Chapter 4 Modify Commands

The **Modify** commands are in the lower portion of the **Analyze** menu. **Analyze** appears in the menu bar once an image is open/active. It also appears in the **Add View** submenu and is accessible with a right-click on the image name in the workspace. **Modify** commands are used to eliminate noise, and correct for bow and tilt. These operations process the captured/stored image, then produce another (modified) version.

Please refer to the following analysis commands available on the NanoScope software:

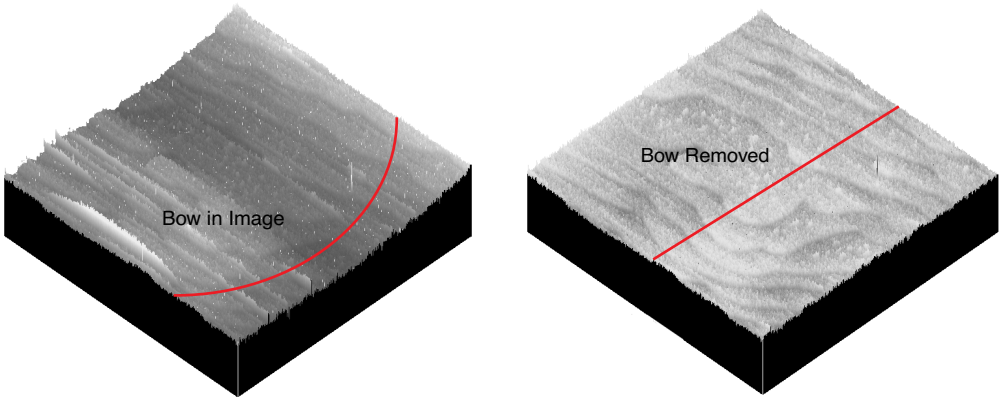
- **Flatten:** Section 4.1
- **Plane Fit:** Section 4.2
- **Lowpass** Section 4.3
- **Erase Scan Lines:** Section 4.4
- **Median:** Section 4.5

4.1 Flatten

The **Flatten** command eliminates unwanted features from scan lines (e.g., noise, bow and tilt). It uses all unmasked portions of scan lines to calculate individual least-square fit polynomials for each line.

Flatten is useful prior to image analysis commands (e.g., **Depth**, **Roughness**, **Section**, etc.) where the image displays a tilt, bow or low frequency noise, which appear as horizontal shifts or stripes in the image.

Figure 4.1a Image Flattened



4.1.1 Flatten Theory

The **Flatten** command is a filter that modifies the data to delete low frequency noise and remove tilt from an image. Each line is fit individually to center data (0th order) and remove tilt (1st order), or 2nd or 3rd order bow. A best fit polynomial of the specified order is calculated from each data line and then subtracted out. In some cases, the stopband (box cursor to exclude features) can be used to remove regions of the image from the data set used for the polynomial fits. Click on the image to start drawing a stopband box. Right-click on a box to delete it or change its color.

Flatten Polynomials

The polynomial equations calculate the offset and slope, and higher order bow of each line for the data (see Table 4.1a).

Table 4.1a Flatten Polynomials

Order	Polynomial	Explanation
0	$z = a$	Centers data along each line.
1	$z = a + bx$	Centers data and removes tilt on each line [i.e., calculates and removes offset (a) and slope (bx).
2	$z = a + bx + cx^2$	Centers data and removes the tilt and bow in each scan line, by calculating a second order, least-squares fit for the selected segment then subtracting it from the scan line.
3	$z = a + bx + cx^2 + dx^3$	Centers data and removes the tilt and bow in each scan line, by calculating a third order, least-squares fit for the selected segment then subtracting it from the scan line.

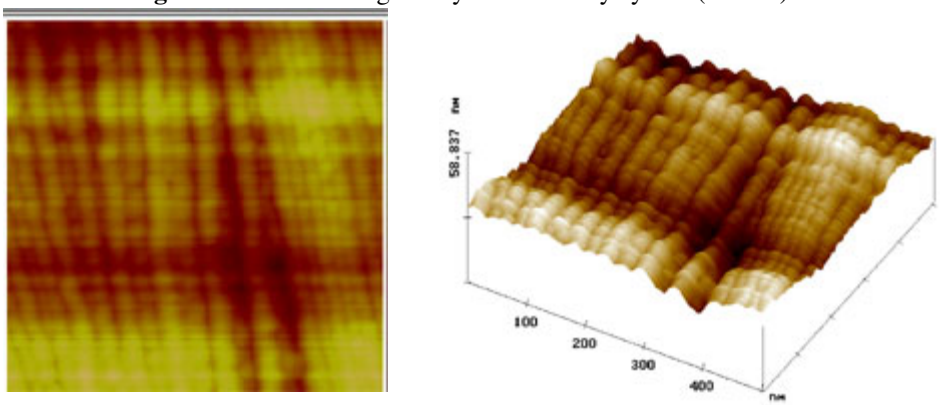
4.1.2 Flatten Procedures

For an image that contains a number of noisy scan lines, use the **Flatten** command to correct the problem.

1. Open the image. Note disjointed scan lines which are misaligned along the Z-axis (some are high and some are low). This effect somewhat resembles an unshuffled deck of cards when viewed on-edge or appears as horizontal streaks or bands. The image may have bow along its Y-axis.

Figure 4.1b shows an image file in its original, raw form as an example for the **Flatten** command. Many of the image's scan lines are disjointed along the Z-axis.

Figure 4.1b Raw Image of Syndiatatic Polystyrene (500nm)



Top View of Image to Flatten

Surface Plot of Image showing Bow

2. You can view the **Flatten View** using *one* of the following methods:

   - Right-click on the image name in the **Workspace** and select **Add View > Flatten** from the popup menu.

     Or

   - Select **Analyze > Flatten** from the menu bar.

     Or

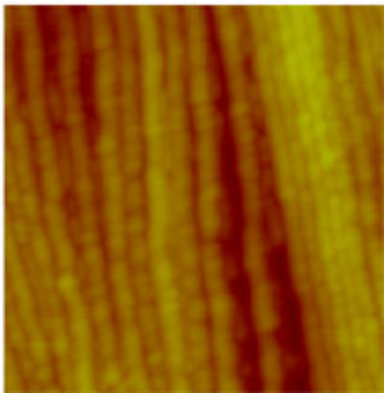
   - Click the **Flatten** icon in the upper toolbar. 

3. Set the **Flatten order** value to **0**. This removes the scan line misalignment.

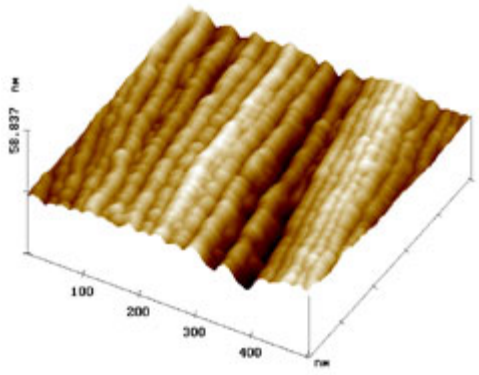
4. Click on **Execute** to initiate the **Flatten** command. The flattened image appears on the display screen.

   Note: Figure 4.1c shows the same image file after using a zero-order **Flatten** (Flatten order = 0). The scan lines are now aligned.

Figure 4.1c Flattened Image of Syndiatatic Polystyrene (500 nm)



Top View of Flattened Image



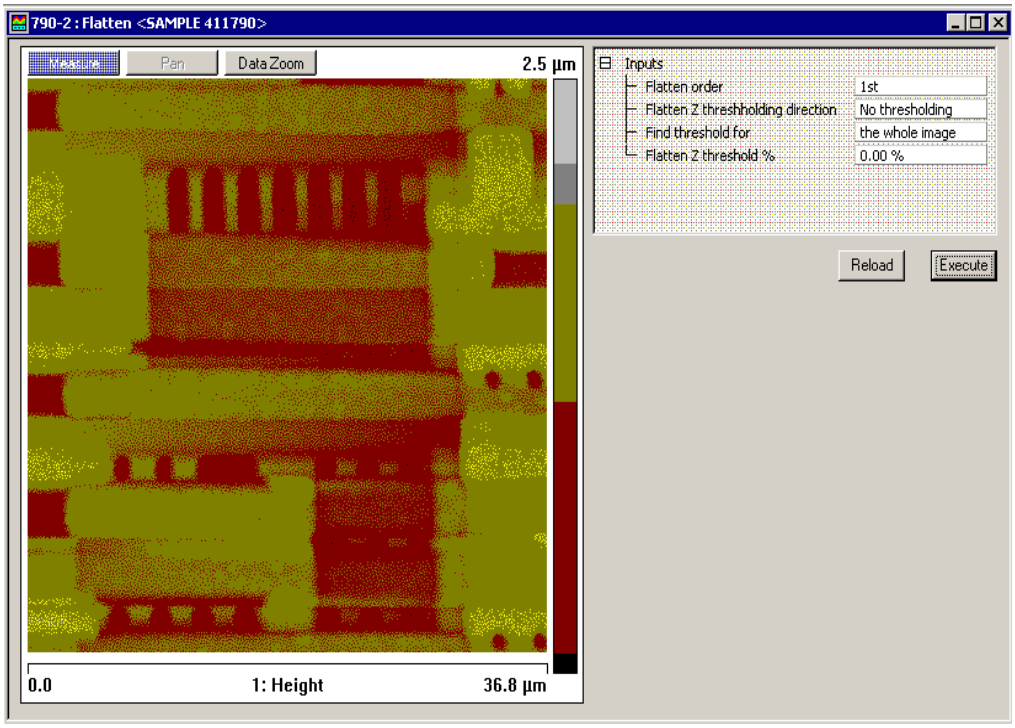
Surface Plot View of Flattened Image

5. To see a variety of effects using the **Flatten** command, enter different **Flatten order** values. Each new change may be undone by clicking on the **Reload** button.

4.1.3 Flatten View Interface

Click **Analyze** in the menu bar and select **Flatten,** or click on the **Flatten** icon in the button bar. A series of parameters appear in the **Flatten View**, allowing the order of the equation to be selected and display parameters to be adjusted to your preference.

Figure 4.1d Flatten View



Input Parameters:

Flatten Order

Flatten Order selects the order of the polynomial calculated and subtracted from each scan line.

Range and Settings:

Flatten Order	**Flatten Order** selects the order of the polynomial calculated and subtracted from each scan line. Range and Settings: • **Zero Order (0)**—Removes the Z offset between scan lines by subtracting the average Z value for the unmasked segment from every point in the scan line. • **First Order (1)**—Removes the Z offset between scan lines, and the tilt in each scan line, by calculating a first order, least-squares fit for the unmasked segment then subtracting it from the scan line. • **Second order (2)**—Removes the Z offset between scan lines, and the tilt and bow in each scan line, by calculating a second order, least-squares fit for the unmasked segment then subtracting it from the scan line. • **Third order (3)**—Removes the Z offset between scan lines, and the tilt and bow in each scan line, by calculating a third order, least-squares fit for the unmasked segment then subtracting it from the scan line.
Flatten Z Thresholding Direction	Specifies the range of data to be used for the polynomial calculation based on the distribution of the data in Z: Range or Settings: • **Use Z >=** —Uses the data whose Z values are greater than or equal to the value specified by the Z thresholding %. • **Use Z <**—Uses the data whose Z values are less than the value specified by the Z thresholding %. • **No thresholding**—Disables all thresholding parameters.
Flatten Threshold for	Applies the Thresholding values for the **whole image** or each line independently. Range or Settings: • The whole image • Each line
Flatten Z Threshold %	Defines a Z value as a percentage of the entire Z range in the image (or data set) relative to the lowest data point.

Buttons on the Flatten Panel

Execute	Initiates the command, based on the order selected.
Reload	Restores the image to its original form.

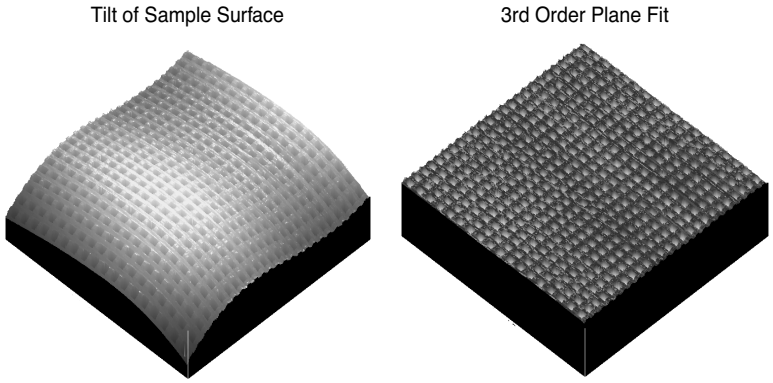
4.2 Plane Fit

The **Plane Fit** command calculates a single polynomial of a selectable order for an image and subtracts it from the image. The **Plane Fit** operation can be applied to either or both of the XY directions.

Box cursors, or passbands, allow specific points to be used in the calculation of the polynomial. Click on the image to start drawing a passband box. Right-click on a box to delete it or change its color.

Figure 4.2a illustrates an image with tilt and bow which could affect the analysis of the surface data.

Figure 4.2a Visual Representation of Plane Fit



4.2.1 Fitted Polynomials

Refer to Table 4.2a to view the polynomials that calculate the best plane fit for the images in the Plane Fit Auto function.

Table 4.2a Plane Fit Auto Equations

Order	Variable	Polynomial Equation
0	X	$z = a$
	Y	$z = a$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a$
1	X	$z = a + bx$
	Y	$z = a + by$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a + bx + cy$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a + bx + cy + dxy$
2	X	$z = a + bx + cx^2$
	Y	$z = a + by + cy^2$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a + bx + cy + dxy + ex^2 + fy^2$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + ix^2y^2$
3	X	$z = a + bx + cx^2 + dx^3$
	Y	$z = a + by + cy^2 + dy^3$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + jx^3 + ky^3$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + ix^2y^2 + jx^3 + ky^3 + lxy^3 + mx^2y^3 + nx^3y^3 + ox^3y + px^3y^2$

4.2.2 Plane Fit Procedures

Use **Plane Fit** to correct the image distortion as follows:

1. Open an image file from the menu bar (**File > Open > Image**) or through Browse (**View > Browse**), then double click on the image.
2. You can view the **Plane Fit View** using *one* of the following methods:
   - Right-click on the image name in the **Workspace** and select **Add View > Plane Fit** from the popup menu.

     Or
   - Select **Analyze > Plane Fit** from the menu bar.

     Or
   - Click the **Plane Fit** icon in the upper toolbar. 

     Note: The **Plane Fit** input parameters appear along with the top view image.
3. Select **X**, **Y**, or **XY**.
4. Select the **Order**.
5. Select **Execute**.
6. Notice that the image distortion is removed, reflecting a flat, planar profile.

Figure 4.2b Saddle Image Before Plane Fit

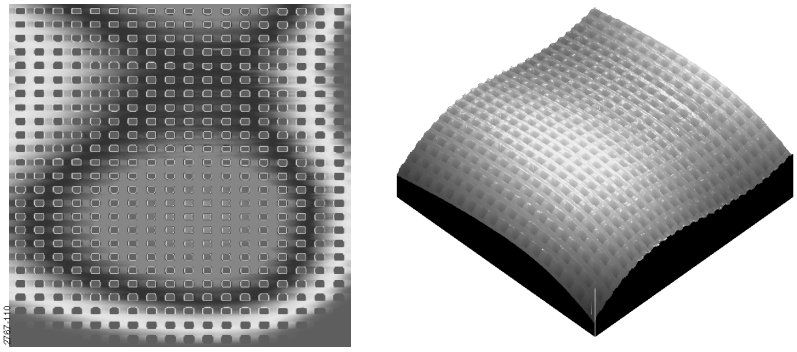


Figure 4.2c Plane Fit View

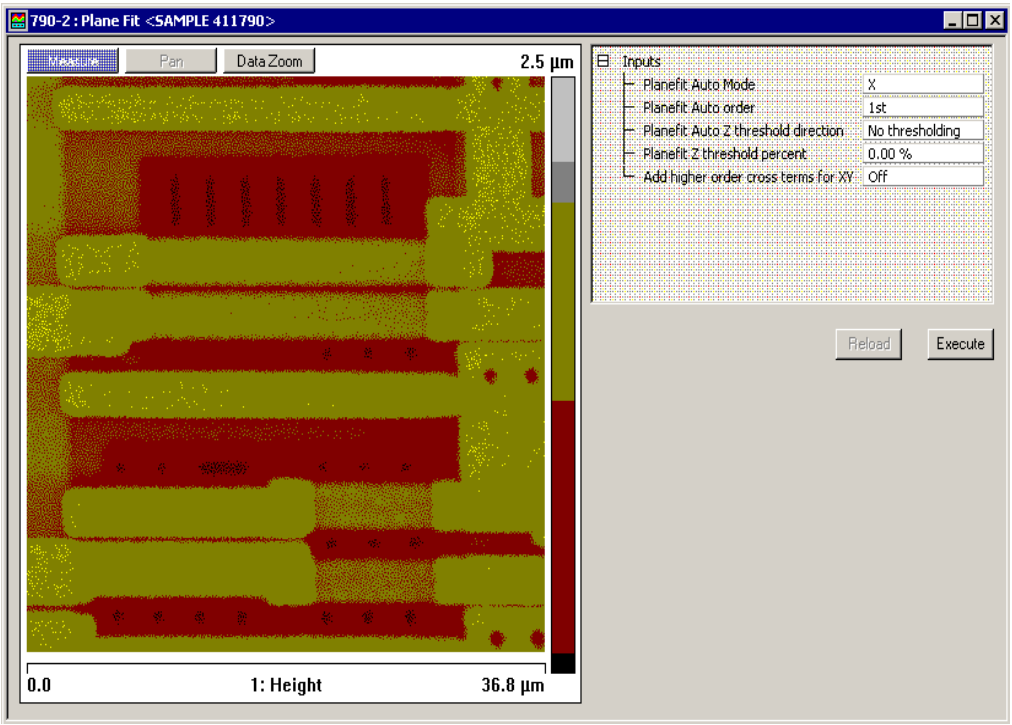
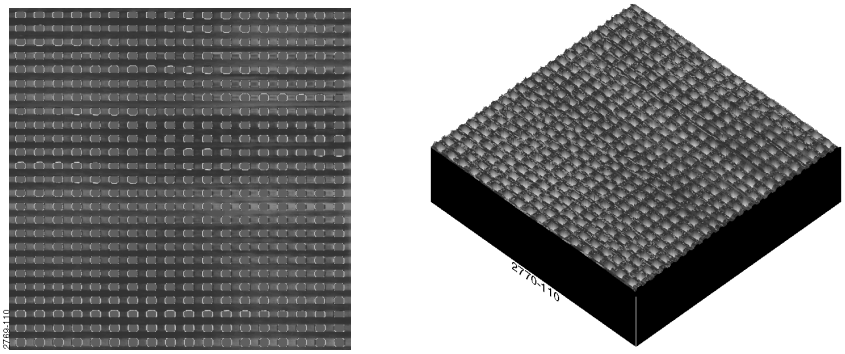


Figure 4.2d Plane Fit Image



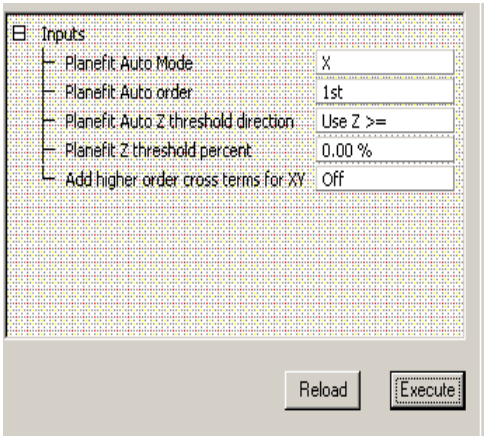
Now, experiment with this image to explore the range of **Plane Fit** capabilities. Try the following:

- Change the **Planefit order** value to see its effects. Notice that there is a vast difference between a value of **1**, **2** or **3**.
- Try plane fitting in one axis (for example, X), but not the other. This generally keeps whatever distortions are presently oriented along the unused axis. For example, the image can be straightened along its Y axis, while leaving the X axis strongly bowed.
- Try using a different **Planefit order** for the X and Y axis (for example, a setting of **3** for X, but a setting of **1** for Y.) This is similar to using one axis, but not the other.
- Compare the effect of **Plane Fit** with **Flatten**. Notice that each command has a significantly different impact upon this image; although, the difference is less noticeable for some other types of images.

4.2.3 Plane Fit Interface

The **Plane Fit** dialog box (see Figure 4.2e) allows the display parameters and the Planefit order to be adjusted to your preferences.

Figure 4.2e Plane Fit Inputs Dialog Box



Buttons on the Plane Fit Window:

Execute	Initiates the plane fit operation.
Reload	Restores the image to its original form.

Input Parameters:

Planefit order	Selects the order of the plane calculated and subtracted from the image.
Z Thresholding direction	Specifies the range of data to be used for the polynomial calculation based on the distribution of the data in Z: Range or Settings: • **Use Z > =** —Uses the data whose Z values are greater than or equal to the value specified by the Z thresholding %. • **Use Z <**—Uses the data whose Z values are less than or equal to the value specified by the Z thresholding %. • No Thresholding—Disables all thresholding parameters.
Z Thresholding Percent	Defines a Z value as a percentage of the entire Z range in the image (or data set) relative to the lowest data point.
Add Higher Order Cross Terms	Turning this on adds higher order cross terms to the polynomial fit when XY is chosen (see Table 4.2a).

4.3 Lowpass

The **Lowpass** modify command applies spatial filtering to a captured image, suppressing high spatial frequency components. Each pixel in an image is replaced with the average value of the 3 × 3 pixels centered on it.

1. Select an image file from the file browsing window at the right of the main window. Double-click the thumbnail image to select and open the image.

2. You can view the **Lowpass View** (see Figure 4.3a) using *one* of the following methods:

   - Right-click on the image name in the **Workspace** and select **Add View > Lowpass** from the popup menu.

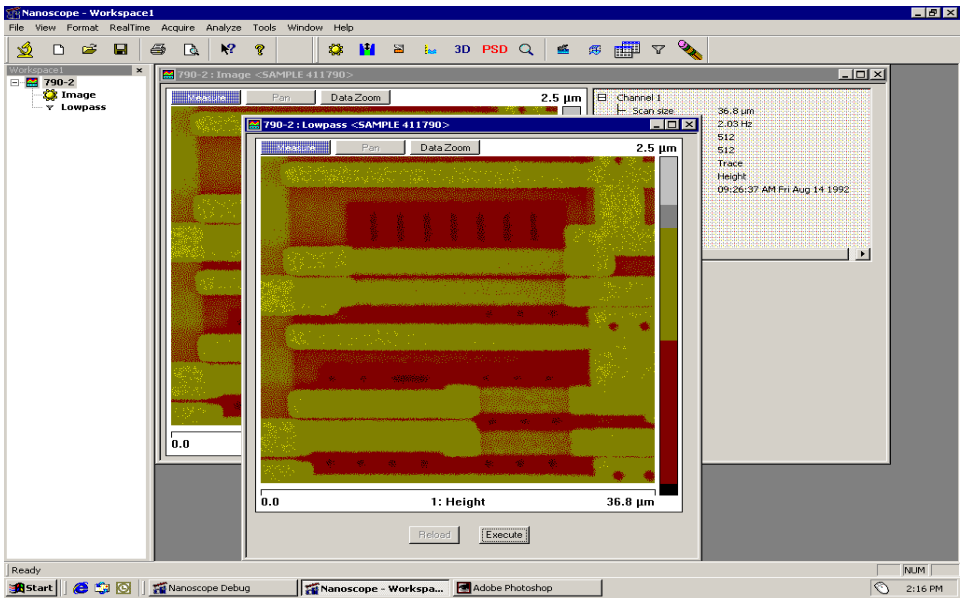
     Or

   - Select **Analyze > Lowpass** from the menu bar.

     Or

   - Click the **Lowpass** icon in the upper toolbar. 

Figure 4.3a Lowpass Image Display



3. Click the **Execute** button in the **Lowpass** window to apply the low pass function to the copy of the image in both windows.

4. To restore the unprocessed image, click the **Reload** button.

   Note: There are no parameter controls for the **Lowpass** modify command.

4.4 Erase Scan Lines

The **Erase** modify command is a retouching function for editing images. Previously, horizontal lines could be replaced with an interpolation from the adjacent lines. In Version 6, the capability is extended to rectangular areas as well.

1. Select an image file from the file browsing window at the right of the main window. Double click the thumbnail image to select and open the image.

2. Open the **Erase View** (see Figure 4.4a) using *one* of the following methods:

   - From the menu bar, click **Analyze > Erase**.

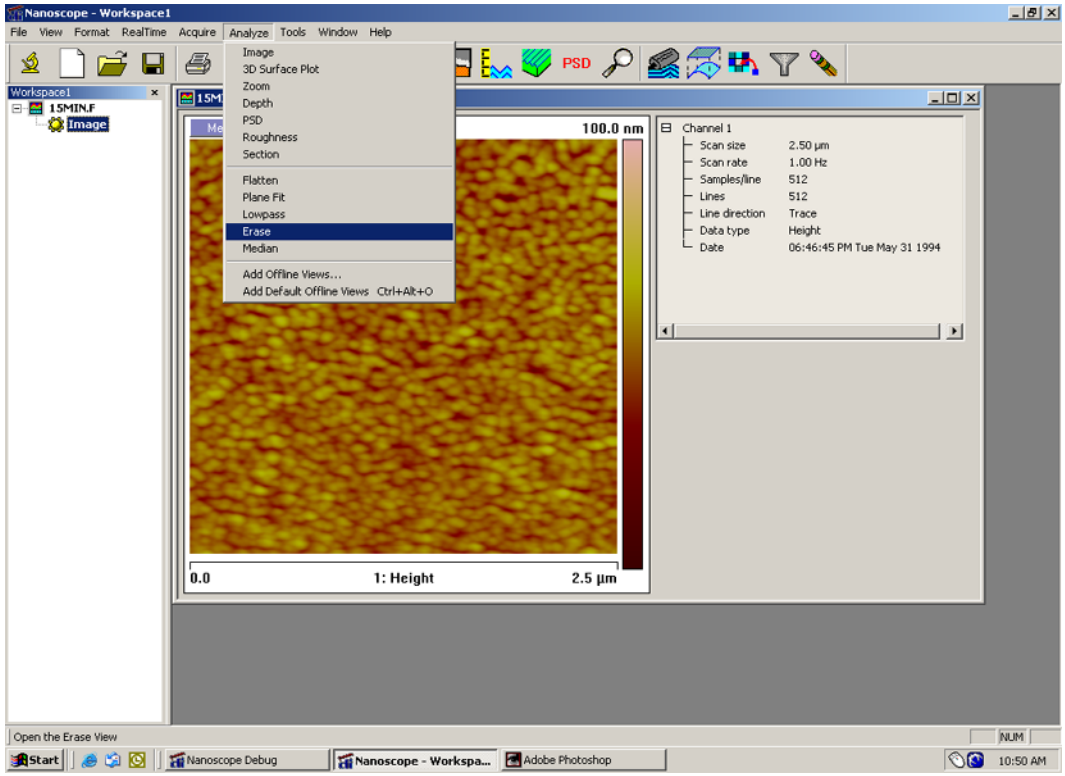
     Or

   - Right-click on the Image file name in the **Workspace** and select **Add View > Erase** from the menu.

     Or

   - Click the **Erase** icon in the upper toolbar. 

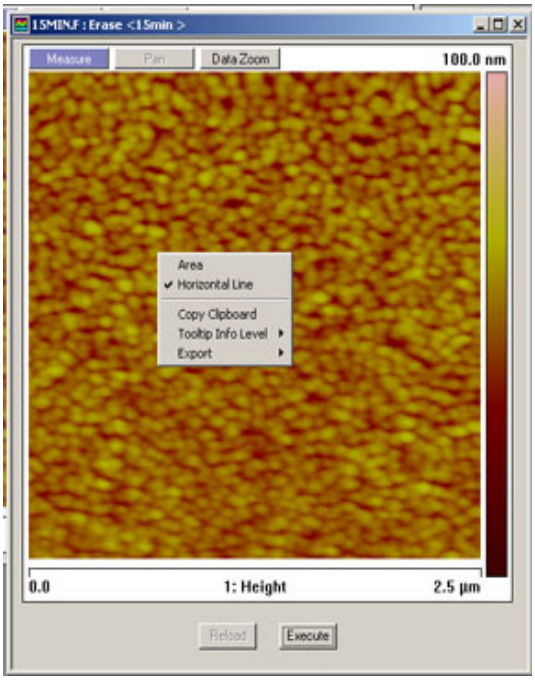
Figure 4.4a The Erase Option in the Analyze Menu



3. A separate window opens, also displaying the image. Right-click in the image to display the **Erase** options menu (see Figure 4.4b). Select either **Horizontal Line** or **Area** and a check mark will appear. The option chosen will remain checked until another selection is made.

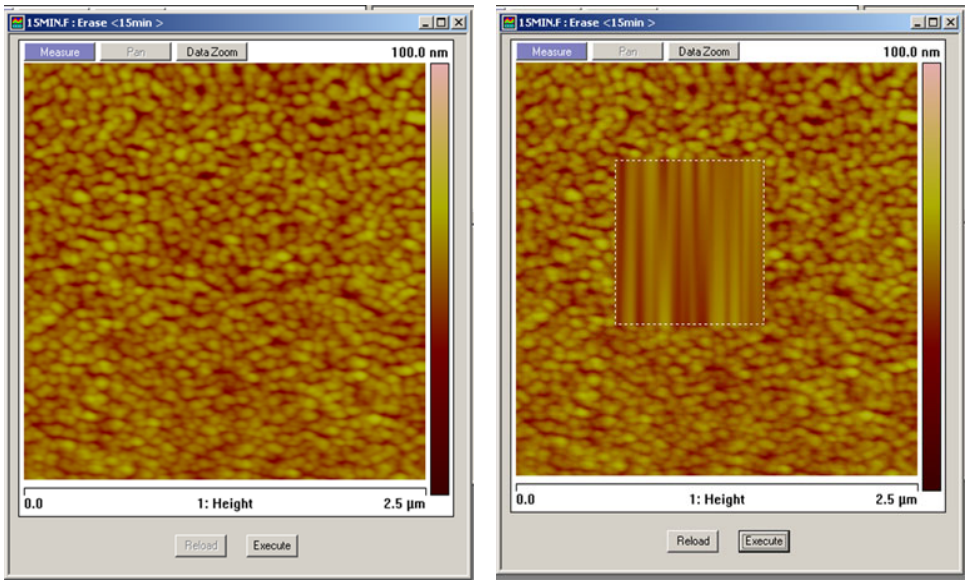
4. Click anywhere within the image to define a horizontal line, or click and drag in the image to define a box to be replaced.

Figure 4.4b Erase Options Menu



5. Click the **Execute** button to perform the interpolation.

Figure 4.4c Effect of the Erase Interpolation on a Rectangular Area



Before After

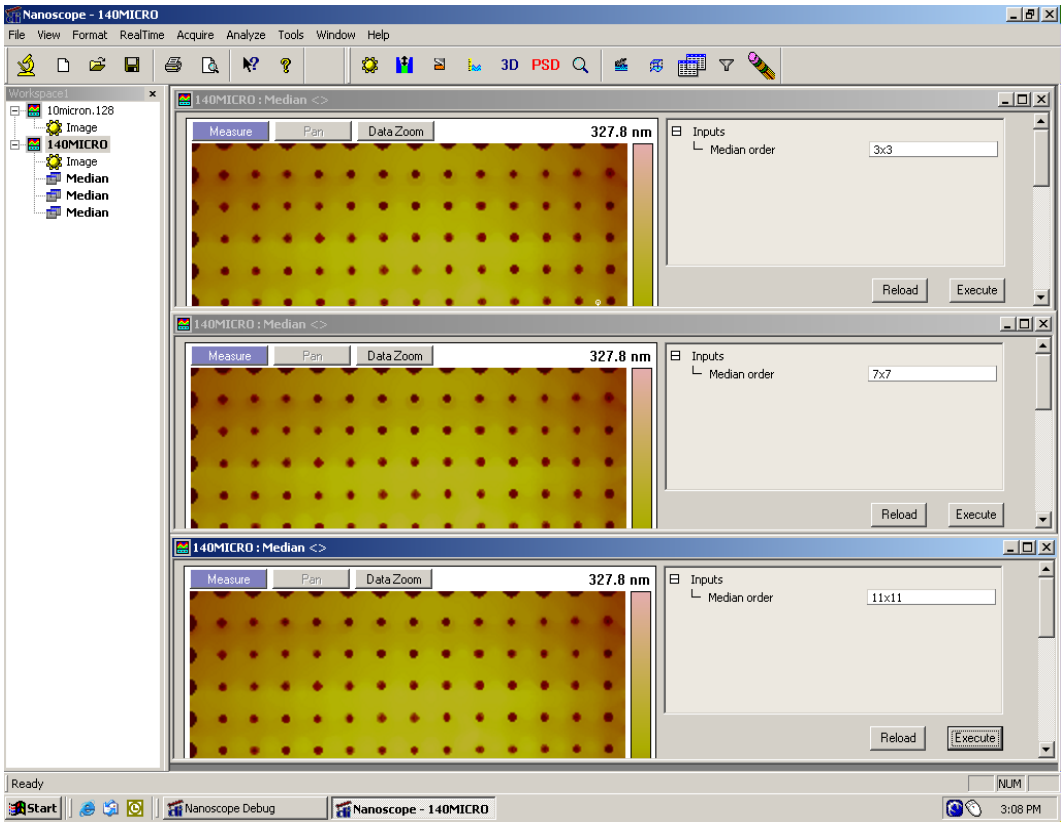
6. Right-click on an **Erase** feature of a modified image (either line or box) for options to complete the operation. Click **Delete** to erase the dashed construction lines from the display of the selected feature. Click **Clear All** to eliminate all construction lines from the display, while retaining the modifications to the image.

7. To eliminate all trace of **Erase** activity to an image, click the **Reload** button while the image is still open in the **Erase** panel.

4.5 Median

The **Median** modify command is similar to **Lowpass**; it reduces the contributions of high spatial frequency, reducing contrast in regions of high contrast. For each pixel in an image, **Median** substitutes with the median pixel value of the n×n array of pixels centered around that pixel. The size of the filter's sliding window pixel array is set under **Inputs > Median order**. Figure 4.5b illustrates the effect of three different size pixel arrays applied to the same image.

Figure 4.5a # Different Pixel Arrays of the Same Image



1. Select an image file from the file browsing window at the right of the main window. Double-click the thumbnail image to select and open the image.

2. Open the **Median View** using *one* of the following methods to open a separate window which also displays the image (see Figure 4.5b):

   - From the menu bar, click **Analyze > Median**.

     Or

   - Right-click on the Image file name in the **Workspace** and select **Add View > Median** from the menu.

     Or

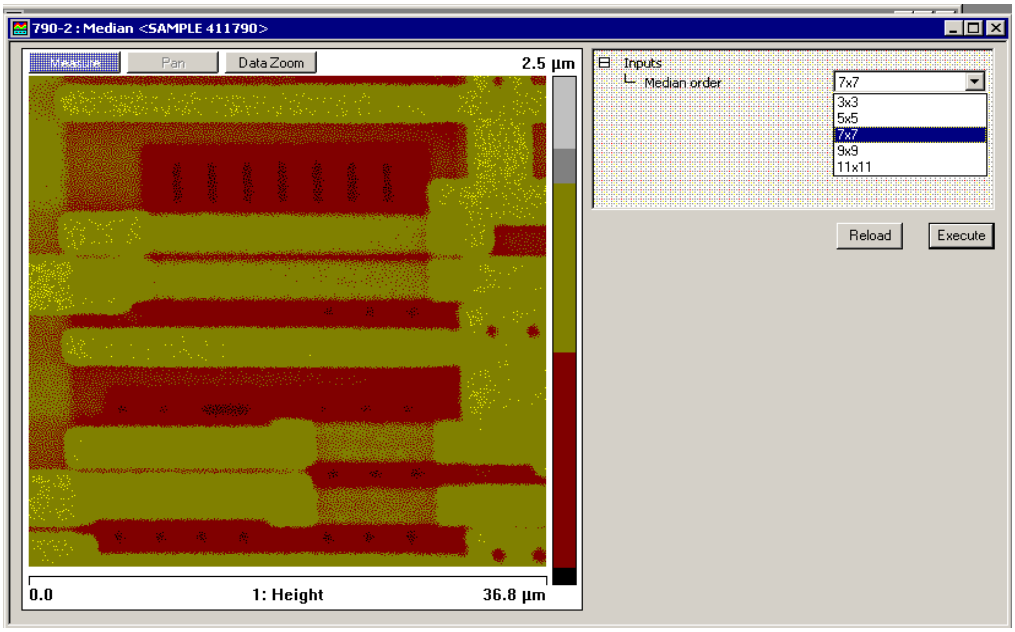
   - Select the **Median** icon. 

3. Select the **Median Order** from the **Inputs** menu: 3×3, 5×5, 7×7, 9x9, or 11×11.

4. Click **Execute** to apply the **Median** filter.

5. Click **Reload** to start over.

Figure 4.5b Median View



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