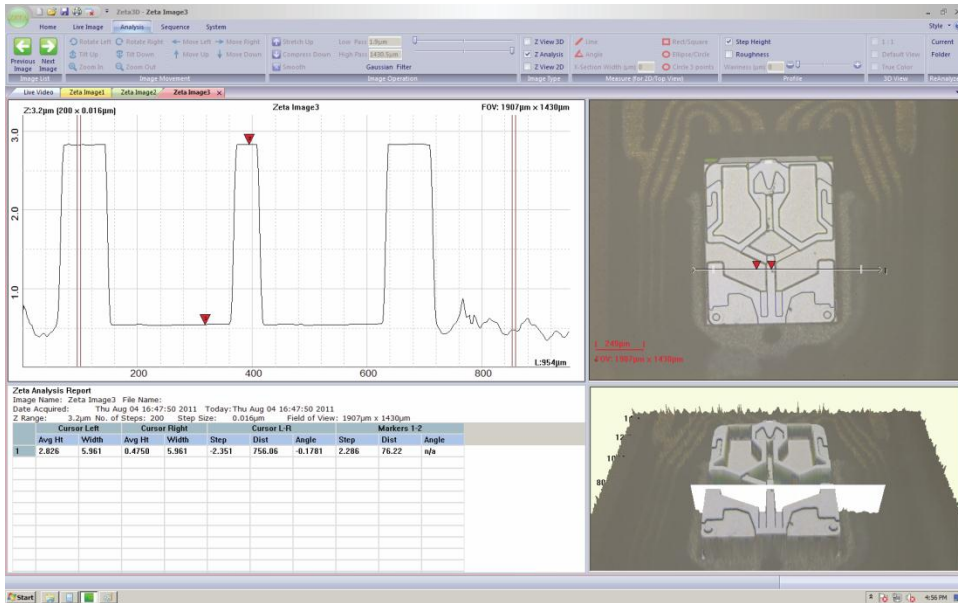


Fig. 49. Result of interferometer scan

CHAPTER 5 **Working with 3D Images**

The output of the Zeta scan consists of two types of proprietary images:

- True color two-dimensional images in which all surfaces are in focus
- Accurate high-resolution three-dimensional images that can be used for step height and roughness measurements

This chapter covers operation for viewing and modifying 3D images. Chapter 6 will cover measurements on both 2D and 3D images.

Topics in this chapter:

- 5.1 Image rotation and movement
- 5.2 Filtering operations
- 5.3 Color choices
- 5.4 Surface height histogram

5.1 Image rotation and movement

The 3D image shows the raw data from a Zeta scan and it is the input used to calculate step height and surface roughness. Viewing the image in different ways can also provide valuable insight into the nature of the surface.

The 3D image appears in two formats. Most image operations are available in both formats.

- To work with a full-screen 3D image, select an image window by clicking on its label, or select the *ZView 3D* checkbox from any window.
- To work with the image that appears in the lower right pane of every analysis window, click within the pane.

The *Analysis* tab contains the *Image Movement* group of buttons, as shown in Fig. 50. Most operations can also be performed by right-clicking on the 3D image and selecting an option from the menu.

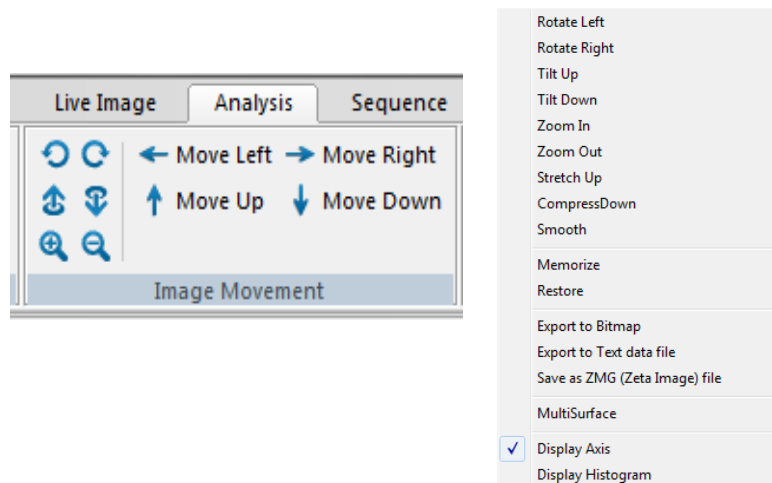


Fig. 50. Toolbar buttons and right-click menu for 3D image movement

You can also use the mouse directly by holding the left button and moving the mouse. Table 3 describes the image operations and how to perform them.

Table 3. 3D image movement operations

If you want to do this...	Then choose one of these options...
Rotate the image left or right	<ul style="list-style-type: none"> • Click the Rotate Left or Rotate Right buttons • Right click to see the menu, then select Rotate Left or Rotate Right • Press and hold the left mouse button while moving the mouse left and right
Tilt the image up or down (pan the image)	<ul style="list-style-type: none"> • Click the Tilt Up or Tilt Down buttons • Right click to see the menu, then select Tilt Up or Tilt Down • Press and hold the left mouse button while moving the mouse back and forth
Move the image left, right, up or down	<ul style="list-style-type: none"> • Click the Move Left, Move Right, Move Up or Move Down buttons • Right click to see the menu, then select Move Left, Move Right, Move Up or Move Down • Press and hold the CTRL key and left mouse button while moving the mouse left, right, back, or forward
Zoom in or zoom out	<ul style="list-style-type: none"> • Click the Zoom In or Zoom Out buttons • Right click to see the menu, then select Zoom In or Zoom Out • Scroll the mouse wheel
Stretch or compress the image (change Z axis only)	<ul style="list-style-type: none"> • Click the Stretch Up or Compress Down buttons • Right click to see the menu, then select Stretch Up or Compress Down • Press and hold the CTRL key while scrolling the mouse wheel
Adjust Z axis scale	<ul style="list-style-type: none"> • To set the Z scale the same as the X and Y axes, click the checkbox labeled <i>1:1</i> in the <i>Z Scale/Ratio</i> group • To optimize the Z scale to fit the page, click the checkbox labeled <i>Default View</i>
Perform image processing operations (smoothing, thresholding or spatial filtering)	<ul style="list-style-type: none"> • Click the Smooth button and choose an option • Right click to see the menu, then left click on Smooth, and choose an option
Restore the image to the original settings	<ul style="list-style-type: none"> • Right click to see the menu, then select Restore
Roll back (hide) part of the surface	<ul style="list-style-type: none"> • Press and hold the shift key and roll the mouse wheel

One additional function also changes the image appearance. By default, the scale of the Z axis is optimized to fit the screen. To change the Z scale to match the X and Y length scales, check the checkbox labeled *1:1* in the *3D View* group, located at the far right of the toolbar on the *Analysis* tab. Select *Default View* to restore the image to its default setting.

5.2 Filtering operations

A surface can be described as a combination of waviness, roughness, and discrete features. Waviness is the base surface or the underlying shape, which is a property occurring over a long length scale (wavelength). Roughness is the surface height variation on a short length scale. Discrete features are items that do not cover the entire surface, such as trenches or steps; these are short wavelength features.

The Zeta 3D software offers several options for modifying the appearance of a scanned surface by filtering the raw data. They are found in the *Image Operation* group of the *Analysis* tab, as shown in Fig. 51. The most useful filter is the Gaussian filter which is accessible on the toolbar. Less common filters are available through the **Smooth** button.

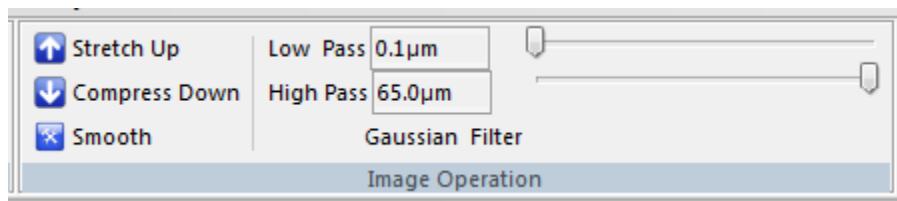


Fig. 51. 3D image filtering options

The Gaussian filter eliminates short or long wavelength effects and displays the surface as if that data didn't exist. Moving the *Low Pass* slider to the right eliminates short wavelength data, such as fine scale roughness. Moving the *High Pass* slider to the left eliminates long wavelength data, such as waviness.

Experimenting with the filters and observing their effects on both the 3D and 2D images is the best way to understand them.

You can save the filtered image data into the original *.zmg file, or save it as a new file name. The original (unfiltered) image data cannot be recovered if you save over the original file name.

It is often useful to filter a surface before performing step height or roughness measurements. For example, removing some surface roughness is often helpful when you are measuring a step height, and removing waviness may be helpful when you want to measure roughness.

5.3 Color choices

Zeta 3D images are presented in True Color. However, for some surfaces there is not enough color variation to adequately delineate all of the features. This can happen for very flat surfaces or very monochromatic surfaces.

Therefore an option to display 3D images in false color is available by using color lookup tables (LUTs). These are text files with an extension of *.lut* located in the software's system folder. A lookup table assigns red, green, and blue values to each of 256 height levels.

To change the color of a 3D image:

1. Uncheck the box labeled *True Color* in the *3D View* group, located at the far right of the toolbar on the *Analysis* tab. The most recently selected LUT file will be used.
2. To select a lookup table, right click on the 3D image and select *Load Color Look-Up-Table (LUT) file*.
3. Choose one of the available LUT files.

Fig. 52 illustrates the effect of changing the color lookup table. The surface is textured, but over a relatively small range of heights. It also has a coating that makes it very uniform in color. The image on the left is in True Color, while the image on the right is the same surface displayed with a lookup table in which blue represents the lowest height and red the highest. It is much easier to visualize the surface variations with this color scheme.

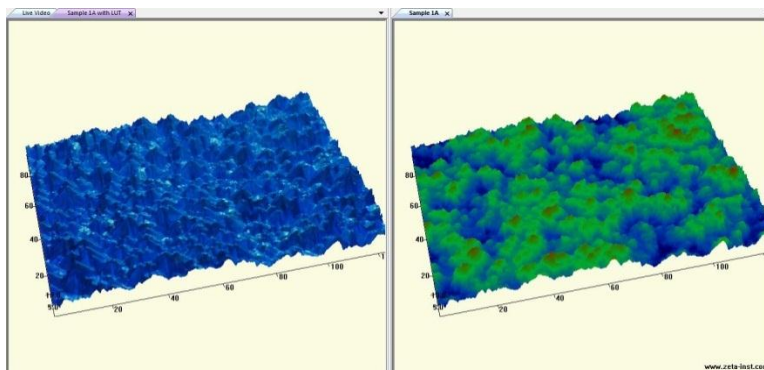


Fig. 52. Surface displayed with two color options

When false color is employed, you can select *Display Color Bar* from the right-click menu to display a key that shows the correspondence between height and color. An example is shown in Fig. 53. The color bar appears at the far left of the screen and shows all colors present in the lookup table. In this example the colors range from black at height zero (the scan bottom) to red at a height of 60 μm (the scan top).

You can adjust the false color definition by selecting *Adjust Color* in the right-click menu, or by pressing the "h" key when viewing a 3D image. This action displays a histogram of colors as shown in Fig. 53.

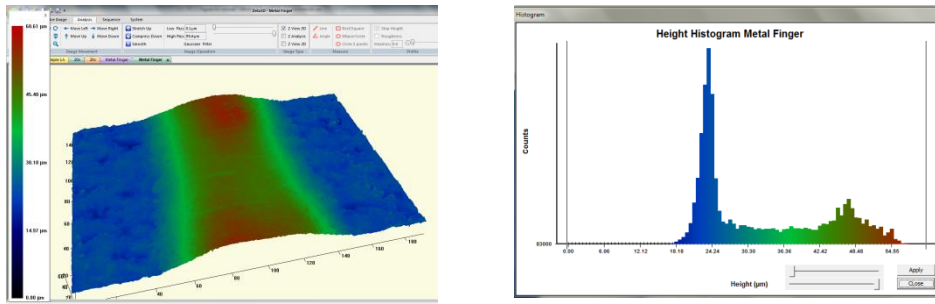


Fig. 53. False color 3D image with color bar (left) and histogram (right)

The histogram window contains a slider control that lets you adjust the color range. The top slider sets the lower height limit; the color for all heights below this one will be set to the zero height color (in this example, black). The bottom slider sets the upper height limit; the color for all heights above this one will be set to the top height color (in this example, red). Fig. 54 shows the effect of changing both limits. Now the black color is applied to every height below 24 μm and red is applied to every height above 47 μm.

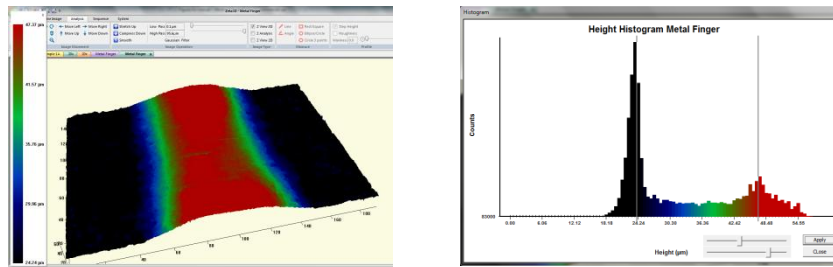


Fig. 54. False color with adjustments to range

5.4 Surface height histogram

The right-click menu on a 3D image includes a selection for *Display Histogram*. This option creates a histogram of the surface heights of all of pixels in the image. Fig. 55 shows an example of a histogram of a surface with a well-defined step with vertical edges. The two peaks in the histogram represent the bottom of the step and the top of the step.

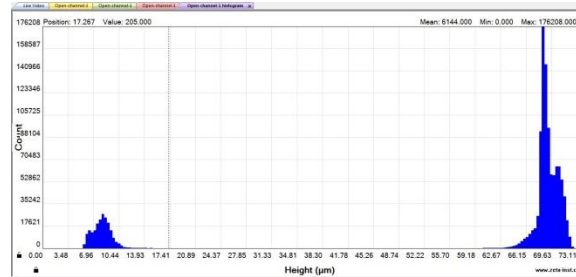


Fig. 55. Height histogram for surface with step

As you move the cursor over the graph, two guide lines follow along. The vertical line appears at the X axis position of the cursor, and the horizontal line appears at the data value (Y axis value) at that X position. The X and Y values are also written at the top left of the graph.

You can zoom in on part of the histogram:

1. Check to see if the axes are locked by observing the small padlock symbols near the graph origin. If an axis is locked, it will stay the same as in the original histogram; if it is unlocked, it will change to reflect the new data set. The symbols are shown in Fig. 56. Click on a lock to change its status.
2. Draw a box around the region of interest by clicking on one corner, then releasing the button on the opposite corner. The histogram will be redrawn showing only the data within the box.
3. To restore the data, close the histogram and create a new one from the original 3D image.

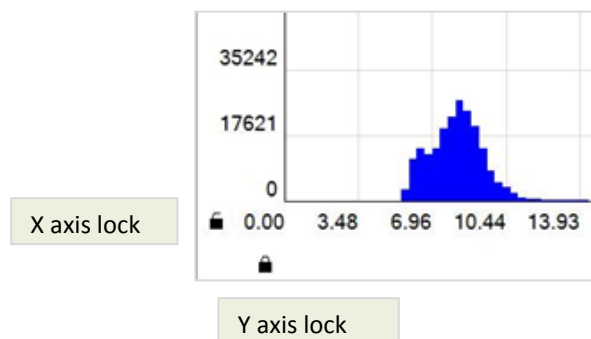


Fig. 56. Axis locks for histogram

CHAPTER 6 **Measurements**

The surface height values measured in a Zeta-20 scan are the basis for detailed analysis of the surface. Step height and roughness calculations share many setup procedures.

Topics in this chapter:

- 6.1 Step height
- 6.2 Roughness
- 6.3 Dimensions

6.1 Step height

Step height along a line

When a scan finishes, the default analysis is a step height measurement. The screen displays a window with four panes as shown in Fig. 57.

You can also perform step height analysis on a stored image, as follows:

1. Open a saved *.zmg file, which opens a new window showing the 3D view.
2. Click the checkbox labeled *Z Analysis* in the *Image Type* group of the *Analysis* tab.

The four panes of the step height analysis each display a different aspect of the measurement. If you change something in one pane, the other panes change automatically.

- The horizontal line shown in the *2D Composite View* defines a cross-section along which the line profile displayed in the *2D Line Profile* pane is drawn.
- The *3D View* shows the cross section line and the scan region in 3D.
- The *Analysis Report* shows calculations performed on the cross section line.
- The cursors in the *2D Line Profile* pane define the calculation boundaries.

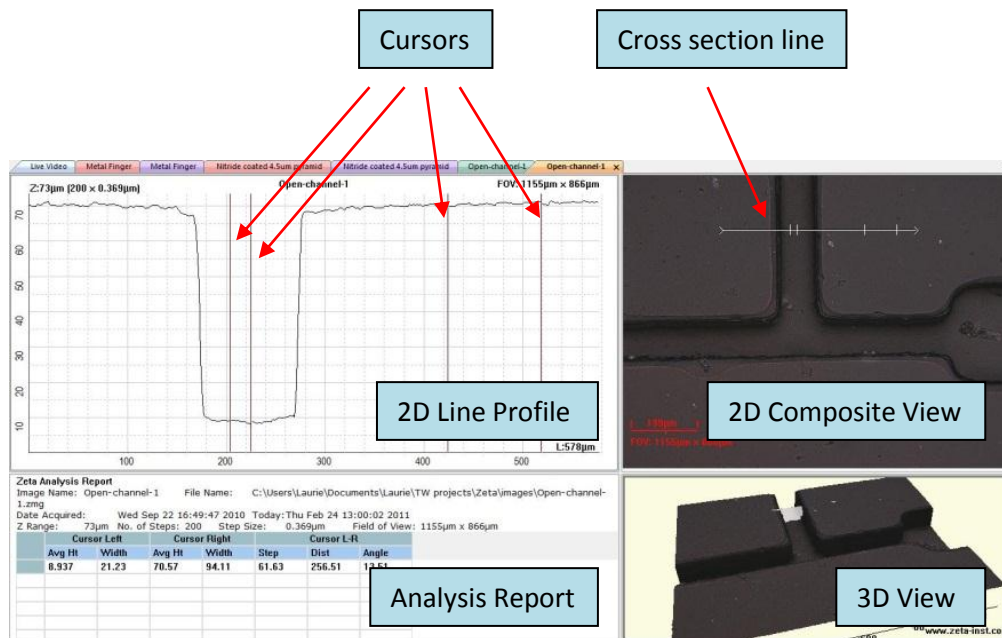


Fig. 57. Step height analysis screen

Step height is the difference in average height between two locations on the sample surface defined by vertical cursors in the *2D Line Profile* pane. The average height of a location is measured with respect to the initial Z position (height) of the scan. The scan start position is somewhat arbitrary, so the average height value is not meaningful unless a reference surface is defined. For calculating step height,

however, the reference height does not matter because subtracting one height from another removes the effect of the reference height.

Operations in the *2D Composite View* pane

You can change the properties of a cross section line as follows:

1. Right click within the *2D Composite View* pane to bring up the menu shown in Fig. 58.
2. Choose *Horizontal*, *Vertical*, or *Oblique* for the cross section line orientation. One line appears on the screen.
3. To change the line length, click and drag one end of the line.
4. To change the line width, enter a value for the desired width in microns. A set of cross-hatch marks shows the width on the image. For each position along the line, the average of the surface height values within the cross-hatched region is used as the height value.
5. To change the orientation of an *Oblique* cross section, click and drag one end of the line.
6. To move the line, click on any part of the line and drag it.
7. To return to the default state (one horizontal cross section), click *Reset Cross Section*.

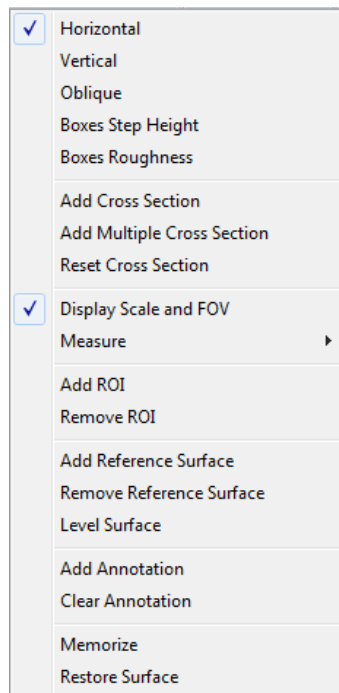


Fig. 58. 2D Composite View right-click menu

You can add a comment on the 2D image as follows:

1. Select the *Add Annotation* function in the right-click menu. The window shown in Fig. 59 appears.

2. Type a message into the text box at the top.
3. Click the **Select Font** button to choose font, size, and other text properties.
4. Click the **Set Text Color** button to choose the text color. The text is written directly on the 2D image, without a background, so choose a color that contrasts with the image color.
5. Click **OK** to create the annotation.
6. Click and drag with the mouse to move the annotation.
7. Add more annotations if needed. Fig. 60 shows an image with two annotations.
8. Remove all annotations by selecting *Clear Annotation*.

The right-click menu also has an option labeled *Memorize*. It saves most changes that you can make using the right-click menu. After performing a *Memorize* function, the saved conditions will be applied to any new scans or any newly opened image files. In addition, any recipes that you save will contain the saved conditions, allowing you to repeat them at a later time.

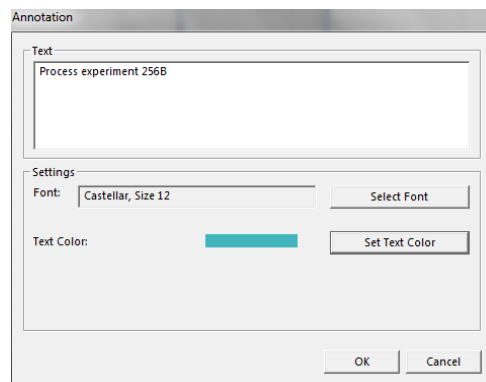


Fig. 59. Annotation editing dialog

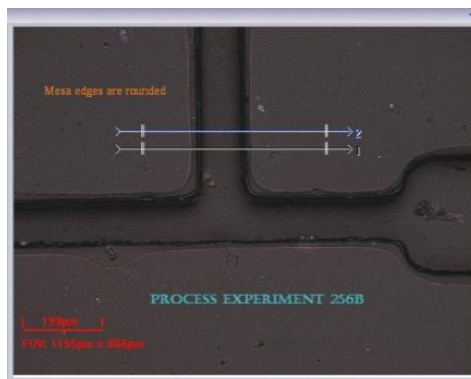


Fig. 60. 2D image with two annotations

Operations in the 2D Line Profile pane

You can change the cursor positions to define the measurement locations. Fig. 61 shows cursors for step height measurement in a profile graph. One pair of cursors defines the left measurement location and another pair defines the right measurement location. The cursor locations are also shown on the cross section line in the 2D image.

The average height for a location is the average of all values within the pair of cursors. The step height is the average right side height minus the average left side height; it can be positive or negative depending on which side is higher.

Define the boundaries of the step height measurement as follows:

1. Move either pair of cursors together by clicking and dragging a point halfway between the two cursors.
2. Move an individual cursor by clicking and dragging any point on the cursor line.

The analysis values change in real time as the cursors move. In addition to step height, the analysis window displays the average height of each location, the width of each cursor region, the distance between the two locations, and the angle between them.

The example in Fig. 61 has a positive step height because the left side is lower than the right side. The wide spacing between the right side cursors allows averaging of the rough surface and provides a more repeatable step height than choosing one single point or small area on the surface.

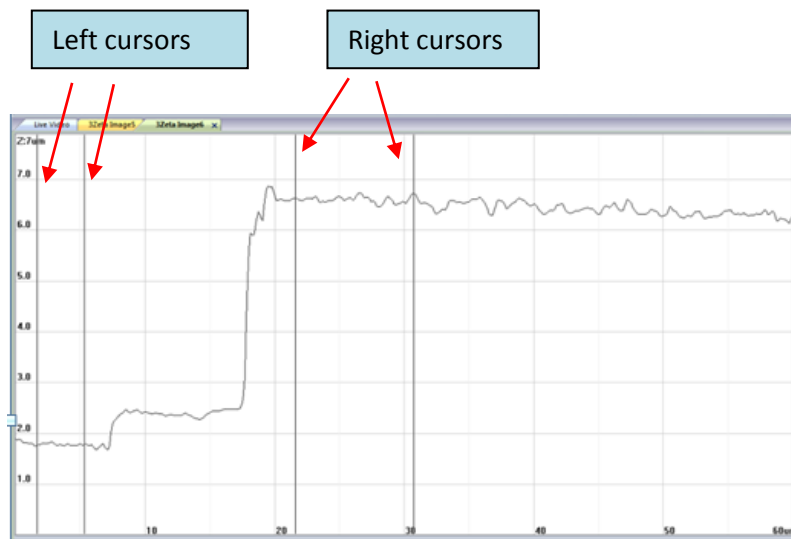


Fig. 61. Cursors for step height measurement

The default Y axis range of the profile is based on the range of heights in the 2D image. To modify the range, select *Set Y-Axis Limits* in the right-click menu.

You can annotate the *2D Line Profile* pane using the same procedure described for the *2D Composite View* pane. The *Memorize* function in the right-click menu of the *2D Line Profile* pane allows you to save the cursor and marker locations (markers are discussed later in this chapter).

Operations in the *Analysis Report* pane

In the *Analysis Report* pane, you can change the appearance of the report in several ways. Right click on the pane to bring up a menu. The first two selections, *Change Background Color* and *Change Text Color*, allow you to change the background color or text color of any cell, row, or column. Fig. 62 shows the right-click menu options and the color selection widow.

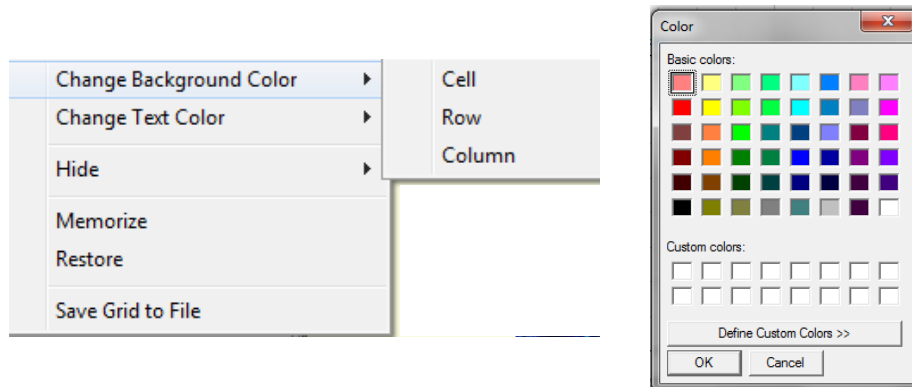


Fig. 62. Options for changing report appearance

The menu option labeled *Hide* allows you to hide any cell, row, or column. The *Memorize* function allows you to save the appearance changes.

Operations in the *3D View* pane

The 3D image displays the surface being analyzed, but it does not directly affect any of the analysis options. You can adjust the image appearance with any of the movement or color commands without affecting the analysis. You can also use the *Memorize* function to save your changes or the *Restore* function to undo them.

Step heights on multiple cross sections

To analyze step height variations, create additional cross sections as follows:

1. Create a cross section with the desired orientation, length, width and position.
2. In the right click menu shown in Fig. 58, select *Add Cross Section*. A new cross section appears a short distance from the first cross section. It will have the same length and orientation as the first one.
3. Click on *Add Cross Section* again to add more lines. As each new cross section is added to the 2D view, a new profile graph is drawn and a new line of analysis results appears. There is one set of data for each cross section line. The cross section lines and analysis results are numbered for clarity. An example is shown in Fig. 63.

4. Change the length of the group of lines by clicking on the end of any line and dragging it. The lines remain parallel and stay the same length at all times.
5. Move one cross section line by clicking on the center of a line and dragging it.
6. For oblique cross section lines only, change the orientation of the lines by clicking on the end of any line and dragging the group of lines. The lines remain parallel and stay the same length.
7. To highlight one set of data, use the cursor to click on the cross section line in the *2D Composite View*. This becomes the active profile and its number changes to 1 (other lines are renumbered at the same time). The corresponding data set moves to the top of the *Analysis Report* pane. The cross sections and data lines are also colored to help show which data sets correspond to which cross section lines. However, the colors are not unique and will repeat as you add more cross section lines.

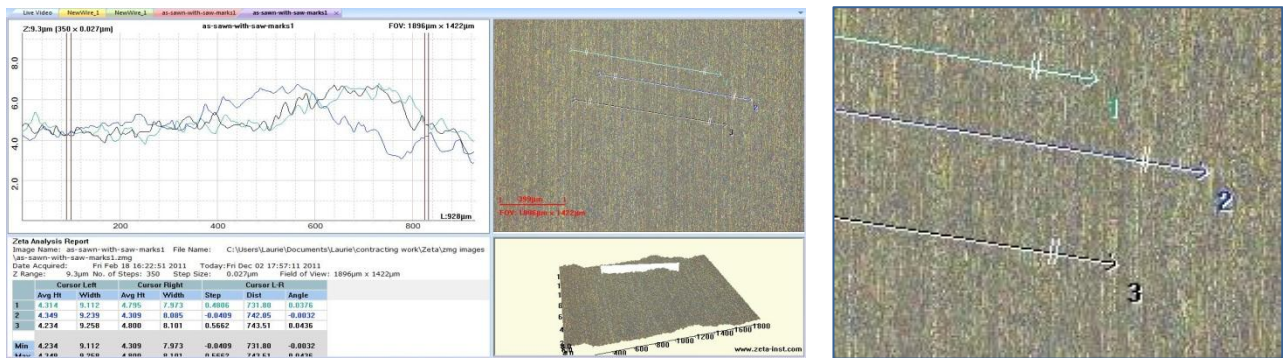


Fig. 63. Three cross section lines for step height analysis

The same set of four cursors is used for analysis on all cross sections. If there are three or more cross sections, the *Analysis Report* also includes statistics for each column of data.

Step heights in multiple locations on one profile

A complex profile may have more than one step of interest. There is only one set of cursors, but similar features called *markers* can be used to provide additional calculations.

Use markers on a profile as follows:

1. Create a cross section with the desired orientation, length and position.
2. Use the vertical cursors to define a step height measurement.
3. In the *2D Line Profile* pane, position the mouse cursor where you would like to put a marker, then right click to bring up the menu shown in Fig. 64.
4. Click *Add Marker*. Two numbered red triangles (markers) appear above the active profile, and are also shown on the 2D image. An example is shown in Fig. 65.

- Click *Add Marker* again to add another pair of markers. Up to three sets can be analyzed. The second pair of markers is green and the third is blue

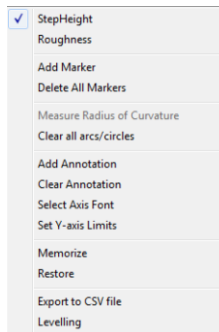


Fig. 64. Right click menu in 2D Line Profile pane

You can click and drag each marker to a new position on the same profile; however, the software will force the two markers in the same pair to stay in order from left to right.

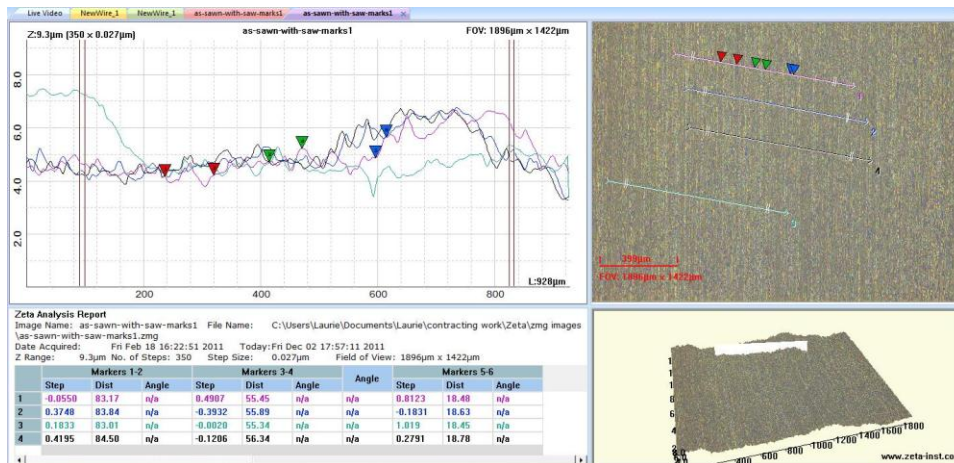


Fig. 65. Profile markers

The *Analysis Report* data automatically adds new columns of data as the markers are added. The step height and distance are calculated between markers 1 and 2 and between markers 3 and 4. An example is shown in Fig. 66. Calculation of the angle between the marker pairs is enabled by right-clicking on the even-numbered marker and selecting the angle measurement.

If there is more than one profile, the X-axis positions of the markers are used to define the calculation points for all profiles. However, the markers will show the correct Y-axis position for only one profile at a time. To move the markers to a different profile, click on a cross section in the *2D Composite View* to make it the active profile. The markers move to the new active profile and the analysis for the active profile moves to the top line of the results table. The actual results do not change because they already used the markers' X-axis positions to find the correct heights for all profiles.

Cursor Left		Cursor Right		Cursor L-R			Markers 1-2			Markers 3-4		
Avg Ht	Width	Avg Ht	Width	Step	Dist	Angle	Step	Dist	Angle	Step	Dist	Angle
3.130	0.5838	0.8818	0.4671	-2.248	2.347	-43.77	-0.0157	2.005	n/a	-0.2311	1.185	n/a
3.102	0.5838	0.8153	0.4671	-2.287	2.347	-44.26	0.7380	2.005	n/a	-0.0871	1.185	n/a

Fig. 66. Step height data from cursors and markers

Profile leveling

When samples are not very flat, a cross section of the surface may show a strong tilt. It is easier to measure step height if you level the profile first. Leveling is performed using the vertical cursors and cannot be done using markers.

Profile leveling does not change the image data. This means that if you draw another cross section on the 2D image, the resulting profile will not be leveled.

To level the profile:

1. Move the two sets of vertical cursors in the *2D Line Profile* pane so that their center points define two positions that you would like to put on a level surface with each other. If there is more than one profile in the graph, the same cursor positions are used for leveling all profiles.
2. With the cursor in the 2D Composite View, right click to bring up the menu shown in Fig. 64.
3. Select *Levelling*. The dialog box shown in Fig. 67 appears.

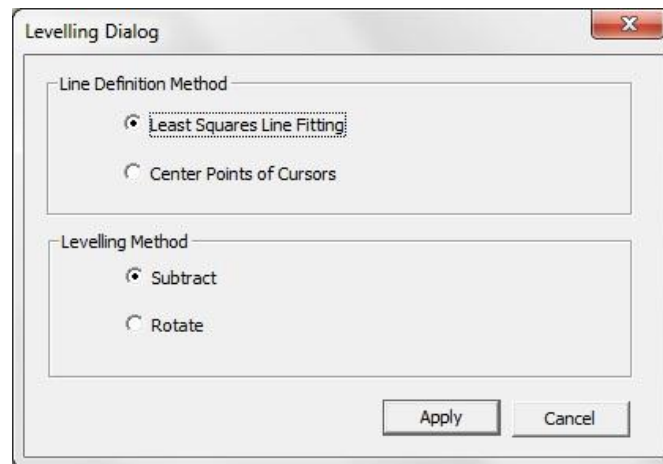


Fig. 67. Leveling dialog box

4. If the surface between the two sets of cursors is fairly linear without any steps, choose *Least Squares Line Fitting* in the *Line Definition Method* frame. This option uses all of the data points between the far left and far right cursors to fit a line. This line becomes the zero height line.

- If the surface contains anomalies such as bumps or pits that do not represent the underlying surface, choose *Center Points of Cursors*. This option uses only two points to fit the zero height line: the data points at the center of each pair of cursors.
- In the *Levelling Method* frame, choose *Subtract* or *Rotate*. The *Subtract* option affects only the Y axis (height) values. The *Rotate* option is more physically accurate, and it affects both the Y axis and X axis values. In most cases, the results are very similar between the two options. *Subtract* is faster and is the default choice.
- Click *Apply*. Analysis data automatically updates.
- To reset the profile, click on the cross section in the *2D Composite View* pane.

An example of profile leveling is shown in Fig. 68. Before leveling, the base surface is strongly tilted. Leveling was done using the *Center Points of Cursors* and *Rotate* options. After leveling, the base surface is set to zero height so the Y-axis is adjusted accordingly. The Y-axis range is also smaller so the step is the focus of the profile graph.

The results change automatically. Before leveling, the Z positions (labeled as *Avg Ht* values) of the data points at the cursor positions are 8 to 26 microns above the scan start position. After leveling, the Z positions are close to zero, and so are the step height between the cursors and the angle between them. The width and distance values changed because the cursors were moved after leveling.

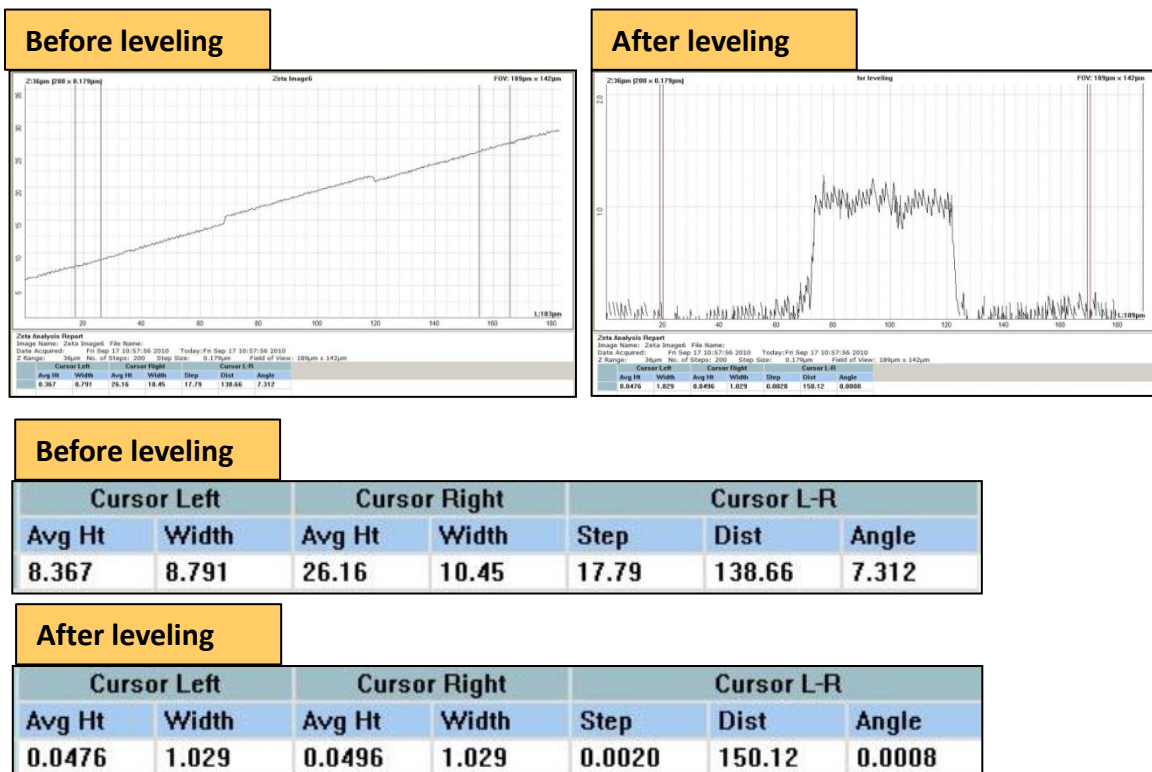


Fig. 68. Before and after profile leveling

Surface leveling

For some operations, leveling the base surface of the raw image is necessary. This includes measuring the volume of a 2D feature.

Level the reference surface as follows:

1. With the cursor in the *2D Composite View*, right click to bring up the menu shown in Fig. 58.
2. Select *Add Reference Surface*. Three boxes appear on the *2D Composite View* image, with lines connecting their center points. The triangle formed by these lines defines the reference surface. Fig. 69 shows the leveling boxes for a surface with a known step feature running down the center of the image.

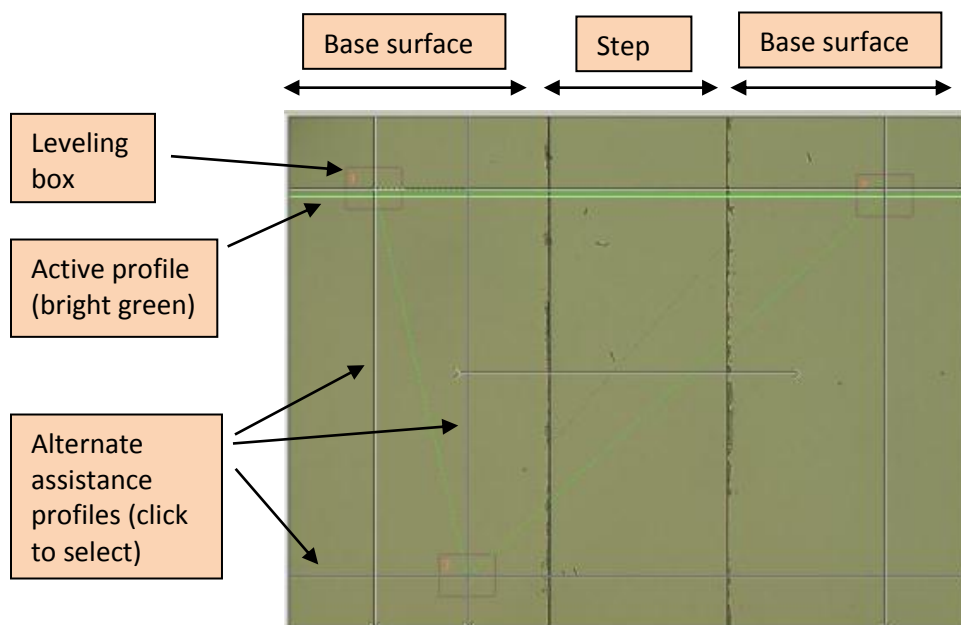


Fig. 69. Leveling boxes for setting reference surface

3. Change the size of a box by clicking and dragging on a corner of the box.
4. Move a box by clicking and dragging the crosshair at the center of the box.
5. Avoid including anomalies such as bumps or pits inside the boxes, but features inside the triangle will not matter since only the three center points define the leveling plane.
6. Observe the line profile pane for assistance. Vertical and horizontal lines are drawn through the center points of the boxes in the *2D Composite View* pane, six lines in all. One line is the active line and is colored green; the profile of this line appears in the *2D Line Profile* pane. The active profile changes as you click on different lines. These profiles help you to decide where to move the leveling boxes. In Fig. 69, the boxes are all positioned on the base surface and not on the step feature.

- In the right-click menu, select *Level Surface*. The plane defined by the box center points is now the zero height plane.

Step height between two areas (boxes)

To provide more averaging, it may be useful to calculate the height difference between large areas on the sample surface.

- First, set the reference plane using the surface leveling procedure.
- In the right-click menu, select *Boxes Step Height*. One red rectangle appears on the 2D image.
- In the right-click menu, select *Add Area Box*. A second red rectangle appears on the 2D image and new calculations appear in the *Analysis Report*.
- If desired, add a third box in the same way. The maximum number of boxes is three.
- Change the size of a box by clicking and dragging on a corner of the box.
- Move a box by clicking and dragging the crosshair at the center of the box.

The *Analysis Report* displays the average height of each box, the length and width of each box, and the height difference between each pair of boxes. Each box is labeled 1, 2, or 3 in its upper left corner. An example of box step height analysis is shown in Fig. 70.

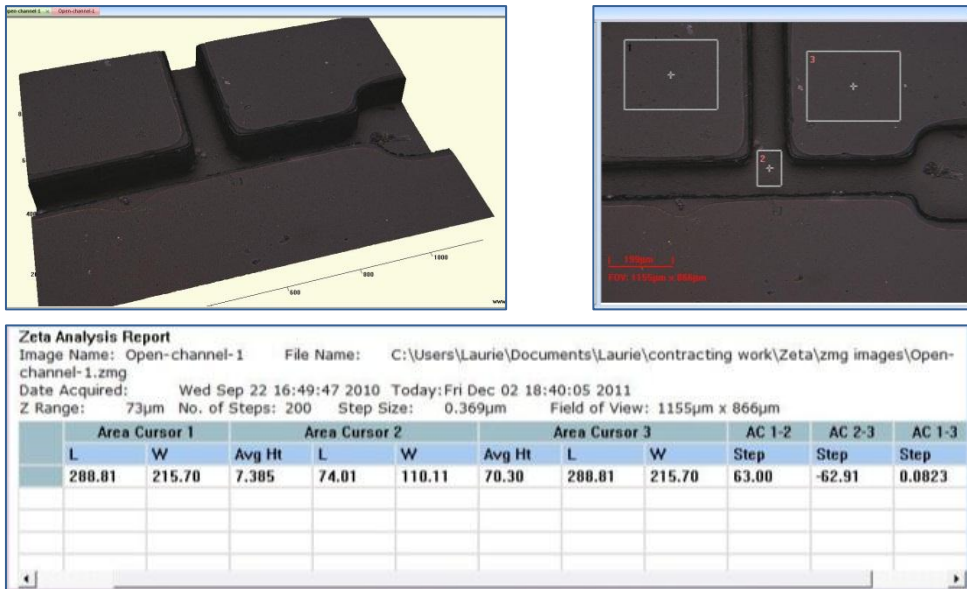


Fig. 70. Box step height analysis

Removing part of the height data

The original image file includes all measurement data from the scan, but sometimes it is desirable to eliminate some parts of it. A defect may make it difficult to position cross section lines or boxes to make

a good step height measurement. In other cases, the sample (or the area of interest on the sample) is smaller than the field of view and the other parts of scan are undesirable. The Cut function allows you to remove parts of the height data.

Use the Cut function as follows:

1. Open a 2D view of an image file.
2. Click and drag the mouse cursor to draw a box around the area of interest.
3. In the right-click menu, select *Cut – selection* to remove the data within the box.
4. Select *Cut – area outside of the selection* to remove the data outside the box.
5. Save the image (usually with a new name).
6. Continue with analysis.

The areas with data removal are not included in any further measurements or calculations.

6.2 Roughness

Roughness is a statistical measure of surface height variation, usually over a small length scale. Zeta software provides eight standard roughness parameters for each analysis region. The 2D roughness parameters comply with ISO standard 4287 and are defined in Appendix A.

Select roughness analysis in either one of these ways, as shown in Fig. 71:

- Position the mouse cursor within the *2D Line Profile* pane and right click to bring up a menu, then select Roughness.
- Check the checkbox labeled *Roughness*, located on the right side of the toolbar in the *Analysis* tab.

Many functions described for step height measurements also apply to roughness measurements, including methods for working with cross section lines, annotating screen shots, and cutting data from the original image data.

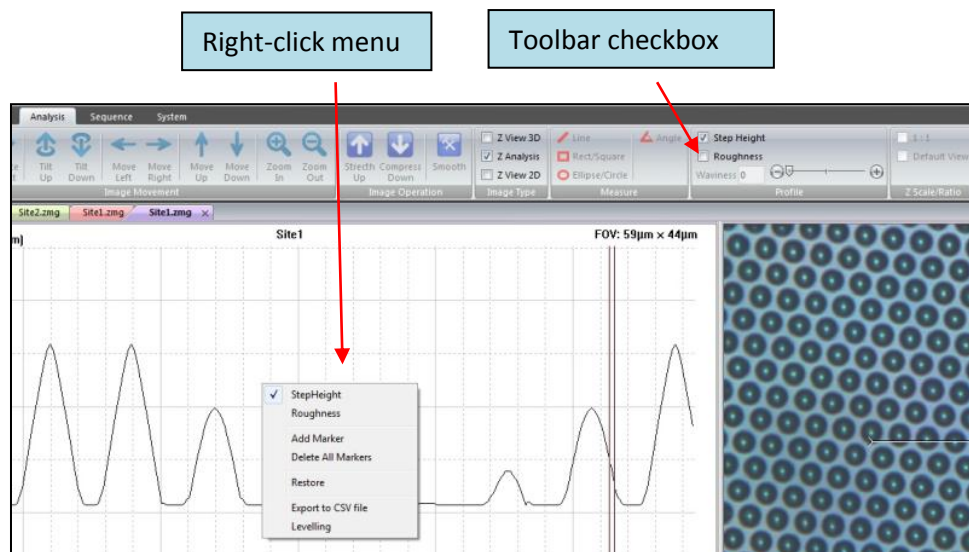


Fig. 71. Two ways to start the roughness measurement

Roughness of a line profile

A typical roughness analysis window is shown in Fig. 72. The *2D Composite View* pane is used to define the locations of cross section lines exactly the same way as for step height analysis. However, the analysis regions for roughness are defined with markers, not cursors. To analyze roughness, follow these steps:

1. In the *2D Composite View*, create a cross section with the desired orientation, length, width and position.

2. Move markers 1 and 2 until they enclose the first area for roughness analysis. Observe the *results* in the *Analysis Report*; they change as you move the cursors.
3. If you would like to analyze another portion of the same profile, add two more markers to the profile and move them to enclose the second analysis area. Add a third set of markers if desired.

For each pair of markers, a set of eight roughness parameters is calculated. The example in Fig. 72 shows that the region between markers 1 and 2 is much rougher than the region between markers 3 and 4.

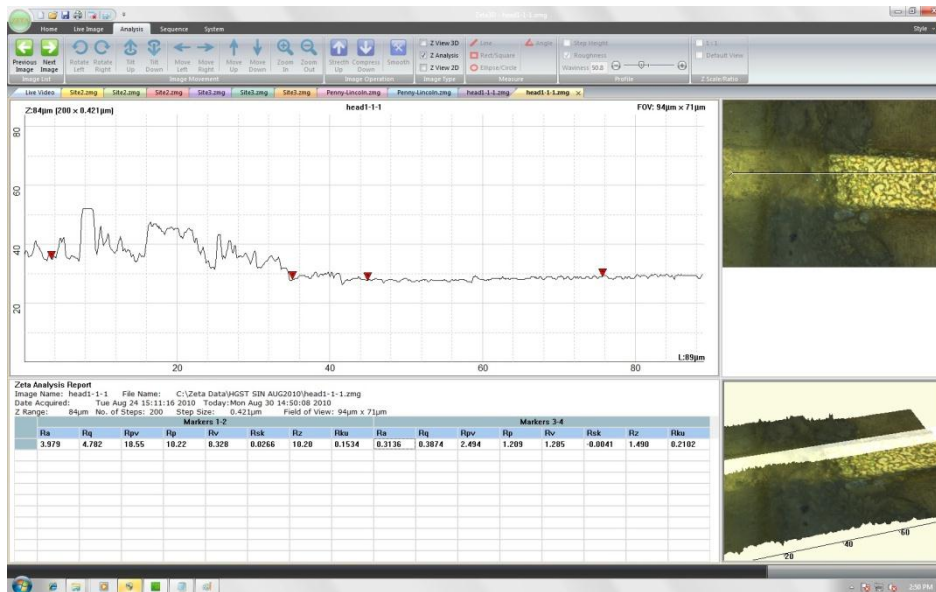


Fig. 72. Roughness analysis window

Roughness of an area (box)

Roughness of a surface may be very uniform or very nonuniform. Sometimes it is appropriate to calculate roughness over an area instead of a line in order to capture the average qualities of the region.

To calculate roughness over an area:

1. With the cursor in the *2D Composite View*, right click to bring up the menu shown in Fig. 58.
2. Select *Boxes Roughness*. One red rectangle appears on the 2D image and new calculations (one set of roughness parameters) appear in the *Analysis Report*.
3. In the right-click menu, select *Add Area Box*. Another red rectangle appears on the image and new calculations appear in the *Analysis Report* pane.
4. If desired, add a third analysis area in the same way. The maximum number of boxes is three.
5. Change the size of a box by clicking and dragging on a corner of the box.

6. Move a box by clicking and dragging the crosshair at the center of the box.

Roughness parameters for an area are written with the initial letter of S instead of R to denote that they indicate roughness for a surface instead of a line.

Waviness

Waviness refers to long-wavelength curvature of the surface. It affects the roughness calculations if its scale approaches the roughness analysis length. The Zeta 3D software provides a way to reduce the effect of sample waviness on a line profile.

1. Create a cross section for analysis and move markers 1 and 2 to the boundaries of the region of interest. When waviness correction is applied, only markers 1 and 2 are analyzed even if other markers are present.
2. Move the waviness slider control from left to right. The control is shown in Fig. 73 and it is located under the *Roughness* checkbox in the toolbar. The far left slider position causes the value of zero to be displayed in the numeric field; this means that no waviness correction will be applied. As the slider moves to the right, the numeric value increases and the amount of correction increases.

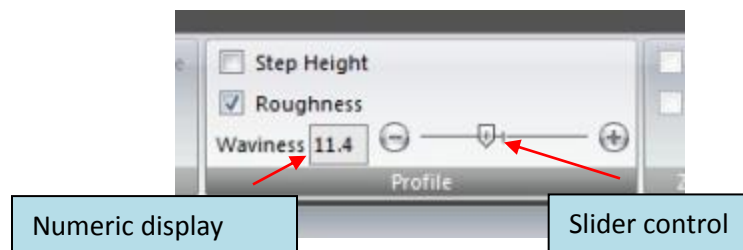


Fig. 73. Waviness controls

3. Observe the *2D Line Profile* graph as the slider moves. A green line is drawn through the original data to show the underlying surface, as calculated using the amount of waviness correction selected by the slider position. The underlying surface height is subtracted from the original data to produce a corrected profile, which is drawn in red. This is shown in Fig. 74.

The waviness correction applies to the shape of the 2D profile graph. This is different from the use of the 3D image Gaussian filter, which applies to the entire scanned surface.

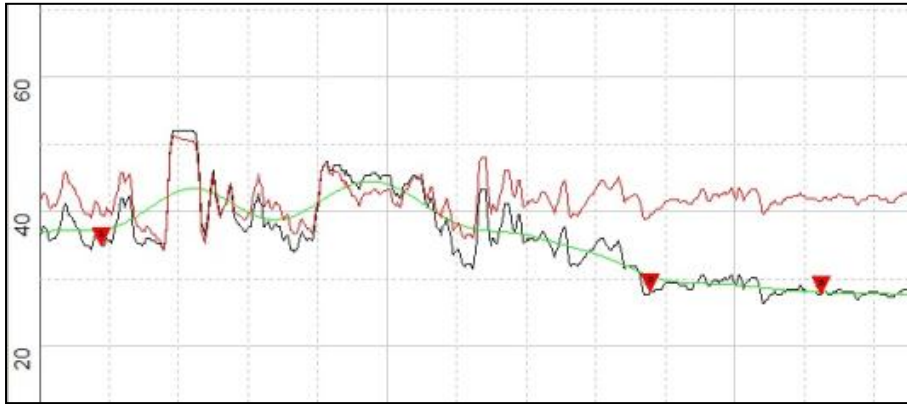


Fig. 74. Waviness profile correction

After waviness correction, a second set of roughness parameters is calculated. They are listed with the initial letter W instead of R to denote that the roughness calculations are applied to the waviness curve.

Roughness parameters

A number of standard parameters are commonly used to describe surface roughness. The eight parameters used in Zeta 3D software are described in Table 4. They are calculated from the individual data points in the analysis area, where each data point is the height deviation of the actual surface compared to the ideal surface. The ideal surface is created by fitting a smooth line or curve to the measured data. The height deviations are positive if they are above the ideal surface and negative if they are below it.

Appendix A contains details about the calculation of these parameters.

Table 4. Zeta 3D roughness parameters

Parameter	Meaning
Ra	Arithmetic average of deviations from the mean
Rq	Root mean squared value of deviations
Rpv	Maximum peak to valley difference
Rp	Maximum peak height
Rv	Maximum valley depth
Rz	Average of (Rp – Rv) from five sections
Rsk	Skewness (asymmetry of distribution)
Rku	Kurtosis (shape of distribution peak)

6.3 Dimensions

Measure lateral (XY) dimensions

Two-dimensional Zeta images can be used to measure lateral dimensions of features on the surface.

Choose a source image

There are two types of 2D images: microscope view and composite view. Microscope view images are digital captures of what you see through the microscope objective. The broad-spectrum light source provides excellent color fidelity (true color) which assists in identifying surface features. However, due to variations in surface height, the full surface may not be in focus.

Composite view images result from a full Zeta scan and show every feature in focus. If you want to measure distances or feature sizes on complex surfaces, such as surfaces with multiple layers, use a composite view image.

Create a microscope view image as follows:

1. Focus on a sample using the procedure described in Chapter 2. Do not perform a scan. The only window open will be the one labeled *Live Video*.
2. In the *Live Image* tab, click *Freeze Video*. The white light image is captured and displayed. A new window is created.

Create a 2D composite view image as follows:

1. Perform a full Zeta scan as described in Chapter 2.
2. Check the checkbox labeled *ZView 2D* (located in the *Analysis* tab) to display a full-screen view of the 2D composite image.

Open a previously stored file as follows:

1. Open a raw data image file (*.zmg file).
2. Check the *ZView 2D* checkbox to display a full-screen 2D composite view image.

Measure distance or angle

The 2D image should be in a full screen view and the *Analysis* tab should be active.

There are six calibrated drawing tools available: *Line*, *Rectangle/Square*, *Ellipse/Circle*, *Circle (3 points)*, *Angle* and *Freeform*. When you draw on the 2D image, dimensions are automatically calculated and displayed. The dimensions are updated in real time if you change the drawing object sizes.

Select and use the drawing tools as follows:

1. Click one of the drawing tools in the *Measure* group of the *Analysis* tab.
2. Alternatively, right click on the 2D image to bring up the first menu shown in Fig. 75.

3. To estimate sizes by eye, choose *Grid* to place a square grid and scale over the image.
4. To make more precise measurements, select *Measure* to see the second menu containing a list of drawing tools. Select one tool and use it as described in the following pages.

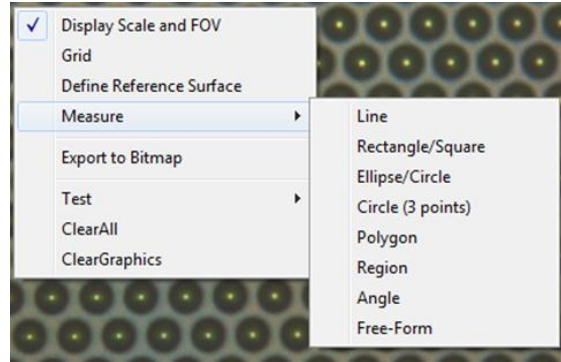


Fig. 75. 2D drawing tools menu

To use the *Line* tool:

1. Hold the left mouse button and drag the mouse in any direction to create a line. The length of the line in microns will be displayed on screen.
2. To generate a horizontal or vertical line, hold the Shift key and left mouse button while dragging the mouse in a horizontal or vertical direction. The line tries to snap to horizontal or vertical even if the drawing motion is a little off.
3. To move a line, click on any part of the line, press and hold the left mouse button, and drag the mouse.
4. To change the length of a line, click on either end of the line, press and hold the left mouse button and drag.

To use the *Rectangle/Square* tool:

1. Hold the left mouse button and drag the mouse in any direction to create a rectangle. The length and width of the rectangle in microns will be displayed on screen.
2. To generate a square, hold the Shift key and left mouse button while dragging the mouse.
3. To move the box, click on the cross at the center of the rectangle, hold the left mouse button, and drag the mouse.
4. To change its size, click on any side, hold the left mouse button and drag.
5. To rotate a rectangle, click on any corner, hold the left mouse button and rotate.

To use the *Ellipse/Circle* tool:

1. Hold the left mouse button and drag the mouse in any direction to create an ellipse. The major and minor axis lengths of the ellipse in microns will be displayed on screen.
2. To generate a circle, hold the Shift key and left mouse button while dragging the mouse.
3. To move the shape, click on the cross at the center, hold the left mouse button, and drag the mouse.
4. To change its size, click on the edge, hold the left mouse button and drag.

To use the *Circle (3 points)* tool:

1. Press the left mouse button on the first point on the desired circle, then drag the mouse and release the button on the second point.
2. Click the left button to set the third point and the final circle.
3. To move the shape, click on the cross at the center, hold the left mouse button, and drag the mouse.
4. To change its size, click on the edge, hold the left mouse button and drag.

To use the *Angle* tool:

1. Click the left mouse button three times. The first click defines the end of the first side, the second click defines the vertex location, and the third click defines the end of the second side. The angle in degrees will be displayed on screen.
2. To move the shape, click on the cross at the center, hold the left mouse button, and drag the mouse.

To use the *Freeform* tool:

1. Select the *Freeform* tool using the right-click menu.
2. Position the cursor at the drawing location starting point.
3. Hold the left mouse button and drag the mouse to trace the outline of the feature.
4. Release the mouse button when the shape is complete. The major and minor axis lengths of the shape in microns will be displayed on screen.

To magnify the image:

1. For temporary magnification, press the Shift key on the keyboard while holding the left mouse button down. This produces a 4X magnifying glass around the cursor.
2. To zoom the image in and out, move the mouse wheel while the cursor is positioned over the 2D image. The cursor location is the center of the zoom area.

To remove all graphics from the image, select *Clear All* from the right-click menu.

Measure by region

Measuring the area or volume of features on the sample surface is accomplished in a very different way from measuring dimensions. The procedure is more complex, but it allows you to make repeated measurements on similar features more quickly than the manual method using drawing tools.

1. Set a reference surface as described in the section *Surface leveling*. To calculate feature volumes accurately, the reference surface must be a plane at the base of the features.
2. With a 2D composite image in a full-screen view, right click to bring up the menu shown in Fig. 75. Select *Measure*, then select *Region* in the drawing tools menu. A dialog box titled *Region Grow* appears, as shown in Fig. 76.
3. Start with Region 1 in the pulldown menu; you can define up to two regions.
4. Choose either *Color* or *Z Height* for the selection method. Experiment with both methods to decide which one works best for a given sample.

Each option uses slider controls to set the upper and lower thresholds for selection. *Color* has three pairs of sliders labeled *Red*, *Green* and *Blue*; the *Move All* checkboxes enables faster operation by moving the three related sliders together. *Z Height* has one pair of slider controls

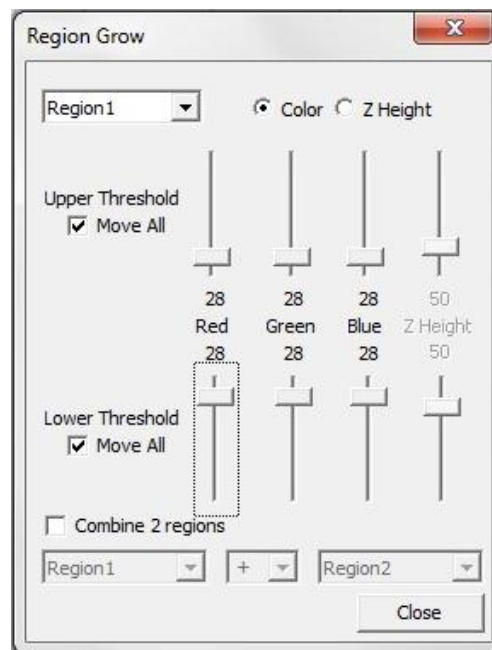


Fig. 76. Region Grow dialog box

5. Use the slider controls to change the upper and lower thresholds. Start with the controls in the middle of their ranges. Do not close the dialog box.
6. Click on a feature in the 2D image. A red outline will appear that defines the boundaries of a region with the properties defined by the sliders.

Every feature is labeled with an index. As soon as a feature is defined, a results table appears to the right of the image pane, as shown in Fig. 77. The reported parameters for each feature are the X and Y locations, the major and minor axis lengths (in microns), the area (in square microns), the volume (in cubic microns), and the X and Y locations of the highest point of the feature.

7. If the outline is not good enough, delete it by right clicking on the feature and selecting *Delete* in the menu. The data is also deleted.
8. Change the upper or lower color thresholds and click on the feature in the image again.

This is an iterative procedure; keep moving the sliders until you are satisfied with the red outline.

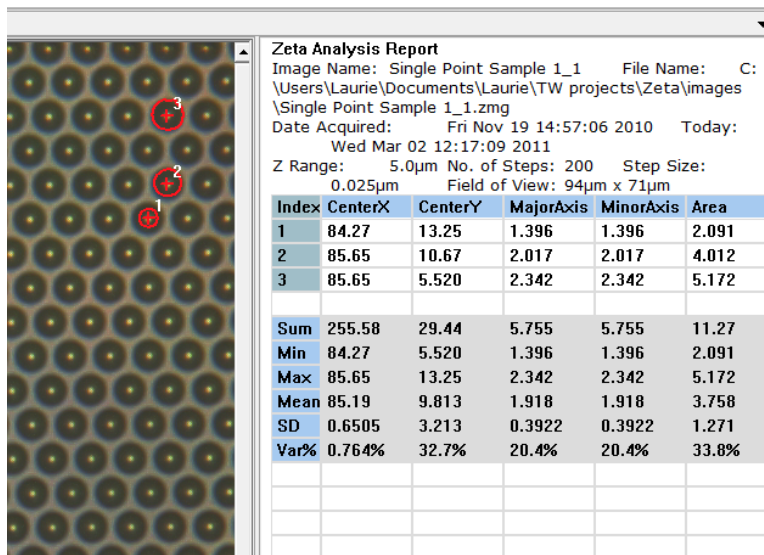


Fig. 77. Measure by Region example

9. Click on another feature in the 2D image to add it to the list. If the new feature is somewhat different in properties than the first one, the red outline may not be accurate. In this case, delete the outline, then adjust the thresholds and click on the feature again.
10. Click on all features of interest in the 2D images to add them to the list. Adjust thresholds as needed to optimize the boundaries for each feature.

Since data does not update automatically when the settings are changed, every feature in the data list might have been defined using a different parameter (color or height) and different slider settings.

When there are three or more features in the list, statistics for each column automatically appear, as shown in Fig. 77.

To select a very complex feature or an area made up of two different types of surfaces, combine two regions as follows:

1. Check the checkbox labeled *Combine 2 regions* in the *Region Grow* dialog.
2. Define Region 1 and Region 2. They can have completely different definitions.
3. Choose whether to add the two regions together or subtract Region 2 from Region 1.

To select only part of a feature:

1. Draw a box around the target area using the 2D drawing tools.
2. Click on the part of the feature that is inside the box; the boundary outline will remain within the box.

To clear all outlines from the 2D image, right click on the image and choose *Clear All*. The data will not be affected.

CHAPTER 7 **Standard Recipes**

Recipe files contain parameters that define measurement and system setup options. If you perform measurements repeatedly, you can create a recipe file to save time and to ensure consistency between runs. In addition, there are some measurements that can be performed only with special purpose recipes.

Topics in this chapter:

- 7.1 Recipe file operations
- 7.2 Scan parameters
- 7.3 Analysis parameters
- 7.4 Location parameters
- 7.5 Report parameters

7.1 Recipe file operations

A recipe file contains instructions for performing a scan and analyzing the results.

Find and open a recipe

There are two ways to browse through folders to locate a saved recipe:

- Click the **Load** button in the *Recipe* group of the *Live Image* tab.
- Press the **Load** button in the *Scan Dialog* window.

The *Open* dialog shown in Fig. 78 appears. Recipes may be located at the top level of the browse window or within folders below this level.

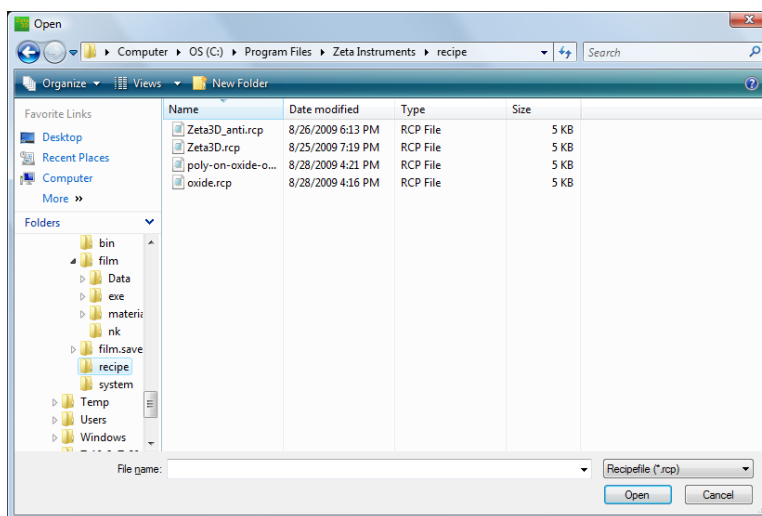


Fig. 78. Recipe Load dialog

Click on a recipe file name to highlight it, then press the **Open** button at the bottom of the window. You may also double-click on the recipe name.

Recipes at the top folder level may also be selected using the pull-down list at the top of the *Scan Dialog* window.

Edit and save a recipe

There are two ways to open a recipe for editing:

- Click the **Edit** button in the *Recipe* group of the *Live Image* tab, as shown in Fig. 79.
- Press the **Edit Recipe** button in the *Scan Dialog* window.

Specific recipe parameters are discussed later in this manual.

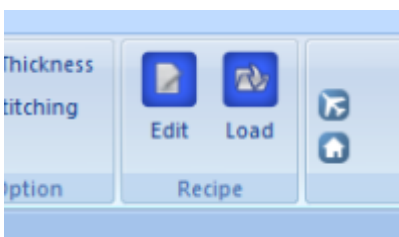


Fig. 79. Recipe edit button in Live Image tab

After editing the recipe, click on the **SaveToFile** button within the *Recipe Edit* window. The Save As window as shown in Fig. 80 appears. In the *File name* input field, type in the recipe name and click **Save**.

You may create folders under the top level of the browse window for recipe organization.

Recipe files must have an extension of *.rcp. Do not change the file extension.

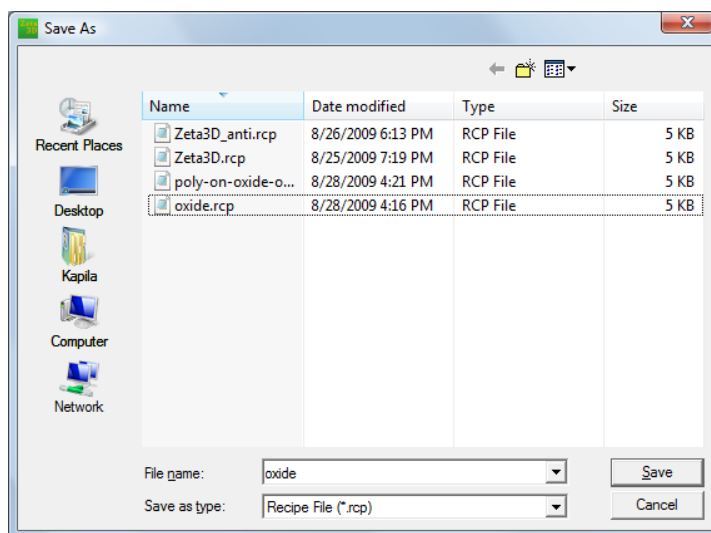


Fig. 80. Recipe save dialog

System operation with a recipe

If you have created a recipe file for your sample, the operation procedure for 3D imaging will be greatly simplified.

1. Load the recipe.
2. Confirm the objective lens selected in the *Scan Dialog* matches with what is on the turret.
3. Locate the area you want to image.
4. Focus on the surface of the sample.
5. Press **Scan**.

Similarly, once you have created a recipe file for your sample, the operation procedure for thin film thickness measure is also simplified:

1. Choose the right objective lens.
2. Acquire dark scan and reference scan data with a clean bare silicon sample.
3. Place the film sample on XY stage. Focus on the sample surface.
4. Acquire film spectrum.
5. Click on **Analyze** to fit the data.

7.2 Scan parameters

The parameters in the *Scan* tab, shown in Fig. 81, replicate the settings that you make in the *Scan* dialog box when you run the system in manual mode. They also allow you to do some things that are not available any other way. The *Scan* tab parameters fall into the following groups: basic scanning, image quality, high dynamic range scanning, and multi-surface scanning.

Basic scanning parameters

The parameters labeled *Upper Limit – Top* and *Lower Limit – Bottom* correspond to the parameters with the same names in the *Scan Dialog*. You can change the values in several ways.

- Set the limits in the *Scan Dialog*, then open the active recipe. The values you see in the *Scan Dialog* appear in the recipe. Similarly, if you edit the values in the recipe, the new numbers will appear in the *Scan Dialog*.
- Use the *Scan Dialog* and keyboard controls to move the optical head up or down, then click on the small box with three dots located to the right of the parameter box. This sets the value to the current head position.
- Edit the parameters directly by double clicking in the parameter box and entering a value. Be very careful when editing this way.

Instead of setting both the scan top and scan bottom, you can use Auto Focus to let the system find the best focus position.

To use Auto Focus:

1. Open the active recipe for editing and check the *Auto Focus* checkbox.
2. Locate the highest and lowest surfaces of the sample using the mouse wheel for fine focus position control.
3. Move the optical head approximately half way between the highest and lowest surfaces.
4. Click **Set Nominal Focus** in the *Scan Dialog*.
5. Set the number of steps, range, or resolution value in the *Scan Dialog*. The default behavior is to center the Z range at the final auto focus position, so the range should be large enough to accommodate the known feature sizes.
6. If necessary, change the way the Z range is set relative to the auto focus position by editing the value of *Auto Focus %* in the recipe. This is the percentage of the Z range that is scanned above the final auto focus position.

The recipe does not have an explicit parameter for the nominal focus position or the range. Instead, if you enter positions directly into the recipe fields for the top and bottom positions, the difference between them is the scan range. The system will search for a good focus between the two positions, then it will reposition the scan to place the focus position at the center of the range (if the *Auto Focus %* parameter is set to the default value of 50%). The end result is that the final scan top and bottom positions will be changed from the values you entered, but the range will be the same.

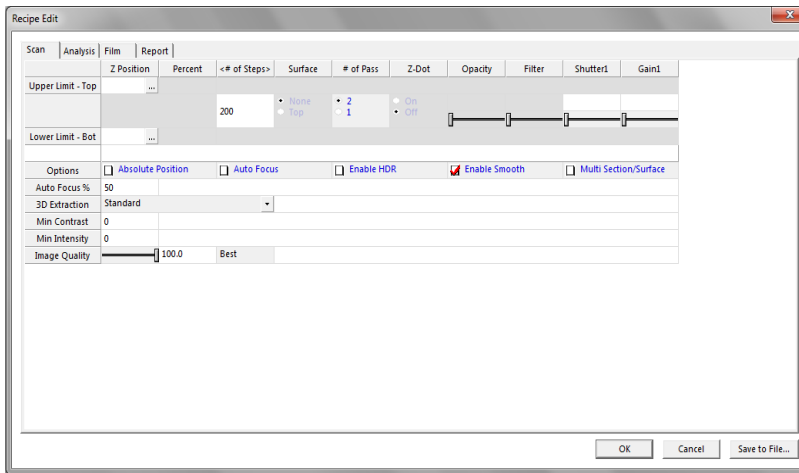


Fig. 81. Scan tab in recipe

The number of steps is the same as in the Scan Dialog. Making a change in the recipe is reflected in the *Scan Dialog* and vice versa.

The number of passes is set to 2 by default.

Image quality parameters

These parameters are usually left at their default settings but may be changed for special purposes.

Min Contrast and *Min Intensity* are used to reduce noise; zero is the default.

The *Smooth* checkbox selects whether to use smoothing on the 3D image; the default is yes (box checked).

3D Extraction defaults to *Standard*.

Visual Quality is a slider control that ranges from 0 to 100. If you reduce the quality below 100, the system stores a color picture less often than it stores the Z-dots image (which contains the actual height information). For example, if the value is 20, then a color image is stored every five measurement steps. The final 2D and 3D images will be less sharp visually, however the underlying surface height accuracy is not affected. Reducing the Visual Quality allows the use of more measurement steps.

Shutter1 defaults to 400ms (for the 1/3-inch camera), which is good for most samples. If the image is too bright, decrease this value, and if it is too dark, increase it, but not above 750ms.

Gain1 defaults to 75 (for the 1/3-inch camera), which is good for most samples. If the image is too bright, decrease this value, and if it is too dark, increase it.

High dynamic range scanning parameters

Some surfaces are more difficult to scan than others. For example, on some solar cell wafers, metal contact lines have very high reflectivity (greater than 90%) while the adjoining nitride regions have extremely low reflectivity (less than 1%). Imaging such a surface in one scan requires the system to have a large dynamic range, while maintaining the required vertical resolution to create a good Z-profile.

The Zeta solution is a scanning technique that includes the use of two different camera settings and an algorithm for optimizing the quality of the image at the interface between the high and low reflectivity regions.

To enable HDR (high dynamic range) scanning, check the checkbox labeled "Enable HDR." This causes two more slider controls to appear, as shown in Fig. 82. They control the shutter and gain for the second camera setting.

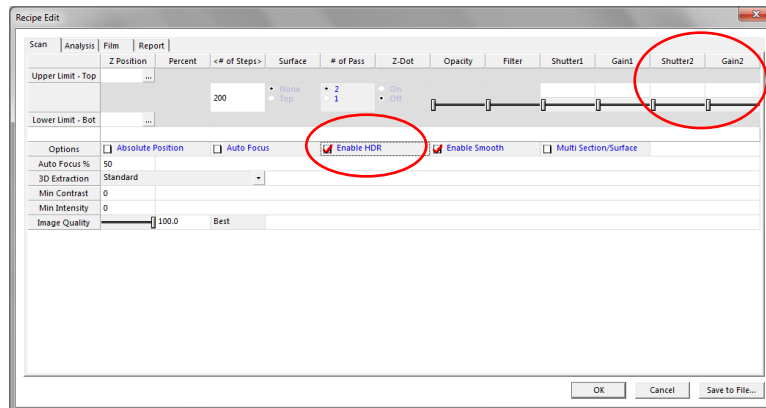


Fig. 82. HDR parameters in Scan tab of recipe

Use this procedure for HDR (high dynamic range) scanning:

1. Open a recipe for editing and check the *Enable HDR* checkbox.
2. Turn *Focus Assist* off.
3. Follow standard procedures to load a sample, find the feature of interest, and focus on the sample.
4. Adjust the illumination until the bright features in the surface are not over saturated while the dark features are visible.
5. Turn *Focus Assist* on.
6. In the *Recipe Edit* dialog, use the *Shutter1* slider control to increase the shutter to 700, then use the *Gain1* slider control to increase the gain until the low reflectivity surface near a high reflectivity feature is well illuminated.

7. Use the *Shutter2* and *Gain2* sliders to decrease both values until the high reflectivity surface is not saturated and is clearly visible.
8. Click **OK** to close the recipe editor.
9. Follow the standard procedure to set top and bottom of the scan range.
10. Click **Scan** in the *Scan Dialog*.

Multi-surface scanning parameters

The Zeta-20 can see through transparent upper layers to image lower surfaces. This capability requires some setup in the recipe. To enable multi-surface scanning, check the box labeled *Multi Section/Surface* in the recipe. The Scan tab appearance changes as shown in Fig. 83.

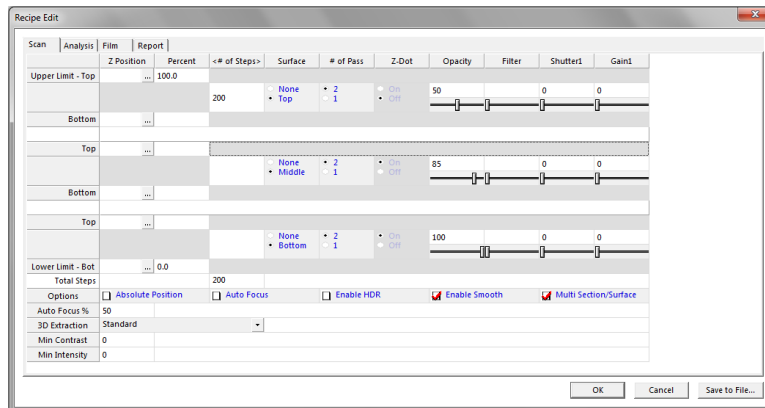


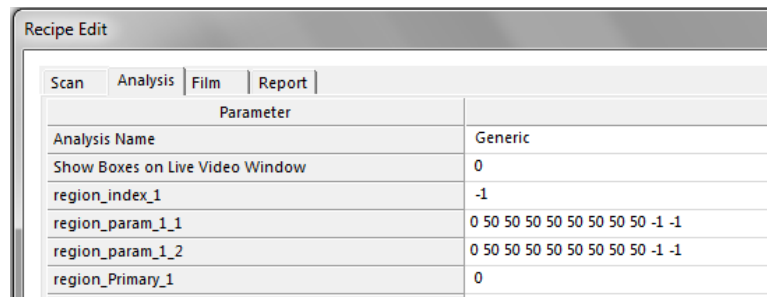
Fig. 83. Multi-surface scan recipe

In multi-surface scanning, the scan range is divided into three sections (for three surfaces). During the scan, the system chooses the strongest focus signal within each range to assign to that surface. Otherwise the strong surface signal would interfere with the ability to pick out the signals from the middle or bottom surfaces.

Multi-surface scanning is discussed in more detail in the next chapter.

7.3 Analysis parameters

The *Analysis* tab for a default recipe is shown in Fig. 84. The appearance of this tab changes depending on the recipe type. There may be many parameters, as in this example, or only a few. In general, you should edit these parameters only with specific instructions.



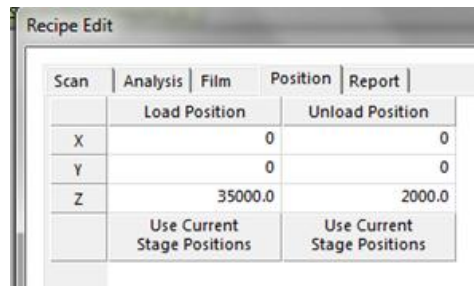
Parameter	
Analysis Name	Generic
Show Boxes on Live Video Window	0
region_index_1	-1
region_param_1_1	0 50 50 50 50 50 50 50 -1 -1
region_param_1_2	0 50 50 50 50 50 50 50 -1 -1
region_Primary_1	0

Fig. 84. Analysis tab in default recipe

7.4 Location parameters

The *Position* tab is shown in Fig. 85. It contains the sample load and unload positions.

To set a position, drive the stage to the desired location, then click the button labeled **Use Current Stage Positions** under the appropriate heading (*Load Position* or *Unload Position*).



Scan	Analysis	Film	Position	Report
			Load Position	Unload Position
X			0	0
Y			0	0
Z			35000.0	2000.0
			Use Current Stage Positions	Use Current Stage Positions

Fig. 85. Position tab in recipe

7.5 Report parameters

The *Report* tab is shown in Fig. 86. The parameters in this tab may change, depending on the recipe type.

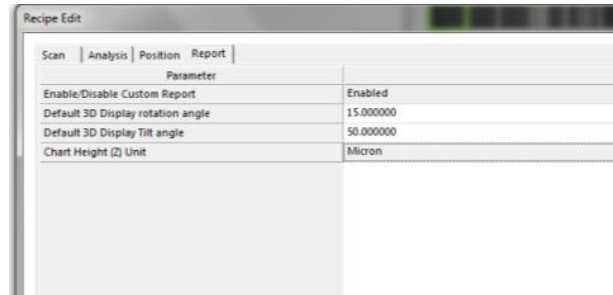


Fig. 86. Report tab in default recipe

The first parameter is *Enable/Disable Custom Report*. Set this value to *Enabled* in order to allow the changes made using the Memorize function (within panes in the analysis window) to be saved into the recipe. However, the individually memorized parameters are not visible in the recipe editor.

Two parameters allow you to set the default appearance of 3D images by setting the rotation and tilt angles.

The *Chart Height (Z) Unit* parameter can be set to Micron or Nanometer.

CHAPTER 8 **Special Purpose Recipes**

This chapter covers several types of special analysis recipes.

Multi-surface scanning is an option in standard recipes, but it applies to specialized samples. Additional procedures beyond standard scanning are needed in order to use its full capability.

Other recipe types are separately purchased custom applications.

Topics In this chapter:

- 8.1 Multi-surface scanning
- 8.2 Pyramids recipe
- 8.3 PSS recipe
- 8.4 Solar Finger recipe
- 7.5 DiamondWire recipe

8.1 Multi-surface scanning

Multi-surface scanning is intended for samples such as the one shown in Fig. 87. A transparent layer covers an open channel which is formed in an underlying layer. Measuring the thickness of the cover plate and the depth of the channel is possible by using multi-surface scanning.

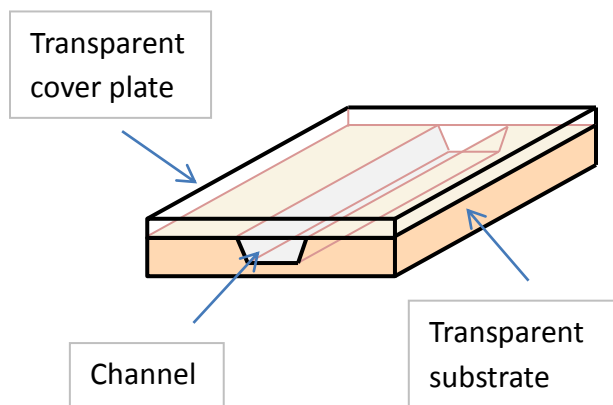


Fig. 87. Structure with open channel under transparent layer

A multi-surface scan divides a standard scan into three vertical sections: top, middle, and bottom. Each section contains one of the surfaces of interest. In Fig. 87 the top surface is the top of the cover plate, the middle surface is the bottom of the cover plate (which is also the top of the channel), and the bottom surface is the bottom of the channel. The Zeta-20 system looks for the best focus within each section and assigns that Z height to the surface which corresponds to the section. You can then view the three surfaces together or separately and calculate the distances between the surfaces.

The multi-surface scan parameters appear in the *Scan* tab of a standard recipe and were briefly described in Chapter 5. This chapter provides more detailed instructions for using this option.

Best results from multi-surface scanning are obtained with cover glass compensated objectives to maximize the signal strength from lower levels. In addition, the dual grid option is recommended for this measurement.

Define the zones and take a scan

The basic principles of scanning remain the same as a standard scan. The system takes up to 200 snapshots of a sample while moving the optical head within a user-defined vertical range, then chooses the strongest focus signal on a pixel by pixel basis to determine the Z height for each pixel. For multi-layer transparent structures, the top surface signals dominate the weaker signals from inner surfaces. Therefore you must define the vertical sections that contain the top, middle, and bottom surfaces in order to assist the software to locate them.

To do so, follow this procedure:

1. Load a sample and focus on the top surface using the *Focus Assist* feature. Note the head position (Z height) for the top surface.

2. Slowly lower the optical head and watch the live image to find the Z height of the middle surface. The Z dots from the *Focus Assist* function come into sharp focus on this surface.
3. Continue lowering the head to find the Z height of the bottom surface. Fig. 88 shows the appearance of the live video image at the three focus positions for a sample similar to the structure in Fig. 87. The Z dots are clearly seen at only three Z heights, which correspond to the top surface, the bottom surface of the top transparent layer (but note that the Z dots only appear over the open channel), and the bottom of the channel.

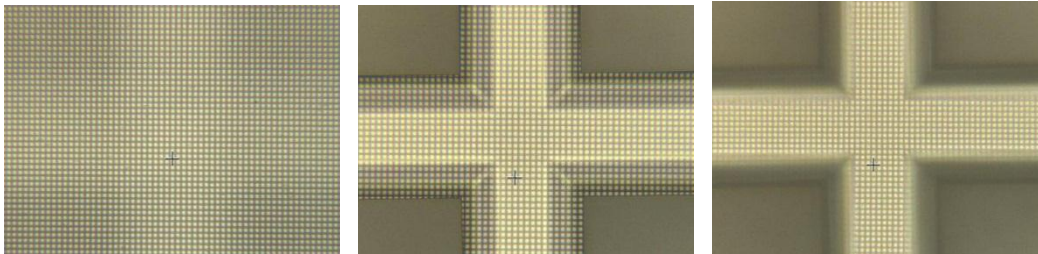


Fig. 88. Live video of Z dots at three Z positions for buried channel structure

4. Load a recipe and open it for editing.
5. Check the *Multi-Surface/Section* checkbox in the *Scan* tab to expand the scan controls to three sections.
6. Set the top and bottom locations for each section so that each one is roughly centered over the three focus positions. To do this, move the head using the **PgUp** and **PgDn** buttons or keys; the F11 key toggles between fast and slow movement. The mouse scroll button is not used in this operation. When the head is at the desired position, click the dots next to a number field to enter the current Z height into the field, as shown in Fig. 89.

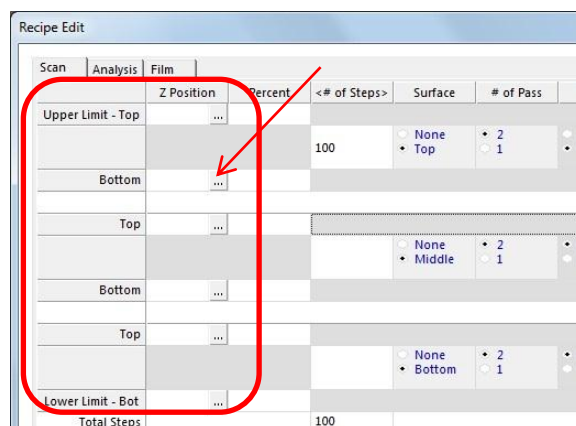


Fig. 89. Section boundary positions and Use Current Position button

The Z height increases as the head moves upward. This means the lowest height will be the lower scan limit. The sections cannot overlap, but the bottom height of one section can be equal to the top height of the adjacent one, and there can be a gap between sections.

7. Enter the *Total Steps* into the recipe editor, as shown in Fig. 90. The software calculates the distance between steps using the *Upper Limit* and *Lower Limit* values. Gaps between zones have the effect of reducing the number of actual measurement steps because measurements are not made in those locations. Therefore you can enter a number larger than 200 for *Total Steps* in order to increase the *Number of steps with image* to 200.

The software displays the number of steps that will be used in each zone. You should use a minimum of 15 slices in each zone.

The software also displays the percent of the total scan distance that each boundary represents, with zero at the bottom.

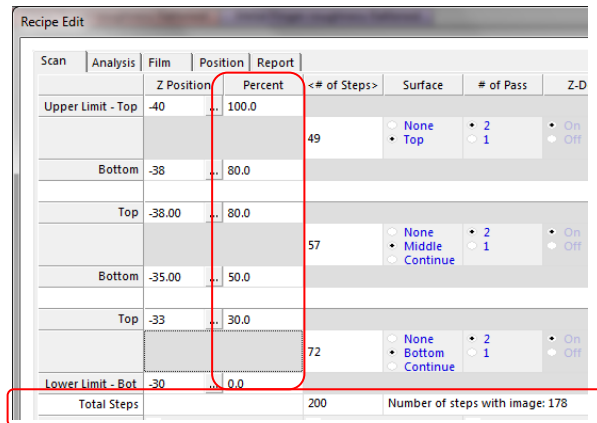


Fig. 90. Percent of scan distance and number of steps displays

8. Close the recipe by clicking **OK** to keep it in memory, or **Save** to save it. You do not have to save the recipe to run it.
9. Click **Scan** to initiate the scan.

Measure step height

After the scan, a 3D image with a step height measurement analysis appears. Fig. 91 shows the result after the left pair of cursors has been moved over the channel.



Fig. 91. Step height measurement on unfiltered image

The step height analysis is different for a multi-surface scan than it is for a standard scan. The software knows that there are three surfaces and displays the average height within the cursors for each of the surfaces. In addition, it calculates the distance between the top and middle surfaces and the middle and bottom surfaces, as shown in Fig. 92.

Image Name: Zeta Image3 File Name:							
Date Acquired: Wed Sep 22 14:53:02 2010 Today: Wed Sep 22 14:53:04 2010							
Z Range: 549µm No. of Steps: 100 Step Size: 5.545µm Field of View: 1155µm x 866µm							
	Cursor Left		Cursor Right		Cursor L-R		
	Avg Ht	Width	Avg Ht	Width	Step	Dist	Angle
Top	520.97	19.21	521.92	7.076	0.9554	379.07	0.1444
Middle	63.78	19.21	49.45	7.076	-14.33	379.07	-2.165
Bottom	21.98	19.21	10.99	7.076	-10.99	379.07	-1.660
Top - Middle	457.19		472.47				
Middle - Bottom	41.80		38.46				

Fig. 92. Step height results for multi-surface scan

Filter the images and reanalyze

The image information for the middle and bottom surfaces is relevant only for the part of the sample that has three distinct surfaces, in this case within the channel. The part of the image outside this region is noise. You can filter out this noise to improve the 3D image and the 2D analysis by following this procedure.

1. Open the 3D image view window.
2. Use the CTRL key with the mouse wheel to expand the Z axis until you can see the two bottom layers more clearly.

Fig. 93 shows the 3D image before and after this operation. In the expanded view, the top surface still exists but it is out of view past the top edge of the screen. The expanded image has also been rotated.

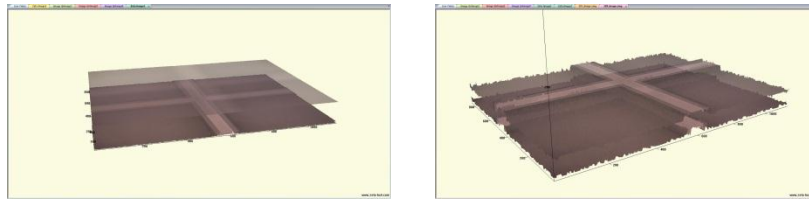


Fig. 93. 3D image in default and expanded views

3. Right click within the 3D image pane to bring up a menu, and select *MultiSurface*. A new control window appears, as shown in Fig. 94.

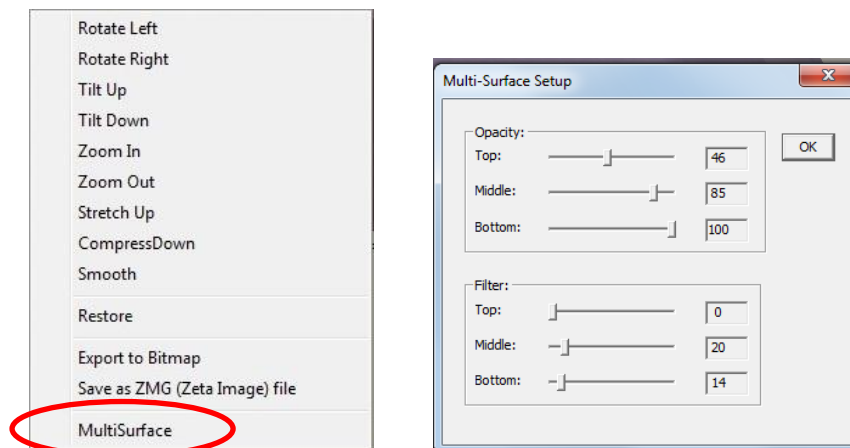


Fig. 94. Multi-Surface Setup control

4. Set the *Opacity* value of the top layer to zero in order to see through it completely.
5. Increase the opacity of the middle layer to emphasize it.
6. Increase the *Filter* value of the middle layer until the noise portions of the image disappear (in this example, the part outside the channel).
7. Reduce the opacity of the middle layer and increase the opacity of the bottom layer to emphasize the bottom layer.
8. Increase the filter value of the bottom layer until the noise portions disappear.
9. Set the opacity of all three layers to approximately 50 per cent.
10. Save the image file to set the filtering values.
11. Close the old analysis window.

- Open the filtered image, select step height measurement, and set the cursors over the channel. The improved analysis is shown in Fig. 95.

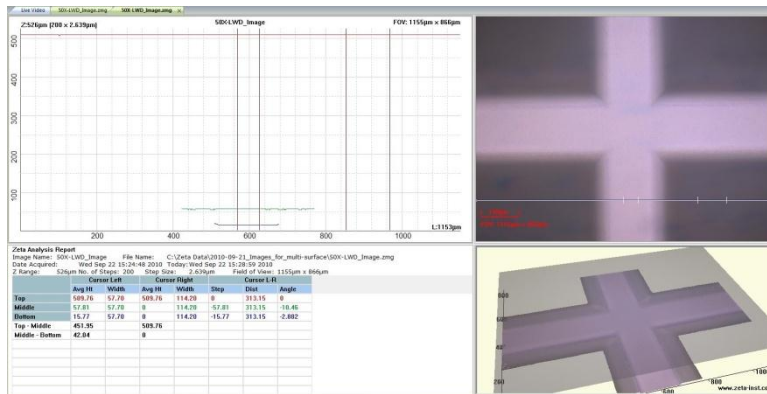


Fig. 95. Step height measurement on filtered image

8.2 Pyramids recipe

Pyramids analysis is a recipe for textured solar cell substrates. Anisotropic wet etching of monocrystalline silicon creates a series of pyramid structures which serve to enhance the absorption of light. This light trapping effect increases solar cell efficiency.

Fig. 96 shows an example of a Zeta-20 scan of a textured silicon wafer for solar cell manufacturing. The size of the pyramids in the vertical and lateral dimensions affects the quality of devices manufactured on the substrate. The Zeta-20 Pyramids recipe analyzes the quality of textured substrates by counting the pyramid structures and measuring their heights.

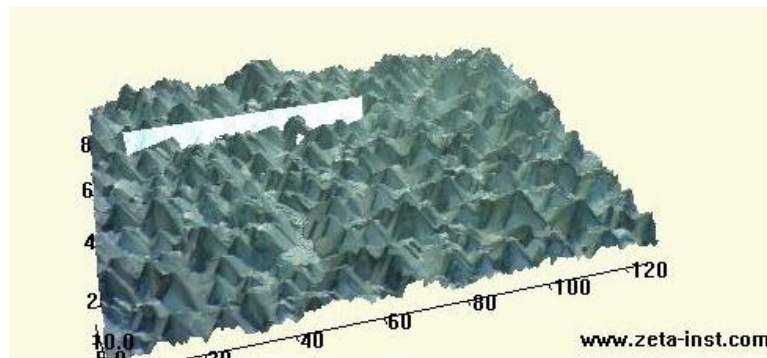


Fig. 96. Pyramid structures on solar cell substrate

The Pyramids recipe is a separately purchased option which requires a software license in order to run.

Scan conditions

Scan the sample with the following conditions:

- 1/3-inch camera with either the 0.35X or 0.5X coupler or 2/3-inch camera with the 0.5X coupler
- 100X objective
- One-pass scan with *Focus Assist* turned off

Image files may be saved for later analysis.

Analysis

Load the Pyramids recipe. Then, in any 3D image window, click on *Z Analysis* in the *Image Type* group on the toolbar. An analysis such as the one shown in Fig. 97 appears.

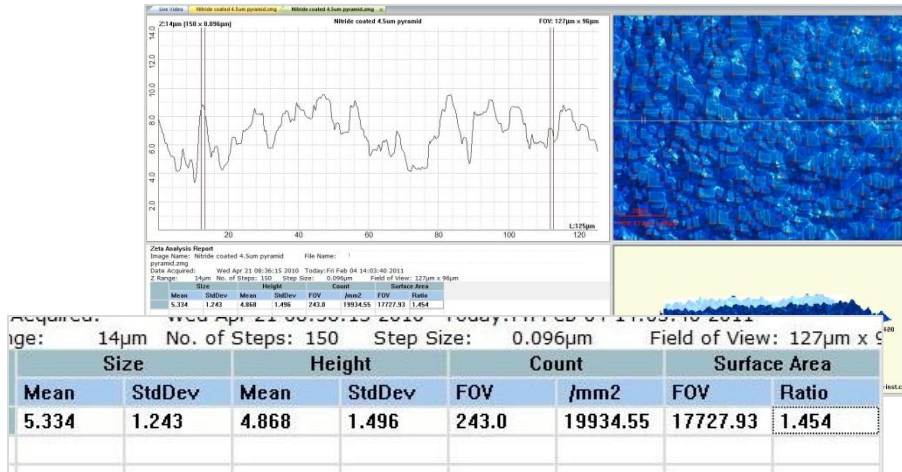


Fig. 97. Cross section screen of Pyramids analysis

The analysis is based on the 2D composite image; the 3D image is presented for illustration only. The software finds the peaks of the pyramids in the field of view and marks them with a red cross, as shown in Fig. 98.



Fig. 98. Pyramid locations after analysis

The 2D line profile is a conventional cross section, but the results pane shows the Pyramids analysis. The results include the following parameters:

Size is the lateral size of the pyramids in microns, showing the mean and standard deviation of all pyramids counted.

Height is the vertical size of the pyramids in microns, showing the mean and standard deviation. The baseline surface is calculated as the height for which 5% of the field of view is below it. The pyramid heights are measured with respect to the baseline surface.

Count is the number of pyramids in the field of view. The density is also calculated.

Surface Area is the total surface area of all pyramids in the field of view (FOV), while *Ratio* is the pyramid surface area divided by the area of a plane the size of the FOV.

Right click on the 2D image pane or the line profile plane to display histograms for the size and height parameters, as shown in Fig. 99. Right click on the data or 3D image panes to redisplay the cross section screen. The results pane is the same for both screens.

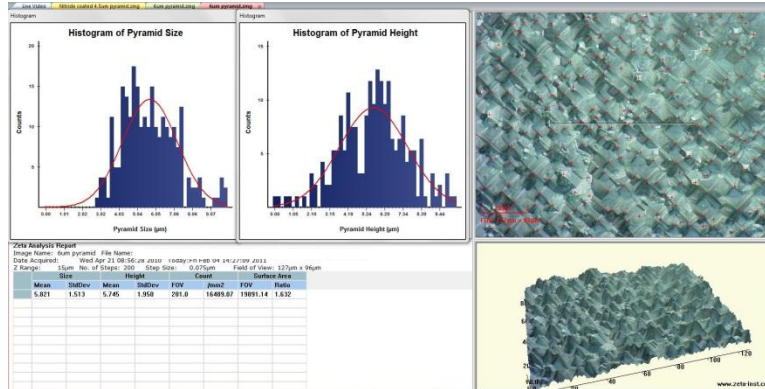


Fig. 99. Histogram screen of Pyramids recipe

Recipe parameters

The Analysis tab of a Pyramids recipe is shown in Fig. 100. The parameters are as follows:

Gaussian Kernel Size and *Gaussian Kernel Sigma* are in units of pixels and control a smoothing filter.

NMS Window Size (Non Maximum Suppression) is also in pixels and may need to be increased for large features (large in the lateral dimensions).

Remove False Count in Pyramid Detection takes values 0 or 1 and allows you to choose between the risk of missing peaks and the risk of detecting false peaks.

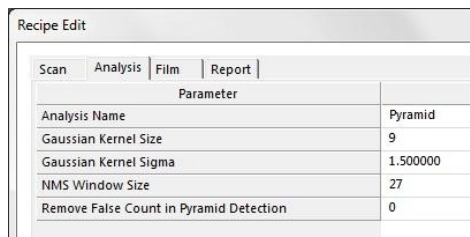


Fig. 100. Pyramids recipe parameters

8.3 PSS recipe

Patterned Sapphire Substrate (PSS) analysis is a recipe for sapphire substrates used in manufacturing high brightness light emitting diodes. The substrates are textured with etching to produce raised structures in a regular pattern. This improves the efficiency of the resulting devices.

Fig. 101 is a closeup view of a Zeta-20 scan of a PSS substrate showing evenly spaced conical structures on the surface. Other processes may use domed structures or flat-topped structures instead of cones. The size of the features in the vertical and lateral dimensions affects the quality of devices manufactured on the substrate. The Zeta-20 PSS recipe analyzes the quality of textured substrates by measuring the height, diameter, and spacing of the surface structures.

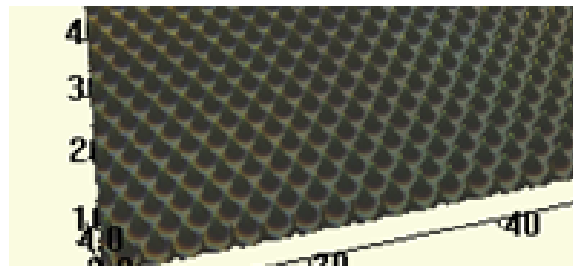


Fig. 101. PSS substrate

The PSS recipe is a separately purchased option which requires a software license in order to run.

Scan conditions

For PSS analysis, the scan must be performed with the PSS recipe because it is important to accurately locate the baseline surface. After scanning with the PSS recipe, any image files that are saved contain the baseline surface information so that they can be reanalyzed later.

Analysis

After scanning, click on *Z Analysis* in the *Image Type* group on the toolbar. An analysis such as the one shown in Fig. 102 appears.

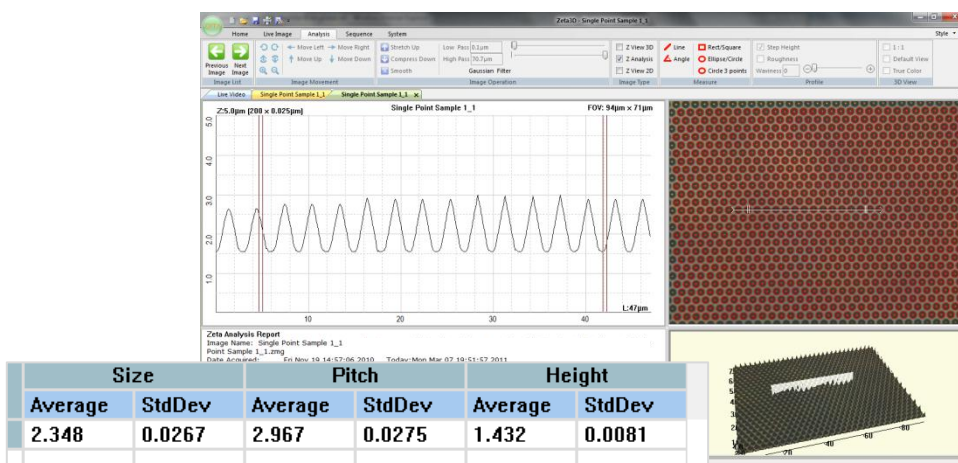


Fig. 102. PSS recipe results

The analysis is based on the 2D composite image; the 3D image is presented for illustration only. The software identifies all of the raised features in the field of view and marks the centers with a red cross and the boundaries with a red line, as shown in Fig. 103. The line profile pane shows a conventional cross section.

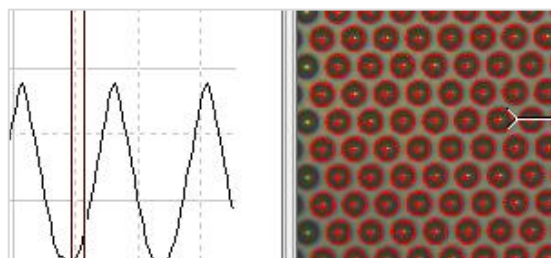


Fig. 103. Detail of PSS recipe feature detection

The results include the following parameters:

Size is the diameter of the structure in microns, showing the average and standard deviation.

Pitch is the distance in microns between structures, with average and standard deviation.

Height is the height in microns, relative to the baseline surface, with average and standard deviation.

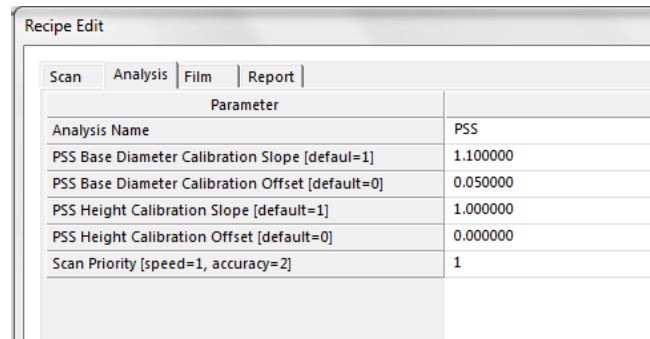
Recipe parameters

The Analysis tab of a PSS recipe is shown in Fig. 104. The parameters are as follows:

PSS Base Diameter Calibration Slope and *PSS Base Diameter Calibration Offset* are used to calibrate the measurement results to Scanning Electron Microscope (SEM) measurements of the feature diameter.

PSS Height Calibration Slope and *PSS Height Calibration Offset* are similarly used to calibrate the feature height to SEM measurements.

Scan Priority can be set to 1 or 2 to determine the number of scans. A two-scan average (parameter value of 2) takes longer but provides more accuracy than a single scan (parameter value of 1).



The screenshot shows a 'Recipe Edit' dialog box with four tabs: 'Scan', 'Analysis', 'Film', and 'Report'. The 'Analysis' tab is selected, displaying a table of parameters for the 'PSS' analysis. The table has two columns: 'Parameter' and 'Value'.

Parameter	Value
Analysis Name	PSS
PSS Base Diameter Calibration Slope [default=1]	1.100000
PSS Base Diameter Calibration Offset [default=0]	0.050000
PSS Height Calibration Slope [default=1]	1.000000
PSS Height Calibration Offset [default=0]	0.000000
Scan Priority [speed=1, accuracy=2]	1

Fig. 104. PSS recipe parameters

8.4 Solar Finger recipe

A common solar cell design consists of a semiconductor wafer with metal contact lines on the surface. The substrate has been processed to absorb light and convert it to electricity, and the metal lines serve as electrical contacts. The metal contact finger dimensions must be tightly controlled in order to maintain low contact resistance without covering too much of the wafer surface.

Fig. 105 shows a Zeta 3D image of a solar contact finger. The background semiconductor has very low reflectivity because it is designed to absorb as much light as possible; often it is coated with silicon nitride. The metal line has very high reflectivity. Measuring both surfaces in the same scan can be difficult for many instruments, but the Zeta-20 uses High Dynamic Range scanning to optimize imaging for both surfaces.

The Zeta-20 Solar Finger recipe measures the height, width, and volume of the metal line. The Solar Finger recipe is a separately purchased option which requires a software license in order to run.

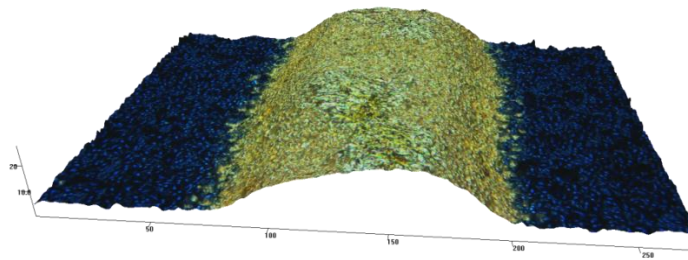


Fig. 105. Metal contact line on solar cell

Scan conditions

Choose an objective that produces an image in which the metal line occupies between 10% and 50% of the field of view, oriented vertically, as shown in Fig. 106. The recipe displays guide boxes on the live video image to indicate approximately where the background and metal areas should be placed.

1. Load a Solar Finger recipe.
2. Focus on the wafer surface and adjust Shutter 1 and Gain 1 to see the nitride surface.
3. Next focus on the metal line and adjust Shutter 2 to see details in the metal surface. Gain 2 must be the same as Gain 1.

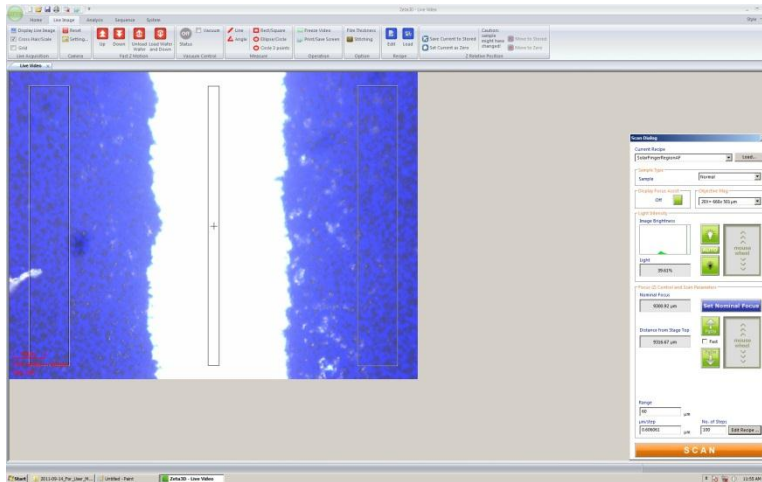


Fig. 106. Guide boxes for finger analysis

4. Take the scan. Two images are taken at every Z height, one using Shutter 1 and Gain 1 and the other with Shutter 2 and Gain 2. (Due to the constant switching of illumination conditions, a High Dynamic Range scan exhibits more flashing than other scans.) For every pixel, the two images are examined and the pixel in best focus is chosen. In this way the background surface is imaged with Shutter 1 and Gain 1 while the metal surface is imaged with Shutter 2 and Gain 2.

Analysis

After scanning, an analysis screen similar to the one in Fig. 107 appears. Ten cross sections cross the metal line. One set of cursors defines the background surface height, while a second set of cursors defines the metal line height.

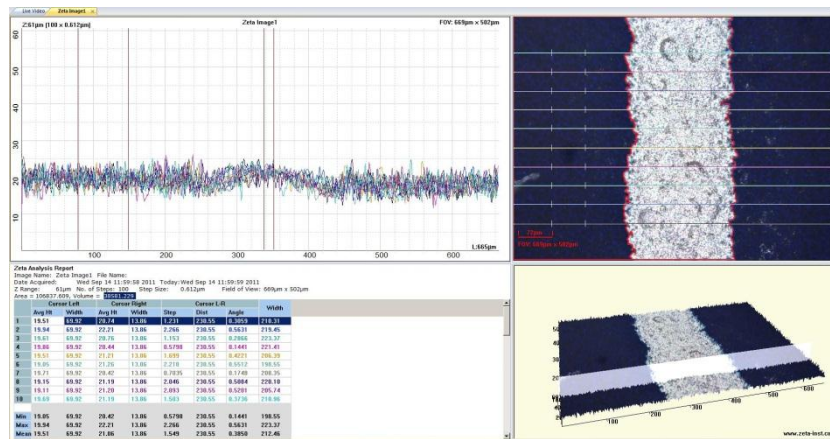


Fig. 107. Result of solar finger recipe

In the analysis results, the step height between the two sets of cursors is calculated for each of the ten cross section lines, as shown in Fig. 108. The width of the line is also displayed, and statistics for the ten data sets appear at the end of the list. The area and volume of the metal line in the field of view are shown in the heading.

Zeta Analysis Report
 Image Name: Zeta Image1 File Name:
 Date Acquired: Wed Sep 14 11:59:58 2011 Today: Wed Sep 14 11:59:59 2011
 Z Range: 61µm No. of Steps: 100 Step Size: 0.612µm Field of View: 669µm x 502µm
 Area = 106837.609, Volume = 38581.229

	Cursor Left		Cursor Right		Cursor L-R			Width
	Avg Ht	Width	Avg Ht	Width	Step	Dist	Angle	
1	19.51	69.92	20.74	13.86	1.231	230.55	0.3059	210.31
2	19.94	69.92	22.21	13.86	2.266	230.55	0.5631	219.45
3	19.61	69.92	20.76	13.86	1.153	230.55	0.2866	223.37
4	19.86	69.92	20.44	13.86	0.5798	230.55	0.1441	221.41

Fig. 108. Detail of solar finger analysis

Recipe parameters

Fig. 109 shows the *Scan* parameters of a Contact Finger recipe. The HDR (High Dynamic Range) option is selected, along with Auto Focus and Smoothing.

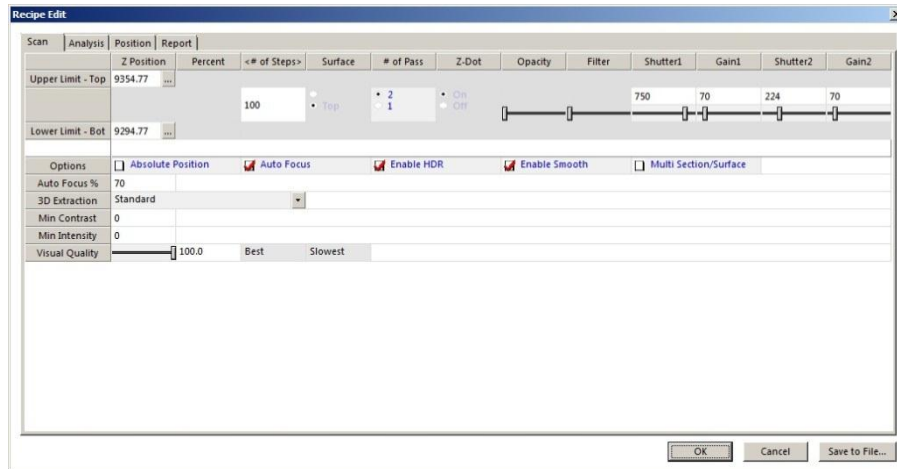


Fig. 109. Scan parameters of solar finger recipe

Fig. 110 shows the *Analysis* parameters of the recipe. The *Analysis* name is "Special."

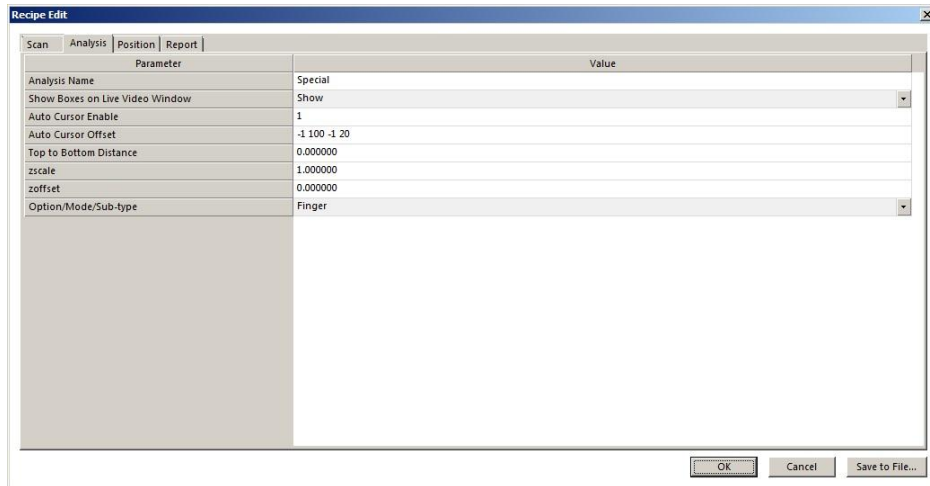


Fig. 110. Analysis parameters of Contact Finger recipe

ZScale and *ZOffset* are for calibration to measurements performed with other instruments. *Auto Cursor Offset* is measured from left or right.

8.5 DiamondWire recipe

Wire saws are used to cut wafers from crystal ingots such as silicon or sapphire. A set of parallel cutting wire moves longitudinally at high speed, while an ingot is pressed against the wires to force them to cut through the ingot. The cutting action has historically been enhanced with an abrasive slurry. However, new diamond wire technology promises to increase cutting speed and reduce costs.

Diamond wire is coated with diamond particles, as shown in Fig. 111. The hardness of the diamond eliminates the need for the abrasive slurry and doubles the cutting speed.

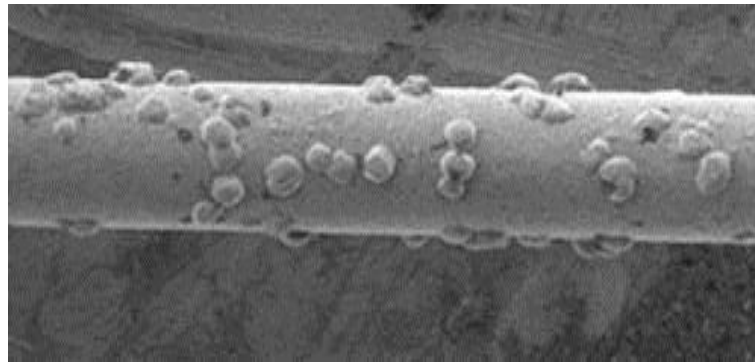


Fig. 111. Close-up of diamond saw wire

Diamond wire is available in different thicknesses (as small as 100 μm) and may have different sizes and densities of diamond particles. These parameters affect finished wafer quality. Also, the wire becomes worn after use. The Zeta-20 DiamondWire application enables inspection of new or used diamond wire for quality control.

The DiamondWire recipe is a separately purchased option which requires a software license in order to run. In addition, a customized fixture is needed to hold the wire under the Zeta-20 objective.

Scan conditions

Choose an objective that produces an image in which the wire occupies between 30% and 70% of the field of view, oriented horizontally, as shown in the 2D composite image in Fig. 112. A commonly used choice is a 50X objective.

Set the scan top and bottom to include as much of the wire as possible.

Scan images may be taken and saved with a standard recipe, then analyzed at a later time with the DiamondWire recipe.

Analysis

The DiamondWire analysis screen is shown in Fig. 112. The recipe detects diamonds in the field of view and indicates them with a red outline in the 2D image.

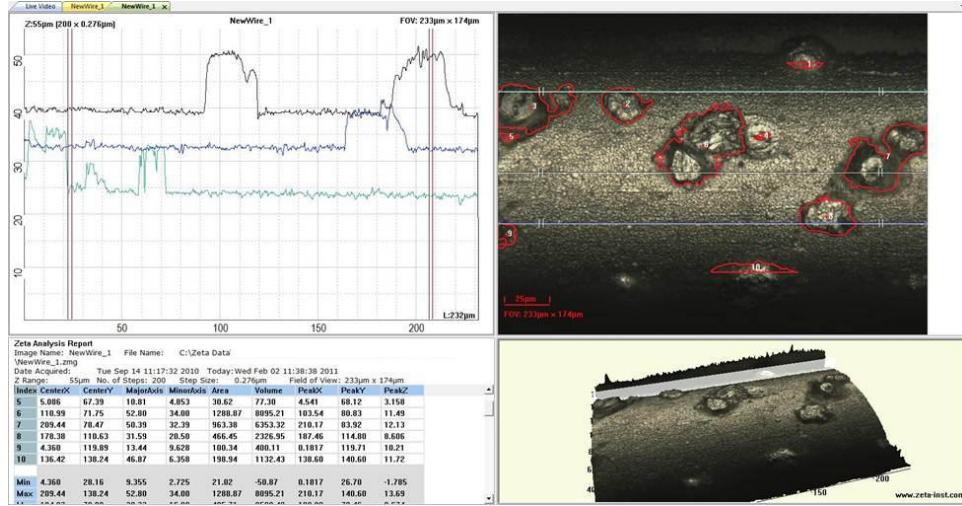


Fig. 112. DiamondWire analysis screen

For each diamond, the results window (detail shown in Fig. 113) reports the XY location, the major and minor axis lengths, the area, the volume, and the height. Dimensional analysis takes the curvature of the underlying surface into account. The recipe includes three cross section lines by default, which can be modified by the user and saved in the recipe. However, the cross sections do not affect the dimensional analysis summary.

Index	CenterX	CenterY	MajorAxis	MinorAxis	Area	Volume	PeakX	PeakY	PeakZ
5	5.086	67.39	10.81	4.853	30.62	77.30	4.541	68.12	3.158
6	110.99	71.75	52.80	34.80	1288.87	8095.21	103.54	80.83	11.49
7	209.44	78.47	50.39	32.39	963.38	6353.32	210.17	83.92	12.13
8	178.38	118.63	31.59	20.50	466.45	2326.95	187.46	114.80	8.606
9	4.360	119.89	13.44	9.628	100.34	400.11	0.1817	119.71	10.21
10	136.42	138.24	46.87	6.358	198.94	1132.43	138.60	140.60	11.72
Min	4.360	28.16	9.355	2.725	21.02	-50.87	0.1817	26.70	-1.785
Max	209.44	138.24	52.80	34.80	1288.87	8095.21	210.17	140.60	13.69

Fig. 113. DiamondWire results

Recipe parameters

Scan parameters are set the same way as for any conventional measurement.

CHAPTER 9 **Film Thickness**

Film thickness measurement is a separately purchasable option for the Zeta-20system. It requires the installation of customized hardware and software components. The information in this chapter is intended for customers who have purchased the Film Thickness option.

Topics in this chapter:

- 9.1 Principle of measurement
- 9.2 Taking reference and sample scans
- 9.3 Analyzing the spectrum
- 9.4 Other operations
- 9.5 Film thickness recipe parameters

9.1 Principle of measurement

Thin transparent films are common in many applications, especially in the semiconductor, solar, and light-emitting diode industries. The most widespread method of measuring the thickness of transparent films is spectrophotometry.

In spectrophotometry, light is reflected from a sample surface and analyzed for wavelength and intensity. A simplified view is shown in Fig. 114, in which one transparent layer is present on a substrate. Some of the incident light reflects from the sample surface, but the rest of it goes through the film and strikes the interface with the substrate. Some of the light that reaches the interface reflects back up toward the surface, while the rest of it enters the substrate (where it is either absorbed or transmitted through).

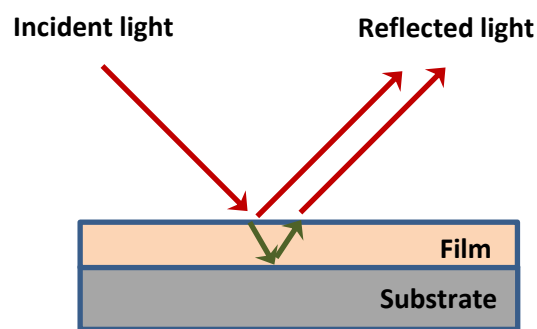


Fig. 114. Principle of spectrophotometry

The light that is reflected from the sample surface is a combination of reflections from the surface directly and from the film-substrate interface. These two reflections interfere with each other in predictable ways which depend on the wavelength of the light, the optical properties of the film, the optical properties of the substrate, and the thickness of the film. By analyzing the reflected light, the film thickness can be determined.

When a broad spectrum of light is used as the incident radiation, the reflected spectrum is very complex. The richness of the data allows the calculation of multiple output parameters, such as the thickness and optical properties of several layers in a multilayer stack. The analysis is done by computing the optical response for an ideal film stack entered by the user, then adjusting parameters in the model until the best fit to the measurements is obtained.

9.2 Taking reference and sample scans

The Zeta-20 illuminator module is equipped with a lever to configure the system for either 3D imaging or film thickness measurement. The lever is located on the front of the Zeta Optics Module, which is the black box above the objective turret. When the lever is pushed in all the way, the illuminator is configured for 3D imaging. When the lever is pulled out and stopped at the next detent position, the illuminator is configured for film thickness measurement.

The Film Thickness measurement requires a reference measurement on bare silicon. If the target sample is relatively small, it is convenient to place the target sample and a reference sample on the stage at the same time. If the target sample is large (for example, a wafer), you must load and unload the target sample and reference sample at the appropriate steps in the procedure.

Set up the system

1. To initiate film thickness measurements, pull out the knob on the Zeta Optics Module to the “Film Option” position.
2. Open the *Film Thickness* dialog by clicking the **Film Thickness** button in the toolbar (in the *Option* group). The dialog is shown in Fig. 115. The *Scan Dialog* also remains open during this procedure.
3. Check the parameters in the *Spectrum* tab of the *Film Thickness* dialog. For most purposes, the default values are the best:
 - Wavelength range: 420 to 720 nm
 - Half cone-angle: 0 degrees
 - Number of angles to average: 1
 - Amplitude correction factor: 1
 - Amplitude factor Fit checkbox: checked
 - Backside reflection factor : 1
 - Backside factor Fit checkbox: checked
4. If you have saved a recipe with these or other parameters, load it by clicking the **Load Fr. Recipe** button and selecting the recipe file. The **Load** button in the *Recipe* group in the toolbar is equivalent.

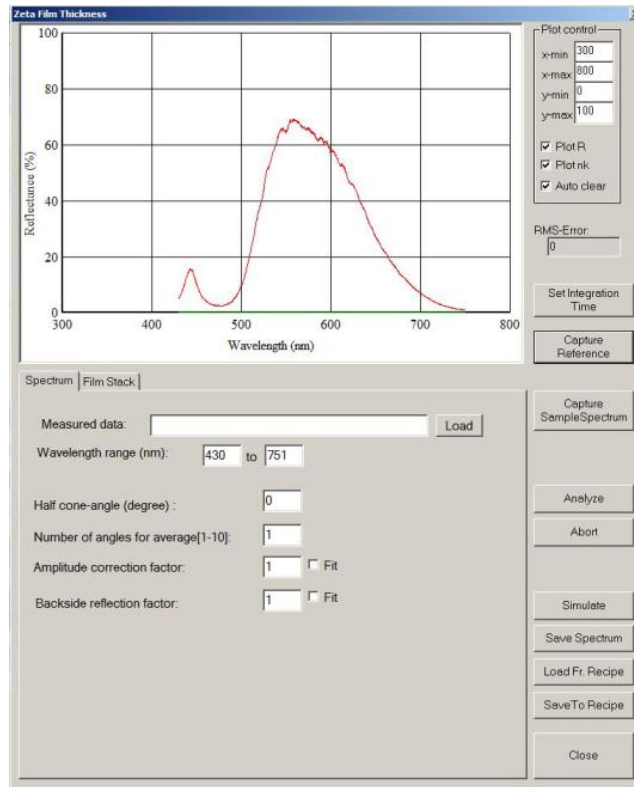


Fig. 115. Film Thickness dialog

Determine the illumination level

1. Load the target sample.
2. Choose the lowest power objective that meets your needs. Use the same objective for the silicon reference scans as you will use for the target sample.

The 5X objective has a measurement spot that is 120 μm in diameter. The diameter of the 10X objective measurement spot is 60 μm , and that of the 20X objective is 30 μm .

3. Focus on the target sample using the procedure described in Chapter 2.
4. If you have trouble focusing on an unpatterned surface, use the *Focus Assist* feature to project a grid onto the surface. The grid is visible only when the surface is in focus. Turn off *Focus Assist* when you are finished.
5. Once the sample is in focus, adjust the illumination level until the features are visible.
6. Record the illumination value (the *Light* parameter in units of %) and the focus position (*Current* under *Focus Control*) from the *Scan Dialog*. If the illumination value is above 70%, the sample surface may have a very low reflectivity. This is often the case for a silicon solar wafer coated with a nitride film. In this case, a 50X or 100X objective should be used and steps 5 and 6 repeated to record the illumination value and the focus position.

7. If desired, save the current Z position with the **Save Current to Stored** button.

Take the reference scan

The film thickness measurement requires a dark scan and a reference scan to compensate for stray light in the environment and to define a reference for surface reflectivity.

1. Load a sample of clean bare silicon onto the XY stage.
2. Use the same objective that you used for the target sample.
3. Focus on the silicon sample. The illumination level may be too high to see the surface well. There are two ways around this; experiment with the method you like best.
 - Select High as *Sample Type* in the *Scan Dialog*. Find the focus position.
 - Open the *Camera Settings* dialog through the button in the toolbar (**Settings** button in *Camera* group). The dialog is shown in Fig. 116. Move the Gain slider control to the left to make the camera image less bright so that you can find the focus position.
4. Click the **Capture Reference** button in the *Film Thickness* dialog. The system takes a measurement and when it is complete, the message shown in Fig. 117 appears.
5. Check the value displayed in the message. If it is greater than 64000, the illumination level is too high. If it is less than 10000, the illumination level is too low.
6. If the value is too low, increase the illumination level and check it again. If the value is too high, decrease the illumination level.
7. If you have trouble achieving an acceptable value, click the **Set Integration Time** button in the *Film Thickness* dialog, which displays the dialog shown in Fig. 118. If the reference value was too low, increase the integration time; if the reference value was too high, decrease the integration time.
8. When the reference value is in the desired range (i.e. between 10000 and 64000), record the illumination level. Other parameters are automatically saved.
9. Unload the silicon reference sample.

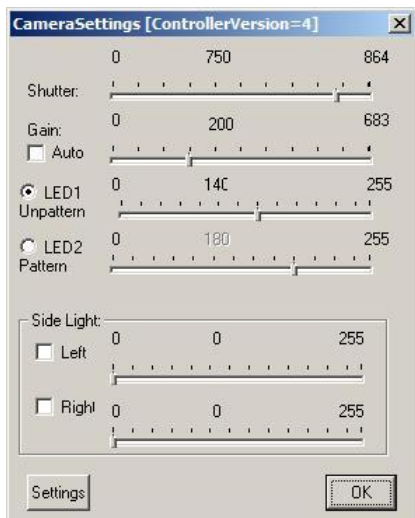


Fig. 116. Camera Settings dialog



Fig. 117. Reference scan value

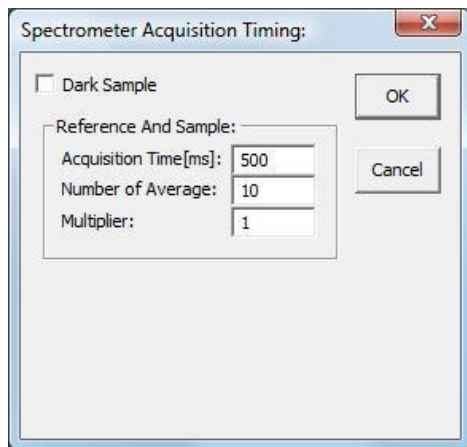


Fig. 118. Spectrometer timing dialog

Scan the target sample

1. Load the target sample again.
2. Use the same objective for the film thickness measurement that you used for the silicon sample reference scans.
3. Set the Z position to the focus position you recorded for this sample. If you saved that position with the **Set Current to Stored** button, use the **Move to Stored** button to return to the position.
4. Make sure you use the same illumination level for the target sample that you used for the reference sample scan.
5. In the *Film Thickness* dialog, click the **Capture Sample Spectrum** button. The system performs a scan, then displays the resulting spectrum. The reflectance measurement is shown with a red curve, while the model fitting is shown with a green curve. The initial green curve is not similar to the red curve because analysis and fitting have not been performed yet.

9.3 Analyzing the spectrum

Use these procedures to define the expected film structure on the sample as a basis for fitting the model to the measurements.

Fix the index of refraction

1. Select the *Film Stack* tab in the *Film Thickness* dialog. It is shown in Fig. 119. The current film stack model is displayed in the white box. The substrate is on the bottom, denoted by “Sub” in the left margin. Other layers appear above the substrate, numbered starting at 1 for the bottom layer.

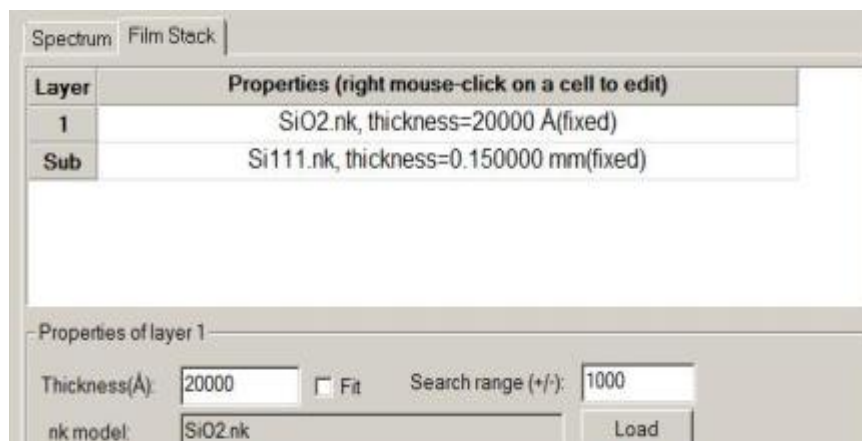


Fig. 119. Film Stack tab

2. If silicon is not the substrate for your sample, change it as follows:
 - a. Click on the substrate layer in the film model (“Si 111” in Fig. 119) to select it.
 - b. In the film properties frame, enter the substrate thickness then press **Load** to display the material selection window, shown in Fig. 120.
 - c. Highlight the substrate material of your sample. Click **Open** to load the optical constant table of the substrate.
 - d. To keep the index of refraction n and absorption coefficient k fixed, choose a file name with an extension of **.nk*.

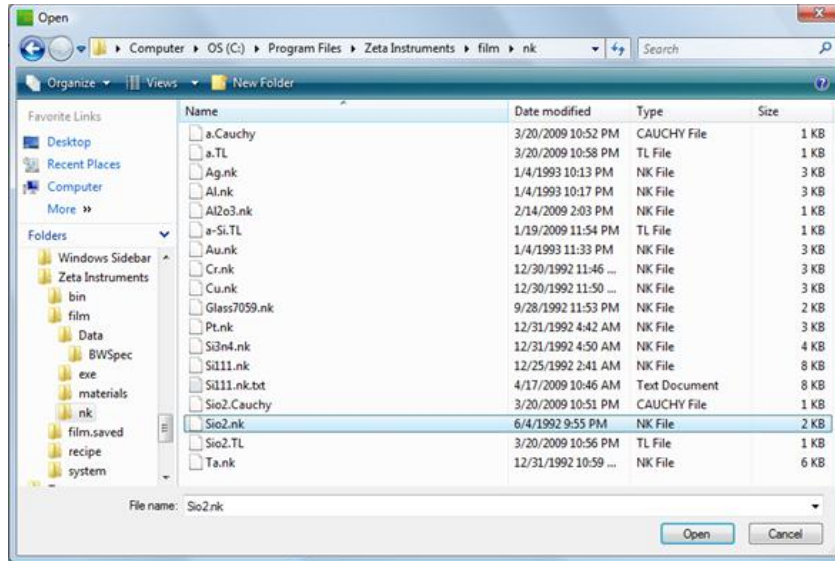


Fig. 120. Material selection window

3. Add a layer as follows:
 - a. Right click on any layer to bring up the menu shown in Fig. 121, then select *Add Above*. An empty layer (blank row) appears above the current layer.

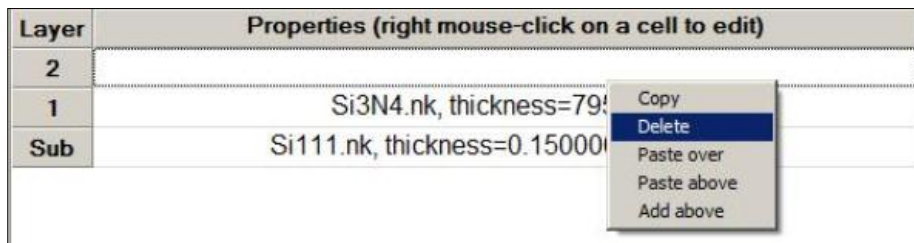


Fig. 121. Layer editing menu

- b. In the film properties frame, enter the nominal film thickness and check the *Fit* checkbox to tell the software to find the actual thickness. Enter a search range, which is the amount above and below the nominal thickness that the model will evaluate initially.
 - c. Press **Load** to display the material selection window.
 - d. Highlight the film material. Click **Open** to load the optical constant table of the film.
4. If additional layers are present, add the above the existing layers using the same procedure. The layer editing menu also provides options for deleting and copying layers.
5. Click **Analyze**. The software tries to fit the model to the measurements; the green curve changes as the software iterates on a solution. If the fitting is successful, the model (green curve) converges to a position close to the measurements (red curve), as shown in Fig. 122.

The final modeled thicknesses are written on the layers in the film model portion of the window. If you click on a layer to select it, the modeled thickness of that layer also appears in the thickness field of the film properties frame.

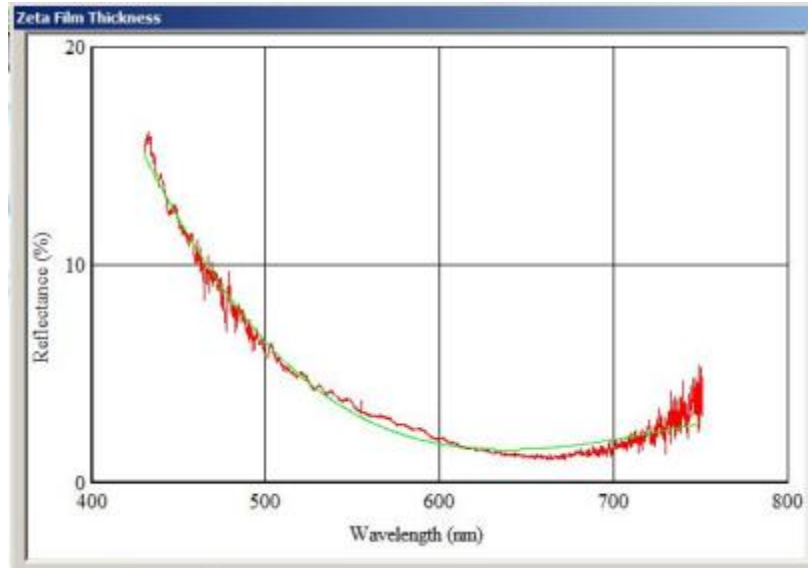


Fig. 122. Example of successful model fit

Model the index of refraction

1. Select the *Film Stack* tab in the *Film Thickness* dialog.
2. *Select* or create a layer for which you want to measure both thickness and the index of refraction.
3. Use the **Load** button to open the material selection dialog. Look for a file whose name is the *material* type with the extension **.Cauchy*. If it exists, select it. If it does not exist, select the file named "a.Cauchy." The film properties window changes to look like Fig. 123.
4. Enter the *nominal* thickness value, the thickness search range, and check the *Fit* checkbox.
5. Enter *the* nominal index value, the A and B coefficients, and check the *Fit* checkbox.
6. Edit other layers as needed. You can create a film stack having some layers with fixed index of *refraction* and others with floating index.
7. Click **Analyze** to fit the model. The final thickness and index values are written on the layers in the model and also in the film properties pane when you highlight a layer.

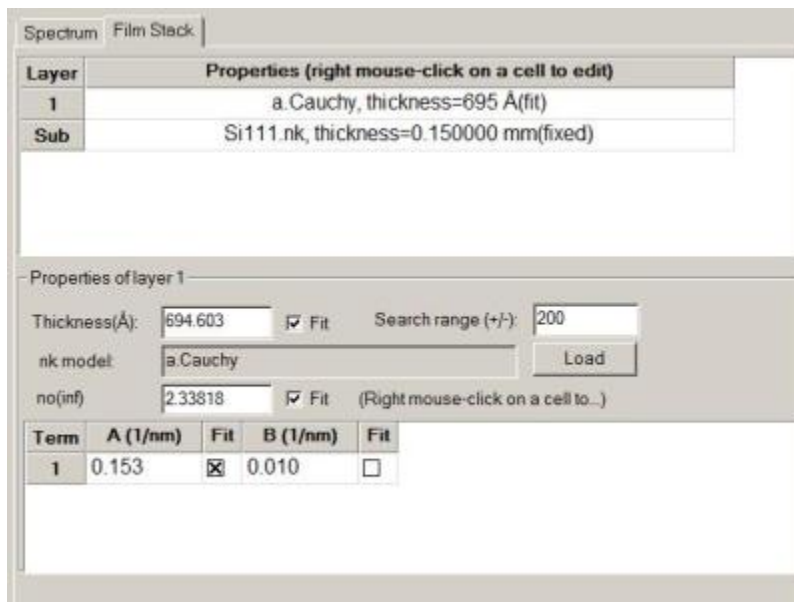


Fig. 123. Film stack with Cauchy model layer

9.4 Other operations

Simulate a film stack

For multilayer film stacks or very thick layers, the spectrum can be very complex. The software may converge on a local solution instead of the correct solution. You can help the software by giving it a better starting point for the analysis.

1. Create the film stack model.
2. Click **Simulate** in the *Film Thickness* dialog. The green line in the graph shows the model spectrum, which you can visually compare to the red measured spectrum.
3. Change one or more parameters in the film stack model, such as nominal thickness or index value, or even material type or number of layers.
4. Click **Simulate** again to see the change in the model spectrum.
5. **When** the model is reasonably similar to the measurement, click **Analyze** for a final fit.

Fig. 124 shows how the modeled spectrum changes for a simple film stack of one layer of silicon dioxide on a silicon substrate for two oxide thicknesses. As the thickness changes from 20000 Å to 35000 Å, the number of cycles in the model increases. The spectrum of the thick layer is a better match to the measured spectrum (red line), so using this film stack model is a better choice for analyzing the measurement.

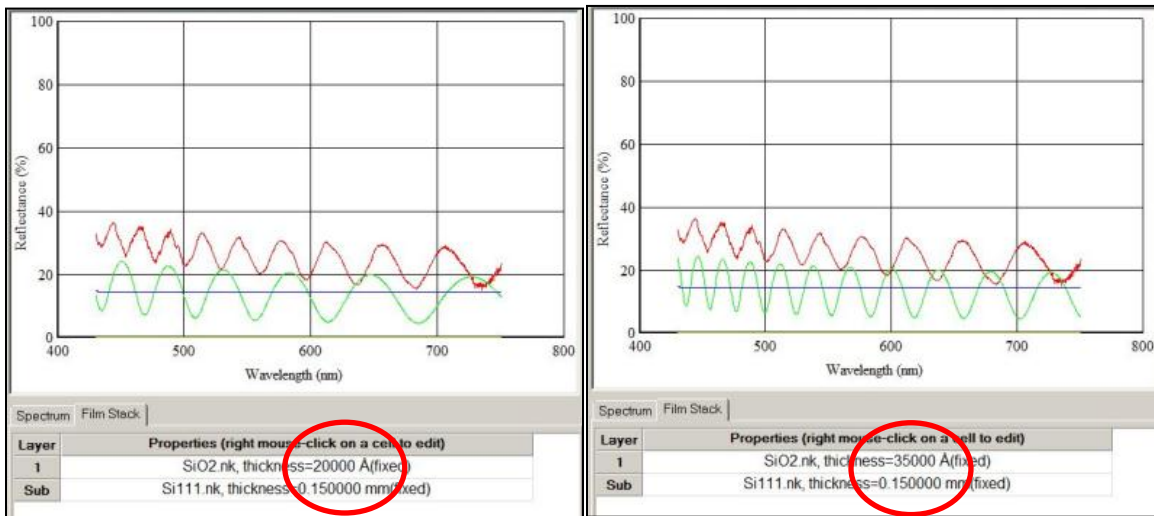


Fig. 124. Spectra for two oxide thicknesses

Change plot conditions

You can change the limits of the spectrum plot axes or choose whether to plot thickness, index of refraction (including absorption coefficient) or both. The plot controls are located to the right of the spectrum plot. Click **Analyze** after you make a change to see the effects.

Save or load a spectrum

You can save a spectrum to a file for later analysis. This is useful for comparing samples measured at different times.

To save a measured spectrum, click **Save Spectrum** and provide a file name in the browser window.

To reopen a saved spectrum, select the *Spectrum* tab and click the **Load** button located next to the *Measured data* field. Select a file from the browser window.

Save or load a recipe

You can save a film stack model and measurement parameters to a recipe to simplify future measurements.

To save a recipe, click **Save To Recipe** and provide a file name in the browser window.

To load a recipe, click **Load Fr. Recipe** and provide a file name in the browser window.

9.5 Film thickness recipe parameters

Fig. 125 shows the *Film* tab in a recipe, which includes parameters for analyzing Film Thickness. Measurement-specific parameters are as follows, with suggestions for setting them.

Wavelength is the range for collecting spectrum data. The available range is 400nm to 750nm; the recommended default range is 420nm to 720nm.

Collection Half Cone is the half cone angle corresponding to the numerical aperture of an objective lens; the default is zero.

Amplitude Factor compensates any effect caused by roughness of the film surface; the recommendation is to check the *Fit* checkbox.

Back Side Reflection Factor compensates any effect caused by roughness of the film/substrate interface; the recommendation is to check the *Fit* checkbox.

Layer Structure defines the film structure, i.e. how many layers, the thickness and optical properties of each layer. Edit the model as follows:

1. Click on a layer or substrate to highlight it.
2. Click **Search** to open the material selection window. Select a properties file (it can be a fixed index of refraction model or the Cauchy model for fitting the index of refraction).
3. Enter the target thickness and search range and check the *Fit* checkbox to find the thickness.

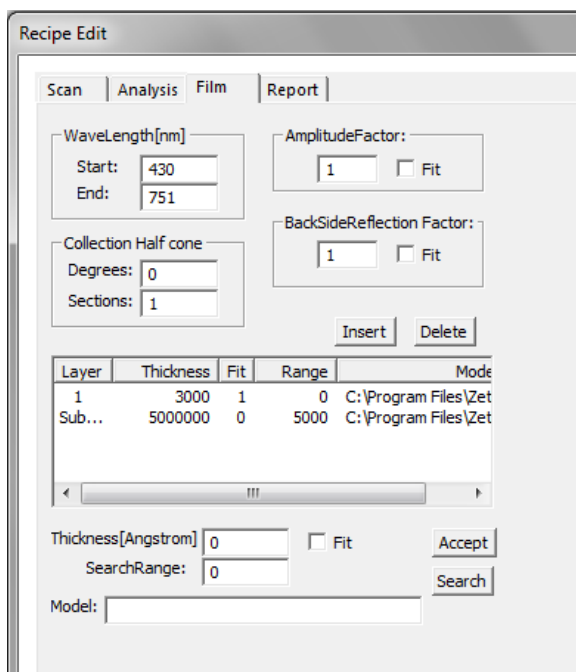


Fig. 125. Film tab in recipe

APPENDIX A Roughness Parameters

The Zeta-20 complies with ISO 4287-1997 for the calculation of roughness parameters.

Zeta 3D software calculates eight parameters to describe surface roughness.

Parameter	Meaning
Ra	Arithmetic average of deviations from the mean
Rq	Root mean squared value of deviations
Rpv	Maximum peak to valley difference
Rp	Maximum peak height
Rv	Maximum valley depth
Rz	Average of (Rp – Rv) from five sections
Rsk	Skewness (asymmetry of distribution)
Rku	Kurtosis (shape of distribution peak)

Data points and mathematical notation

The parameters are calculated from the individual data points in the analysis area. A single data point is designated as

$$r_j$$

where r is the height deviation of the actual surface compared to the ideal surface and j is the index number of the data point.

The ideal surface is created by fitting a smooth curve to the measured data. The height deviations are positive if they are above the ideal surface and negative if they are below it.

Parameters calculated from 2D profiles (cross section lines) are written with the initial letter R. If waviness has been subtracted from the 2D profile, the parameters calculated from the baseline surface are written with the initial letter W.

Parameters calculated from 3D surfaces (as in the boxes roughness function) are written with the initial letter S.

Subscripts denote the specific parameter.

R_a

The most commonly used parameter to describe roughness is R_a . This is the arithmetic average of the deviation values of the individual roughness data points. It is calculated as

$$R_a = \frac{1}{N} \sum_{j=1}^N |r_j|$$

where N is the number of data points in the sample.

R_q

Root mean square (RMS) roughness R_q is the root mean square average of the roughness data points. It is the second moment of the amplitude distribution function, a probability function that gives the probability that a profile of the surface has a certain height at any position.

$$R_q = \sqrt{\frac{1}{N} \sum_{j=1}^N r_j^2}$$

Fig. 126 shows a roughness profile for a surface. There are 512 points in the sample. Since the surface is relatively flat, the arithmetic mean (shown in red) can be used to represent the ideal surface.

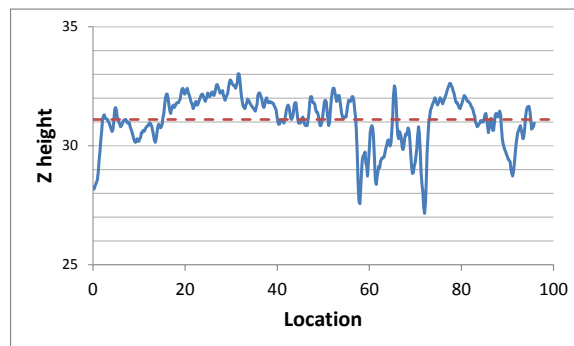


Fig. 126. Example roughness profile

Fig. 127 shows the same data plotted as deviations from the ideal surface. This graph shows the absolute value of the deviations. The red dashed line shows the calculated R_a value (arithmetic mean of the absolute value deviations) and the green dashed line shows the R_q value (root mean square). R_q is more strongly influenced by peaks and valleys than R_a because of the squaring operation.

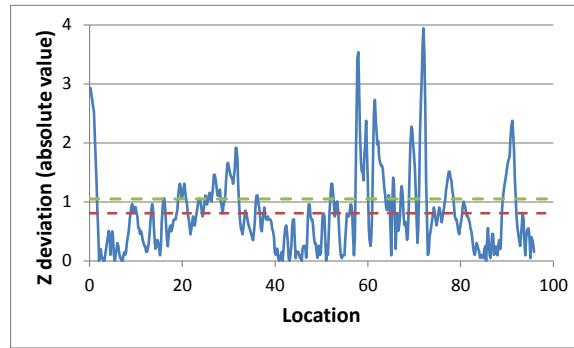


Fig. 127. Roughness deviation values with Ra (red) and Rq (green)

R_{pv} , R_p and R_v

These parameters describe the extremes of the individual data points. R_p is the highest peak in the roughness profile, R_v is the deepest valley and R_{pv} is the difference between these values.

$$R_p = \left| \max_{1 \leq j \leq N} r_j \right|$$

$$R_v = \left| \min_{1 \leq j \leq N} r_j \right|$$

$$R_{pv} = R_p - R_v$$

R_z

The profile is divided into five sections and R_{pv} is calculated for each section. R_z is the average of the five R_{pv} values.

Fig. 128 shows the roughness deviation values of the example data set, but this time the plot shows the actual deviation values which can be either positive or negative.

The profile is divided into five sections of equal length. Within each section, the highest peak and lowest valley are found. They are marked with red diamonds in Fig. 128. The difference between the highest and lowest points within a section is the local R_{pv} value, shown with a green arrow within each section. The average of the five local R_{pv} values is R_z . The difference between the highest point in the entire profile and the lowest point in the entire profile is the overall R_{pv} value, shown with a black arrow at the right of the plot.

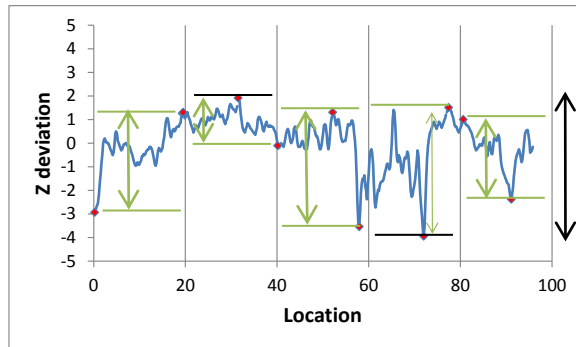


Fig. 128. Roughness deviation actual values with Rpv values

R_{sk} and R_{ku}

These parameters describe the shape of the amplitude distribution function. R_{sk} is the skewness, a measure of asymmetry, while R_{ku} is the kurtosis, a parameter that is sometimes described as the spikiness of the amplitude distribution function. Skewness is the third moment and kurtosis is the fourth moment of the function.

$$R_{sk} = \frac{1}{NR_q^3} \sum_{j=1}^N r_j^3$$

$$R_{ku} = \frac{1}{NR_q^4} \sum_{j=1}^N r_j^4$$

APPENDIX B System Administration

Software licenses

The following applications must be purchased separately. Access to these applications is controlled with software licenses. A license is an alphanumeric code which works for a single computer only.

- PSS analysis (patterned sapphire substrate)
- Pyramid analysis (solar cell surface texture)
- Diamond
- Diamond Wire
- Stitching

When one of these analysis recipes is loaded, the software checks for a valid license. If no license is found, an error message appears and the recipe will not load. The message is shown in Fig. 129.

The Zeta-20 system will be configured properly at installation. If an option is purchased later, or if the license file is missing or corrupted, the licensing error message may appear.

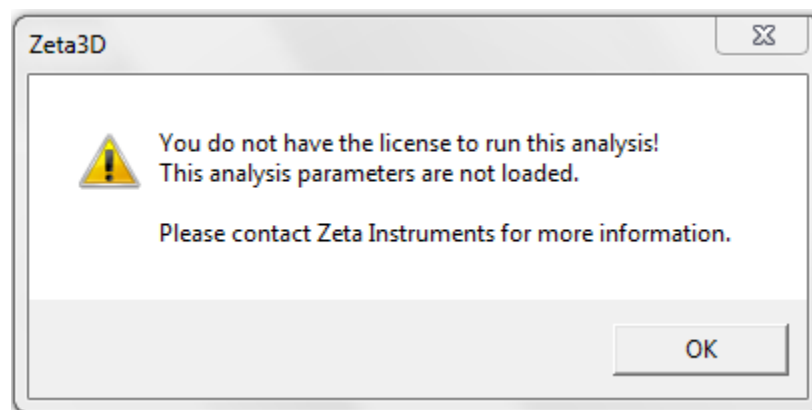


Fig. 129. Licensing error message

To obtain a license, you must provide a computer identification code to your applications support representative. Click on the blue question mark (the "About" button) near the upper right corner of the screen, which is shown in Fig. 130 with the help text that appears when the cursor hovers over it.

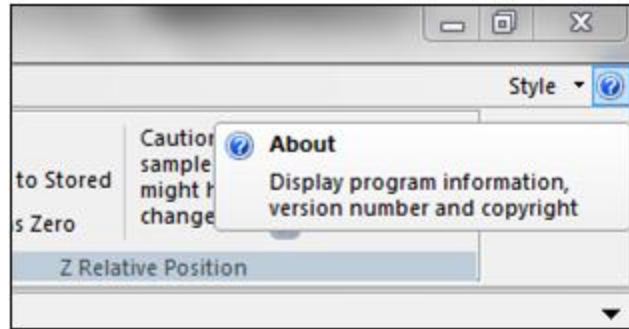


Fig. 130. The "About" button

In response, the software displays a message similar to the one in Fig. 131. The current software version and build date are displayed along with the Software License ID.

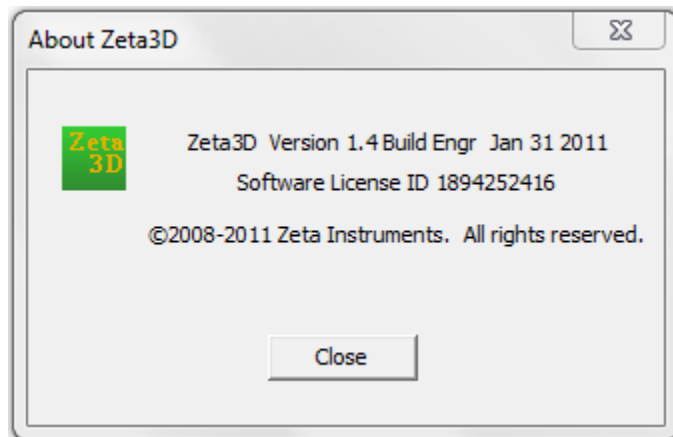


Fig. 131. Software version and license ID

User Manager

At installation, the Zeta-20 has one user account for logging in. The user name and the password are both set to "a" (small letter a).

The User Manager allows the system administrator to create more user accounts. There are three types of user accounts:

System Administrator – Access to all functions including User Manager and System Setup

Power User – Can run and edit recipes, sequences and production runs

Operator – Can load and run recipes, sequences and production runs

The User Manager function is located under the *Home* tab of the Zeta3D software, as shown in Fig. 132.



Fig. 132. User Manager button

The *User Manager* dialog window is shown in Fig. 133. To add or change user accounts, edit the User Name and Password fields directly, then select the access level from the pull-down menu. To delete an account, clear the fields. When finished editing, click the **Save to File** button. Another popup window asks you to confirm the changes; click **Yes** to save the changes.

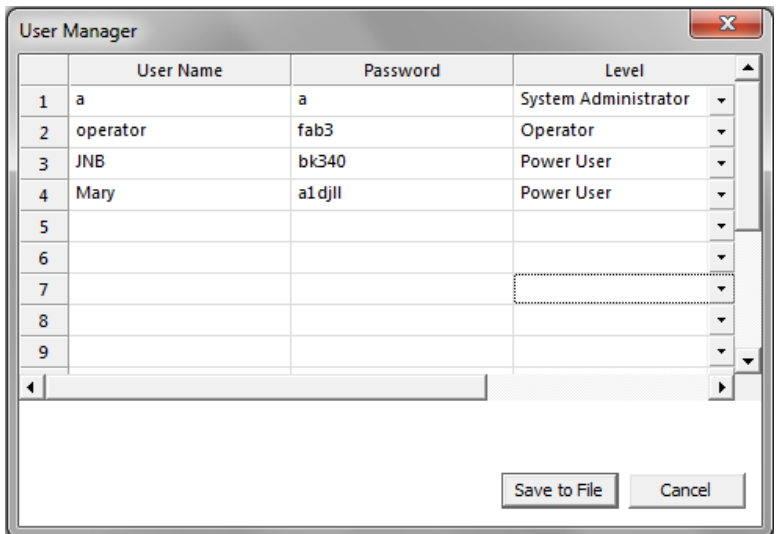


Fig. 133. User Manager dialog

APPENDIX C Facilities Information

Information in this section describes the Zeta-20 system as of the time of publication. Information is subject to change without notice.

Specifications

System specifications

Light Source	High brightness white LED
Nose piece	5 Place
Vertical travel	30 mm
Camera	Digital, 1024x768 pixels, 1/3rd inch

Computer and monitor minimum specifications

Processor	Intel Pentium Dual Core
Graphics	3D accelerator
RAM	3GB
HDD	320GB
Display	20 inch LCD display

Zeta 3D software

Live video, True-color imaging
3D imaging
Image analysis including filtering, cross section and feature width measurements
Roughness, Waviness and Step Height measurements
Optional Film Thickness measurements

Facilities Requirements

Zeta-20 requirements summary

Dimensions: W x D x H

Base tool: 12 x 16 x 22 in. (30.5 x 40.6 x 55.9 cm)

Computer: 15 x 18 x 4 in. (38.1 x 45.7 x 10.1 cm)

Monitor: 20 x 5 x 16 in. (50.8 x 12.7 x 40.6 cm)

Weight: 65 lbs (29.5 kg)

Voltage: 100-230VAC

Current: 2 A

Operating temperature: 18°C – 30°C, non condensing, $\pm 1^\circ\text{C/hr}$

Power supply

AC power supply

By configuring the computer's AC input select switch, the Zeta-20 can operate with AC voltage of either 100-120V or 200-230V. The 24V power supply and the monitor can accept the different AC voltages without any change, but the computer needs to be configured correctly.



Caution

Before powering up the system, check the computer's AC select switch before plugging in the AC power cord. The computer will be damaged if the switch is not set correctly.

For 110V to 120V AC power (nominal 115V):

With a tool such as a flat blade screwdriver, move the horizontal bar to the bottom position. You will see "115" in the top opening. Refer to Fig. 134.

For 200V to 230V AC power (nominal 230V):

Move the horizontal bar to the top position. You will see "230" in the bottom opening. Refer to Fig. 134.

115V position

230V position



Fig. 134. Computer AC select switch