AVI PHOTOMASK METROLOGY SYSTEM
USER MANUAL

Automated Visual Inspection
952 S. Springer Rd.
Los Altos, CA, USA

Phone: +1 650/941-6871
Fax: +1 650/941-4821
Website: www.aviphotomask.com
Email: info@aviphotomask.com

Credits

Automated Visual Inspection

952 South Springer Road

Los Altos, CA 94024 USA

www.aviphotomask.com

email: info@aviphotomask.com

Phone +1 650/941-6871 Fax +1 650/941-6871

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1 Introduction

1.1 Overview

The AVI Photomask Metrology System measures photomask defects and linewidths using images from a reticle inspection system or other microscope/video source. It provides highly accurate and repeatable measurements that are generally used to decide if a given defect or linewidth is large enough to require repair or disposal. The system also maintains a database of measurements, and allows an image of any measurement to be printed, along with a report on the defect.

In addition to defects and linewidths, the AVI system measures CD and edge uniformity, corner radius, butting error, OPC sizes, and maximum dimensions of large defects. It also allows manual point to point measurements.

1.2 How It Works

The AVI Photomask Metrology System uses the patented Flux-Area Measurement technique to measure the amount of light absorbed by a dark feature, or transmitted by a clear feature. It takes an image from an existing microscope and generates a reference image of the region around the defect as if the defect was not present. It then computes the difference in total light between the real image and the reference image. This is the light flux that was absorbed or transmitted by the defect. The flux is proportional to the effective area of the defect. That area is converted to a diameter and displayed.

Conventional systems measure the edge-to-edge size of a feature. This does not directly correlate to effective area, and does not accommodate partially opaque regions.

1.3 Specifications and Limitations

1.3.1 **Accuracy**: The AVI system accuracy has been tested in several studies by comparing AVI measurements of design defects on test masks to wafer prints measured with SEM. Average deviation between the AVI measurements and wafer CD errors is 3 nm on the wafer, which is the repeatability of the wafer SEM measurements.

By comparison, SEM measurements of the test masks show about twice as much deviation from the wafer measurements, compared to AVI flux-area size.

1.3.2 **Repeatability:** A typical system, using images from a KLA353uv, will provide rms. repeatability of 5 nm for defects larger than 0.2 microns, and 6-8 nm for defects smaller than 0.2 microns, or larger than 0.5 microns. Long term repeatability is typically twice the short term, and tool-to-tool repeatability is typically better than 10 nm (dependent on calibration).

1.3.3 **Soft (non-opaque) Defects:** The AVI measures the *effective size* of a defect, regardless of its opacity. The *effective size* is the size of an equivalent opaque defect that would absorb or transmit the same amount of light, and therefore cause the same effect on the printed wafer. Conventional systems try to measure the physical size of the soft defect, if it is visible, which provides only a rough guess of how that defect will print.

1.3.4 **Minimum Feature Size:** The AVI will accurately measure any defect that can be seen. The smallest defects on VeriMask 890 masks (0.08 microns) are measured with the same accuracy (deviation from the design size of the defect), as are larger defects. As defects get smaller the repeatability gets worse because there is so little light coming from the defect. More measurements need to be averaged to get the same repeatability as larger defects.

The smallest defect that can be seen is typically 1/10 the size of the optical wavelength (0.05 microns for visible light, 0.03 microns for I-line). Note however that the edge roughness of typical masks is about 0.05 microns, so measurement of features smaller than that can be meaningless.

1.3.5 **Maximum Feature Size**: The largest measurable defect is limited only by the provided image's field of view. However the printability of a feature larger than about 2 wavelengths corresponds to its shape more than its area, so conventional edge-to-edge measurements are usually used for precise sizing of large features (larger than about 0.8 micron).

The AVI will accurately measure the defect's area, but in some cases, point-to-point measurements may be more useful. The AVI measures the "Maximum Diameter" of large defects such as glass- and pellicle-side particles. It also allows two-click, point-to-point measurements on the live image.

1.3.6 **Allowable Backgrounds:** Isolated and edge defects can be measured with one click when a corner is not in the *immediate area*. The *immediate area* is defined as twice the blur distance, which is 0.4 microns on visible light systems, and 0.3 microns on UV systems. This is the size of the red box in the measurement image.

If there is a corner too close to the defect (indicated by the profile in the measurement image not having any flat baseline), a reference image should be provided (see the procedures section). This is because the AVI system figures out what the image would look like if the defect was not there. When the background consists of straight lines this is easy. However, corners can not be interpolated because their intended radius of curvature is unknown, so a reference image defines “correct”.

Note that using a reference image will increase the noise in your measurements because you are adding the video noise and edge roughness from the two images.

1.4 Environment

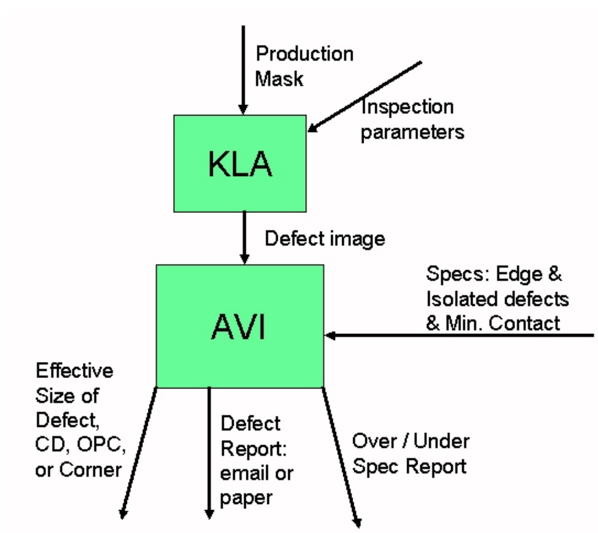
The AVI Photomask Metrology System operates from a standard video signal provided from a KLA Terastar, Lightning, KLA 3xx, KLA 2xx, DRS-I, DRS-2, Lasertec or other similar machine (called the Test Tool). The AVI machine consists of a PC computer running Windows 98 equipped with a high quality video digitizer system and the software. The system comes with a built-in 10-100 Ethernet adapter. The software can also be run under WinXP or Win2000.

1.5 How the AVI is Used in Production

The AVI Mask Metrology System is primarily used to improve defect disposition, to improve the decision of what to do when defects are found during mask inspections.

To get maximum value from the AVI metrology system's excellent accuracy and repeatability it should be used to help define the defect acceptance specifications, as well as for measuring defects in production. Ideally a test mask with designed defects, such as a VeriMask, is printed on a wafer. The smallest design defects will not print on the wafer. The largest defect that does not cause a 'misprint' on the wafer is considered to be the largest acceptable defect on masks for this process. Typically there are separate specs for edge and isolated defects.

If the specifications were defined based on less accurate measurements, even SEM, then the effective accuracy of the AVI will only be as good as the specification measurements.



1.6 Typical Application Processes

1.6.1 **Determine the maximum defect size specification.** Optimally a test mask is printed with the lithography process and the largest acceptable edge and isolated defects are determined, along with a "guard band" based on the measured variability of the wafer and the mask measurements. The mask defects are measured on the AVI, so that the specifications are calibrated to the flux-area size.

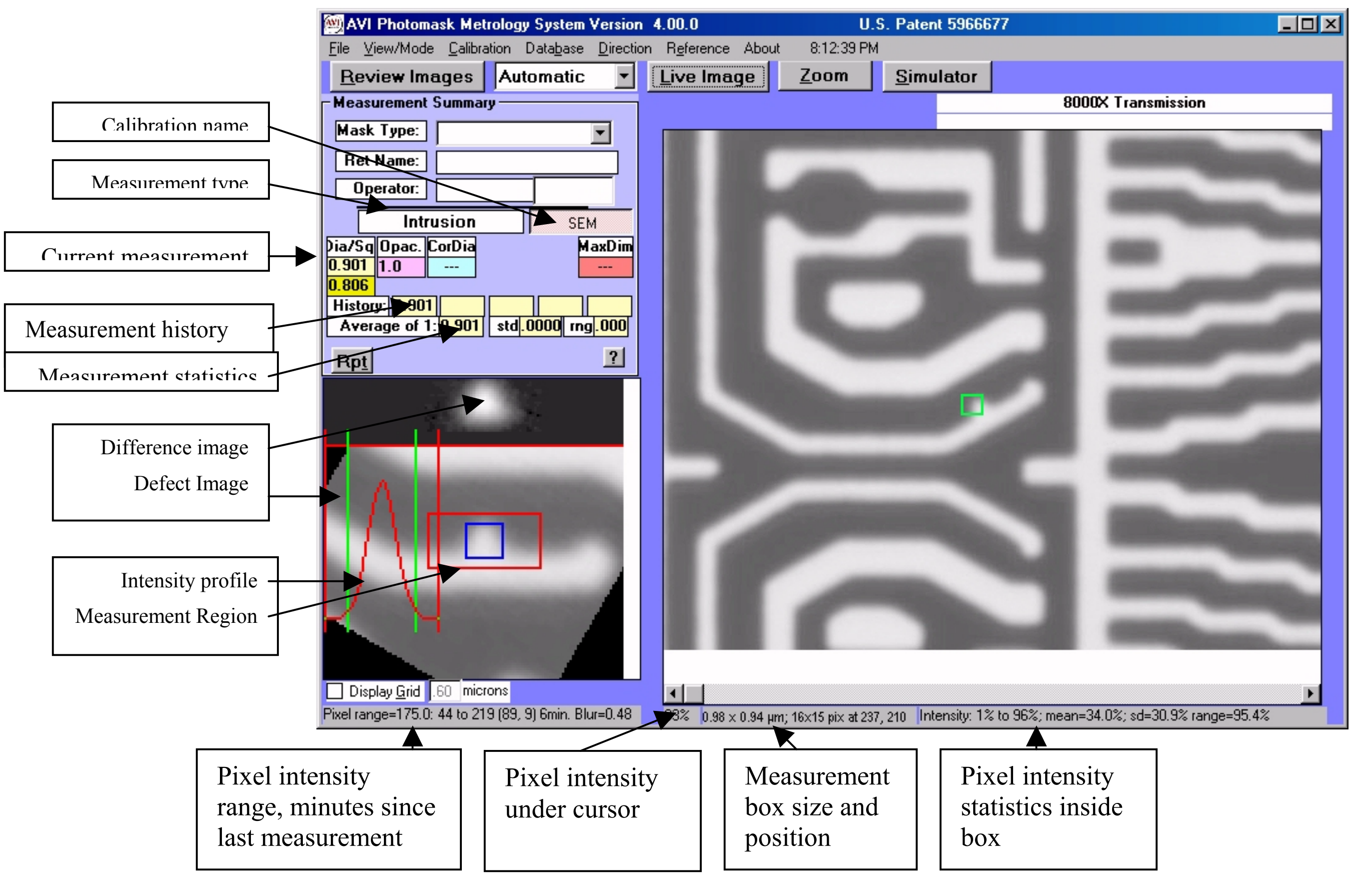
Frequently the specifications are already given, and no testing is performed.

1.6.2 **Measure and disposition defects.** After inspection determine if defects are larger than spec, requiring repair.

1.6.3 **Measure repairs.** Repairs often affect the quartz transmission in a fashion that inspection tools have difficulty detecting. The AVI is very accurate for measuring CDs of repaired features.

1.6.4 **Monitor mask writers.** Measure corner radius and edge roughness to detect mask writer problems before they cause failures.

2 Measurement Features



2.1 AVI Measurement Displays

- **Input parameters**: Mask Type (often renamed to "Customer"), Reticle or Mask Name, Operator. The top value, Mask type or Customer, is a drop-down list. You can add new values by selecting the blank value and typing in the new value. You can then enter custom specs and stepper setups in the [File | Custom Specs] screen. The other two values are recorded in the defect database for use in reports.

- **Measurement Type:** Displays the measurement type. Depends on the feature marked for measurement, as described in Chapter 6. Two ambiguous cases (linewidth vs. butting error; and contacts vs. hole) are specified by selecting the type in the drop-down box above the main image.

- **Calibration** ("SEM" in the figure). When enabled (click on it) all measurements are corrected as defined in the non-linear menu.

- **Dia/Sq:** label for the Diameter and Square Root of Area below.

- **Dia:** This is the effective defect area converted to a diameter. It is the diameter of an opaque circular defect that would absorb or pass the same amount of light as the measured feature. This is the most accurate and repeatable measurement, and is the best predictor of defect printability.

- **Sq:** Square root of the area. This is a useful measurement for square objects, such as contact holes.

- **Opac** (Opacity): This is the measured opacity or transmission of the defect. 1.00 means perfectly opaque (for a spot or chrome extension) or perfectly clear (for a hole or clear intrusion). It is accurate to 5% for defects larger than 0.5 micron (or 0.36 micron on UV images).

- **CorDia** (Corrected Diameter): This is the Diameter corrected for measured opacity. A non-opaque (or non-transparent) defect absorbs light like a smaller opaque (or transparent) defect. The corrected diameter is the diameter you might measure on a SEM or other measurement system. The Diameter will correlate better to what prints on the wafer. This value is not displayed if the Opacity is close to 1.0.

- **MaxDim** (Max Dimension). The perimeter of large defects (greater than 1 micron) are traced, and the maximum distance across the perimeter is measured and displayed. This is used for measuring large dirt particles, mostly on glass and pellicles. Sometimes a medium size defect will display an overly large value here because it is affected by surrounding detail. The “measurement image” will display the perimeter in green and the location of the maximum dimension in red.

2.2 Using the Measurement Statistics Functions

There are several functions available to help you get better measurements using statistics:

2.2.1 Measurement History and Statistics

- By default, diameter measurement history and statistics are displayed in the statistics section. To display history and statistics for another measurement (such as Opacity), click on the desired measurement. This applies to *all* measurement types, such as corner radius and OPC.

- Setting the number of measurements to analyze: click on the “Average of ‘n’” box

- History: displaying of the last ‘n’ measurements. The last 5 measurements are displayed. Additional measurements can be seen by right-clicking on any of the individual values.

- Retake a measurement in the same location: **Right** click on the [Rpt] button or press the [Enter] or [R] key.

- Automatic collection of ‘n’ measurements: press [Rpt] button. All previous measurements are cleared, and the most recent measurement is retaken with a new image. Press [Esc] key to stop it before it’s done. To retake the measurement continuously in the same spot, hold down the Shift key when you click on [Rpt], and press [Esc] to stop.

- Automatic statistical analysis of the previous ‘n’ measurements: Mean, standard deviation, and range of those measurements are displayed below the 'n' most recent measurements.

- Display the values of all measurements used in the statistics (useful when you’re doing statistics on more than 5 values): Right click on any of the individual measurement values.

2.2.2 Clearing Statistics

- Clear an individual (bad) measurement from the statistics by clicking on it. The value is removed and the statistics recomputed.

- Clear all measurements: click on any of the 3 statistical displays (average, standard deviation, or range), or press the “0” key.

2.2.3 Saving Statistics to Other Programs

- Copy measurement history to clipboard: File | Copy Measurements[Ctrl-C]

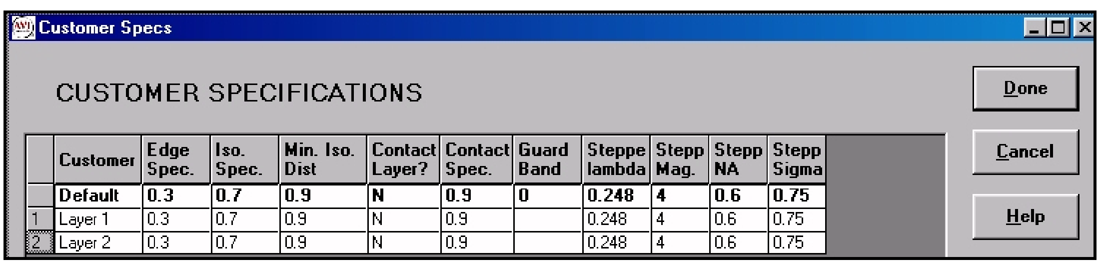
- Save measurements to a spreadsheet file (CSV format): File | Save Measurements [Ctrl-V]

2.3 Other Items on the Main Screen

- **Display of Previous values, Average, and Standard Deviation** of recent measurements. These are found above the measurement image on the main screen. You can change the number of measurements that are averaged by clicking on the “Average of …” box. Up to five most recent values are displayed where it says “History”, even if you average more. Click on the “?” to get a list all the things you can do and change. NOTE: This feature does not know if you have moved to another defect unless you use the “Rpt” button, so you should clear old values by clicking on the average value or pressing “0” before starting a new set of measurements.

- **Specifying customer, mask and operator information**. Click on the text area and type the information. This information is printed in defect printouts and saved in the database.

- **Setting defect specifications**. You can set up “maximum defect size” specifications for edge and isolated defects. In addition, the minimum distance of an isolated defect from an edge can be specified. The spec settings are displayed just above the main image. You can have different specs for each layer or customer. The specs will update when you select a new layer or customer from the top box in the Info box. To enter new specs, click on any of the specs above the main image, and the Customer Specifications screen will appear. Click on any values to change them. Click on the “Help” button or on any of the grid headers to get an explanation of each column.



	Customer	Edge Spec.	Iso. Spec.	Min. Iso. Dist	Contact Layer?	Contact Spec.	Guard Band	Steppe lambda	Stepp Mag.	Stepp NA	Stepp Sigma
	Default	0.3	0.7	0.9	N	0.9	0	0.248	4	0.6	0.75
1	Layer 1	0.3	0.7	0.9	N	0.9		0.248	4	0.6	0.75
2	Layer 2	0.3	0.7	0.9	N	0.9		0.248	4	0.6	0.75

To enable specifications: in the System Setup screen ("File | System Setup" or "Ctrl-Y"), check the “Show Specs” box and press OK. To set the specs for each mask type, click on any of the spec displays above the main image. The Customer Specs screen will appear.

Set the “Spec: Min Iso. Dist” (minimum isolated distance). This is measured from the defect center to the edge. Defects closer than one “blur distance” (0.5 micron for optical systems, and 0.36 microns for uv) will always be considered edge defects because the distance to the edge cannot be accurately measured.

- **View Menu.** This provides options for viewing pixel statistics in the selected region, viewing the image with contrast normalized in the region, or in false color. Also provides a command to turn off the yellow warnings that intentionally obscure the measurement image. Each of these commands has a key for easy access: "s" for statistics, "n" for normalize, "f" for false color, "y" for turn-off-yellow message.

- **Specifying a direction to measure**. (Top menu line) This lets you override the automatic measurement direction logic. Use it if the red box in the measurement image isn't parallel to adjacent lines. Retake the measurement after setting this. This is reset after each measurement unless you set the "Direction | Don't Reset" item. The direction menu also allows you to turn off image rotation if the image is being rotated when it shouldn't.

- **Reference menu.** Allows you to mirror or rotate the image, especially for aligning a corner for use as a reference. The "Restore" command is used for restoring the original image, especially after field correction of saved images.

- **Display Grid on measurement image**. (Below the "measurement image.") You can display a grid, adjust its spacing (in microns, by typing in a new value), and drag the grid to align with your defect.

- **Display Target on live image**. This is used to help an operator position a feature to the same spot every time, or give a visual reference for a certain size, e.g. 2 microns, especially for measuring on-chrome defects. Note: the check mark is hidden if no "target diameters" are given in the system setup screen. Seldom enabled.

- **Intensity range display**. This is a diagnostic for identifying illumination problems. The first pair of numbers is the visible intensity range (in a scale of 0-255). The second pair is the confidence level for the first pair. If the confidence is low (below 8), then the intensity from the most recent good image is used. The visible intensity range shouldn't change by more than 10 when images with good bright and dark areas are measured. The last number is the time (in minutes) since the AVI software was last able to measure both bright and dark intensity.

- **Print Image**. This button prints the Defect Report (large and measurement images, the inspection summary, and the detailed measurements) to any attached or network printer. Same as File | Print. You can setup the printer with File | Printer Setup.

- **Review Images**. This button brings up a screen for reviewing the database, including a button for searching for specific measurements and saving them to a spreadsheet file. See Database sections under Procedures.

- **Contrast**. This button performs a contrast enhancement that makes small spots and holes more visible. It has almost no effect on edge defects. This can be used on live or saved images.

- **Zoom**. Clicking this button, or right-clicking on any spot in the image expands the image to make it easier to see and mark small defects. Note that right-clicking on the image centers the image on the spot you clicked.

- **VeriMask Mode**. Used for taking a series of measurements all using the same reference image. Mark the relevant spot in the reference image, ignore the measurement, and then click this mode on. Now each time you mark a feature to measure it will use that specified reference image. Note: this checkmark is enabled by the "Show Verimask Chk" item in the system setup menu.

3 Calibration

3.1 Calibration Description

This is critical information for getting good results from the AVI system. Please read it carefully. For best calibration results, be sure that the digitizer gain is set correctly and that field correction is enabled if needed (not needed on KLA and Lasertec systems).

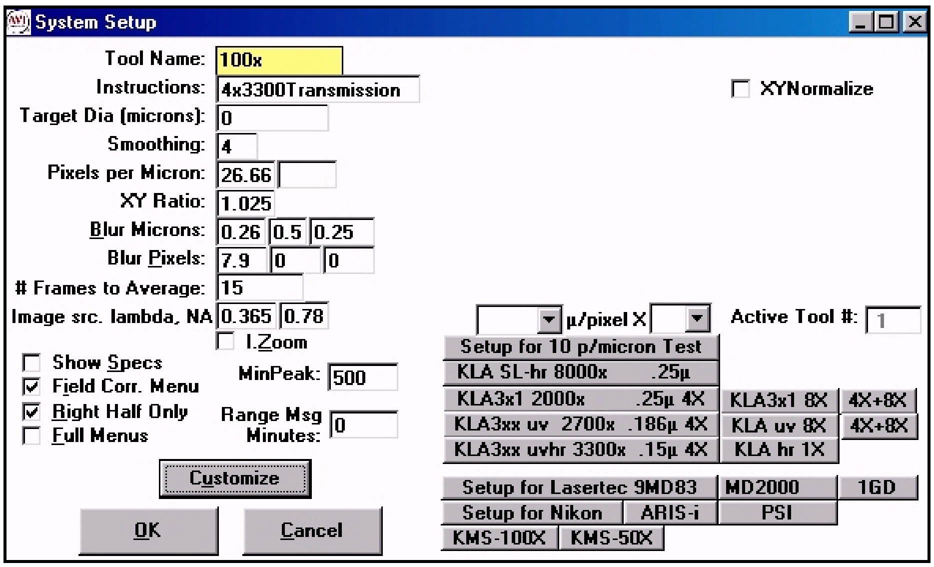
The AVI has three levels of calibration.

1. **Linear Calibration (required)**
    - Performed using pitch measurement only, or using specified resolution from KLA inspection tool.
    - Matches the AVI parameters to the optical system it is being used with.
    - Set at installation, remains set until the optical system is modified.
    - Typically takes 5 to 15 minutes.
2. **Nonlinear Calibration (optional)**
    - Multipoint correction for spots, holes, edges, dark lines, clear lines, and contacts.
    - Matches the flux-area measurements to an existing standard, such as SEM, Verimask measurements, PSL sizes, KMS measurements, etc.
    - Set at installation, remains set until the optical system is modified, or the reference system changes.
    - Typically takes 1 hour if the reference values are available.
    - SEM correction values can be calculated automatically.
3. **Intensity Calibration (required)**
    - Determines the observed intensity levels for dark and clear regions on current mask, and current illumination.

- o Performed by measuring an edge between clear and dark areas larger than 1 X 1 micron.
- o Must be performed at the start of each new mask.
- o Typically takes 30 seconds to 2 minutes.
- o Automatically performed any time a measurement is made near large dark and/or clear areas.

3.1.1 Initial System Parameter Setup

The AVI has preset calibrations for many optical systems in the extended system setup menu: Ctrl-Y Ctrl-Y. In the right side of the menu you will see a list of common tools. Click on the tool that you are using as an image source for the AVI.



For image sources that are not predefined you must enter the image source wavelength (lambda) and numerical aperture (NA). These values are used in calculating the SEM correction and in the Stepper Simulator.

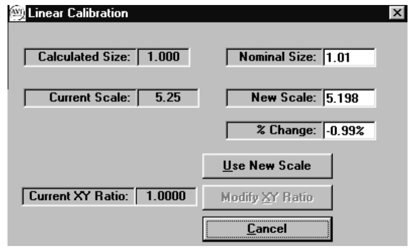
You can measure the PixelsPerMicron parameter (below) or compute it: Pixels/Micron = Electronic-Mag / PixelSize. For example, 4x magnification with .15 um pixels gives 26.67 um/pixel

3.1.2 Linear Calibration Procedure:

- This **must** be performed on a set of lines with known pitch. Performing linear calibration on line widths, contacts or anything else will produce inaccurate and non-reproducible results. If you selected a setup for a KLA system above, then this step will be a verification that you selected the correct values.
- Measure the pitch by drawing the measurement box across as many lines as possible. If possible, skip the first and last lines in a line set. Those lines are slightly asymmetrical because they have a dense pattern on one side and none on

the other. Cover as much of the length of the lines as possible, to average out non-uniformity in the lines.

- View the "Linear Calibration" screen (in the Calibration menu, or Ctrl-L) and enter the design pitch. Verify that the change is reasonable, and press "Use new scale".



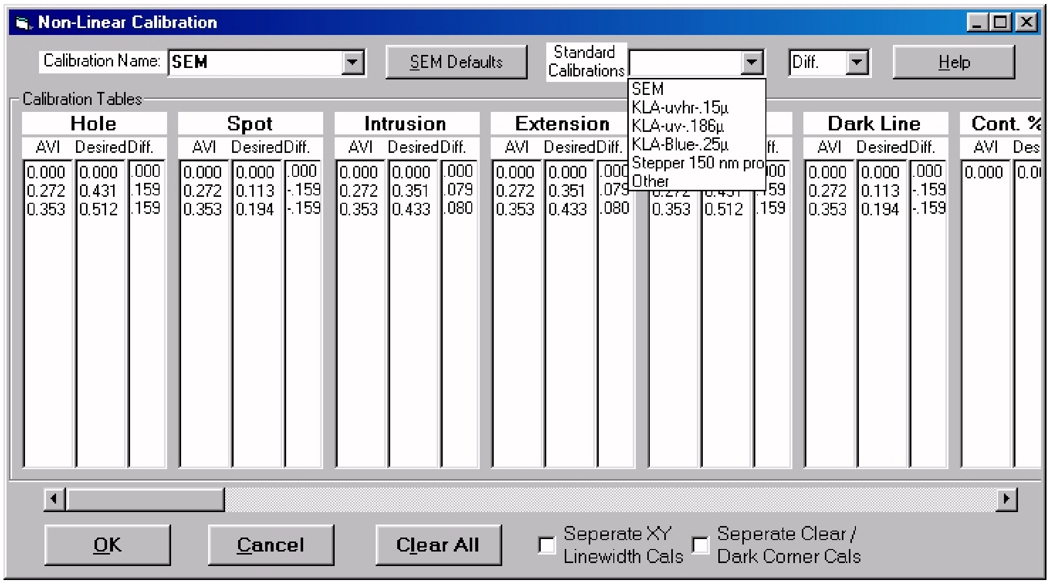
- Linear Calibration should be performed on both vertical and horizontal lines for best results. Measure one direction and set the "pixels per microns", then measure the other direction and set the "XY Ratio". The XY Ratio varies by about 2% on laser scan inspection tools because the scan rate for review mode is not controlled as carefully as for inspection. On tools with regular cameras (such as Aris-I and microscopes) the XY Ratio is usually exactly 1.0.
- The result of this calibration is the "Pixels per micron" parameter that can be seen at the top of the System Setup screen. This calibration does not change from year to year unless the optical system geometry is modified.

3.1.3 Non-Linear Calibration Procedure:

Please read the following section on calibration theory.

You can define any number of calibrations, corresponding to measurements from other tools, depending on your customers' needs. Each non-linear calibration defines separate size mappings from AVI to the reference sizes for spots, holes, extensions, intrusions, dark lines, clear lines, and contact area ratios. Each measurement type can have 0-16 separate points defined for each measurement type. Each point is an AVI size and the corresponding desired size.

Multi-point calibrations allow you to duplicate measurements from non-linear metrology techniques—most frequently this is used to duplicate Verimask and PSL sizes. Click on the "Help" button in the "Non-Linear Calibration" menu for instructions for entering the correction points (AVI / Corrected size pairs).



- **Define a non-linear calibration:**

  Calibration data can come from the following sources: Verimask or SEM defect sizes, PSL spot sizes, AVI sizes from a different inspection tool, design size from a test mask.

  1. Open the Non-Linear calibration screen: Ctrl-N or Calibration | Non-Linear

  2. Type in the name for the new calibration at the top.

  3. Type in the AVI measurements and the Desired measurements. You can also use cut and paste (Ctrl-C and Ctrl-V) to copy values from Excel or a text file.

  4. Click “OK” The calibration button will then be visible on the main screen. Click on that button to enable the calibration. The button is pink when it is enabled, and gray when the calibration is disabled.

- **Create a SEM size calibration**:

  A) **Theoretical**: enter the correct wavelength and NA in the system setup menu, and then click the “SEM Defaults” button. The offsets will be calculated and displayed. Then click “OK”.

  B) **Experimental**: 1) Measure several clear and dark lines on a SEM and with the AVI. 2) Determine the average difference between the AVI and SEM (typically 0.125 µ). 3) Type Ctrl-N, or "Calibration | Non Linear" to see the "Non Linear Calibration" screen. 4) Click on "SEM Defaults" and enter the difference (offset) for your system. 5) Click "OK".

- **Create a size calibration to other optical system**:

  A) **Theoretical**: Click the drop down box labeled “Standard Calibrations”. Select an existing calibration or “Other” to enter the wavelength and NA of the target system. The theoretical values will be entered.

  B) **Experimental**: 1) Measure two instances of each feature type on the target system (the smallest and largest considered significant), and record this “Desired” size. 2) Measure those same features on the current system and record the “AVI” sizes. 3) Enter those sizes in the given columns. Keep zeros on the top row to insure that very small features never come up as "negative" size.

- **Separate XY Linewidth Calibrations:** Enable this only if you are duplicating linewidth measurements from a KMS or Leica metrology system: these systems give different measurements in the X and Y directions.
- **Separate Clear / Dark Corner Calibrations:** Enable this only if you are calibrating corner defects to Verimask corner sizes.

3.1.4 Intensity Calibration Procedure:

- Accurate flux-area measurement require accurate measurement of the illumination intensity. In laser-scan images, such as KLA or Lasertec inspection tools, the illumination is very stable, and only needs to be measured at the start of measurements on each plate.
- To set the intensity range, find an edge between large dark and clear areas, or any region with dark and clear areas larger than 1.5 microns square. In that region mark anything, such as an edge, to measure. During that measurement the AVI will detect and record the intensity range between clear and dark areas. The measurement result can be ignored, but the intensity range will be measured.

3.2 Monitoring Calibration

- Many shops check the calibration of the AVI weekly, although customers report that no recalibration is required except after major hardware adjustments on the image source. Two years between recalibrations is typical.
- Calibration monitoring consists of measuring the same set of defects on a reference mask (typically a VeriMask) at the given interval. We recommend taking 5 measurements of each defect using the [Rpt] button, and recording the mean and standard deviation of at least three different edge defects in the critical size range (0.3-0.7 microns).

3.3 Calibration Theory

This section discusses application of the AVI's non-linear calibration capability.

3.3.1 Calibration To SEM Standards

The ideal mask metrology calibration standard has been SEM measurements, until recently. There are two problems with SEM measurements, both due to the fact that photomasks are used optically, but SEMs measure mechanical/electrical qualities.

2. **Interpretation of height and slope:** Feature sizes are shrinking towards the chrome thickness. This means that sometimes the chrome is not cleared out of the bottom of features, and it means that if a chrome edge is not vertical, its slope will cause a significant reduction in light flux through a clear feature. For this reason, since 1999 there has been increasing debate about measuring the "top", "middle", or "bottom" of chrome edges in SEM measurements.

3. **The optical size of a feature is different than its physical size.** Imagine a grid of 1 micron lines and spaces (pitch of 2 microns), with 100% opaque chrome and vertical edges. You would expect to measure exactly 50% total light transmission through the grid. In fact the transmission is less because light that passes close to the chrome edges is diffracted away from the microscope lens, making the chrome lines appear wider, and clear lines narrower. This effect is called "edge diffraction".

The optical size of a chrome line is approximated by:

OLWdark = PLW + Ores/2,

where OLWdark is the Optical linewidth of a dark line, PLW is the physical linewidth (e.g. measured with a SEM), and Ores is the optical resolution:

Ores = 0.61 * wavelength / NA (known as the Rayleigh limit).

The size of a clear line is the complement:

OLWclear = PLW - Ores/2.

One consequence of this is that we can estimate the "SEM" size of a line accurately from its optical absorption, taking into account the optical effects of edge slope. This correction is available in the "Nonlinear Calibration" screen.

Another consequence is that SEM measurements of isolated defects: spots and holes, are significantly inaccurate, compared to the effect seen in a 0.13 micron process wafer. The error is typically 0.2 microns! This was measured by comparing the wafer linewidth variation caused by isolated defects near an edge. See *Improved Method for Measuring and Assessing Reticle Pinhole Defects for the 100nm Lithography Node* by Darren Taylor, Anthony Vacca, et al. presented at SPIE Photomask Japan April 2002.

A third consequence of this is that all optical feature measurements will vary depending on the optical resolution. For example, there is typically a 30 nm difference between an edge defect's measured size from a KLA blue-light (.25 micron pixel) inspection system, and a KLA high resolution (.15 micron pixel) system. This means that a mask shop with various inspection tools, or with customers using a range of inspection tools must use a uniform calibration, corrected to a single mask or inspection tool.

The difference between optical and SEM line widths is accommodated in the lithography process by adjusting process line widths and exposures. However defect sizing is not treated as carefully in lithography process definitions. If it were, then the spec for maximum pinhole size would be about 0.5 micron larger than the spec for maximum pindot size in the same process!

Because process definitions still define a single "isolated defect" spec and a single "edge defect" spec, the defect measurement system calibration must adjust for the "edge diffraction" effect in the stepper.

3.3.2 Conclusions

1. The optical size of mask features are different from their physical (ideal SEM) size.

2. The optical size of mask features must be corrected for edge diffraction to allow comparison between machines with different optical resolution.
3. The difference between the optical sizes at various resolutions, including SEM (infinite resolution) is a constant offset for all feature sizes. The offset does vary with shape: edge defects have approximately ½ the offset for lines and isolated defects.
4. The AVI system will calculate the theoretical size correction to SEM (infinite optical resolution), other inspection systems, or to the stepper resolution.
5. Because the flux-area measurement is very linear, a correction can also be made by measuring a particular defect of each type on all systems whose measurements are to be matched, and using the “Non-linear calibration” to match them.
6. There is a trade-off in deciding what so use for a calibration standard:
    a. SEM: Intuitive, and fairly easy to reproduce, but farthest from the stepper output.
    b. High resolution inspection tool: Intuitively good, easy to reproduce.
    c. Low resolution inspection tool: Easy to reproduce, and closest to the stepper output.
    d. Stepper output (or AIMS or Simulator): A logical choice, but different steppers will require different calibration offsets, and only AVI systems have software to perform defect measurements to this calibration.

3.3.3 **"Non Linear” Calibrations:** Conventional linewidth calibrations, such as NIST and others based on NIST, e.g. KMS and LWM, are **not** based on optical transmission. They generally report opaque lines 0.1 um wider, and clear lines 0.1 um narrower than AVI. For example, a 2 micron pitch grid with SEM 1 micron lines and 1 micron spaces will transmit about 45% of the incident light, instead of the expected 50%. The “SEM Correction” allows you to derive SEM measurements from the AVI flux-area measurements.

3.4 Calibration Backup: Save and Restore

We strongly recommend that you make two copies of the backup on floppies: keep one with the AVI tool and one at your desk. These can be used in case of a catastrophic failure of the AVI computer or to restore a new system to the old calibration. Be sure to update these backups whenever you change the calibration (rarely, maybe once or twice a year).

- To save the current calibration and setup to a floppy or other file: click on “File | Backup Calibration”. Select “A:” to save to the floppy, or select another directory.

- To restore a saved calibration and setup: select “File | Restore Calibration”. Select “A:” to restore from the floppy, or select another directory.

4 AVI Stepper Simulator

The AVI Stepper Simulator capability is an option. Please contact your AVI sales representative for more information.

The stepper simulator function is normally activated automatically when a defect is measured. Its display can be toggled manually by clicking the [Simulator] button. The display can be zoomed in the same fashion as the main image.

Measurements (CD and contrast) are performed simultaneously for dark and clear lines so that the defect is dispositioned on the smaller, more sensitive feature.

The parameter display box can be dragged so that it does not obscure the key part of the image.

The pixel intensity under the cursor is displayed in red when the cursor is on the simulator image. It can be toggled between percent and absolute values by pressing the "%" key.

4.1 Simulator Parameters

- **Lambda** (microns) **and NA (**unitless) **for the Source image.** These are defined in the System Setup menu. These values can be modified manually, although changes made from the main screen are not saved to disk—they are reset when the program is restarted.
- **Lambda, NA, and Sigma (**unitless) **for the Stepper.** These are defined in the [Custom Specs] menu [Ctrl-U]. Multiple setups can be defined by entering different mask types, then entering the values for each mask type in the Custom Specs menu. These values can be modified manually—they are reset when the program is restarted.
- **Exposure** (arbitrary units): This is set automatically to produce the CD defined in the [Design CD] parameter. It can be adjusted manually. The automatic value is restored when the Design CD is changed.
- **Focus:** (microns) This defaults to best focus. This can be adjusted manually. The CD measurements and exposure are recomputed for each de-focus value.
- **Design CD (clear and dark):** (microns) These values are computed from the mask image, and can be modified manually. The exposure is computed to produce

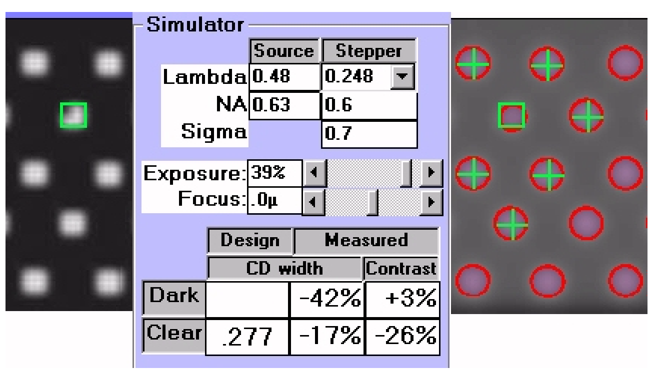
this CD in the simulator image. The design values can be restored by clearing a manual value.

- **Measured CD (clear and dark):** (percent error) These values are computed from the image at the defect position, at the exposure which gives the design CD in the normal area.
- **Measured Contrast (clear and dark):** (percent error) These values are computed from the image at the defect position. These values are independent of the exposure and design CD.
- **K1 value:** (unitless) This is computed on lines only. It is the ratio of the defect size to the stepper optical resolution. "Low K1" features are the most difficult to print correctly. When clear and dark lines are measured, the K1 of the smaller of the two is computed.

4.2 Linewidth Error Measurements

- The image is rotated as needed, and the dark and clear linewidths are measured at the defect and nearby for a reference value. If a line is very wide it is not measured, and its width is not displayed.
- The peak intensities, dark and clear, are measured adjacent to the defect and at the location of the reference value.
- If you click on a separate reference location, the new location is used as the reference. This will give spurious CD errors if the wrong reference feature is selected.

4.3 Contact Error Measurements



- Contacts in the region that was marked are located and measured. By default the closest six contacts are used as references for CD and contrast.
- If you click on a contact, that single contact is used as the reference. Click away from a contact or on the image edge to restore the automatic reference average of nearby contacts.
- Very faint contacts are not measurable because they are too small to print or detect.

5 Standard Measurement Operation Summary

- Put the defect to measure near the center of the image.
- Make sure that the reticle inspection tool is set to the proper magnification and default contrast and brightness.
- Enhance the image (using the [Zoom] and [Contrast] buttons) if the defect is difficult to see.
- Measure the defect, usually by clicking and dragging the mouse diagonally across it (see "The Different Defect Measurements" section for details on measuring each defect type).
- Check the “measurement image” for proper measurement.
- Retake measurement if needed by marking the defect more carefully,
- Or mark a reference image point if needed (when the profile doesn’t have flat baseline regions near both ends).
- Read the measurement off the screen.

5.1 Capturing and Enhancing the Image

- Click on the [Live Image] button.
- Click on the [Zoom] button, if necessary. Right clicking on the defect produces the same effect, and centers the image where you clicked.
- Click on the [Contrast] button to enhance an isolated defect. This is useful only on isolated defects: it has no effect on edge defects.

5.2 Measuring Defects

- Be sure that the Reticle Inspection System is set to the correct magnification and the default contrast and brightness.
- Be sure the desired calibration is selected.
- Mark the Defect: usually by clicking and dragging diagonally across it. Try to start and end in the middle of the defect’s edges. Doing this carefully will reduce the frequency of retries. (see "The Different Defect Measurements" section for details on measuring each defect type).
- The defect will appear, with a box drawn around it, in the “measurement image” in the lower left corner of the screen.
- The defect size is displayed in the boxes above the “measurement image” if it measured successfully. A record of the five most recent measurements is displayed below the “Current” size display.
- Use a reference image if needed: corner defects, or defects where the red box has a corner or angle in it.
    - Mark the defect as usual, but disregard the measurement.

  - Find a similar pattern and CLICK (do not drag) on the spot corresponding to the defect location in that reference pattern. The click tells the AVI that you're giving a reference position, not a defect to measure.
- Click on the [Rpt] (repeat) button to average several measurements to reduce noise.

5.3 Determining if a Measurement is Valid

After making a measurement check these things:

- Make sure that the blue box surrounds the defect you're measuring.
- Make sure that the red box lines up parallel to adjacent lines (if any).
- Make sure that the "difference Image" at the top of the "measurement image" looks like the defect you're measuring: usually just a dark or bright spot.
- Make sure that the profile displayed on the image looks like a bump on a flat line (the bump may go up or down), where the bump's width corresponds to the defect or linewidth. The baseline (outside the bump), should have at least a little bit of flat area on both sides. No flat area in the baseline is caused by features near the measurement area, corners or angles. Nearby straight lines won't cause confusion. If the blue and red boxes are ok but the profile is poor, a reference image should be used.
- If you're measuring with a reference image, then the "difference image" at the top of the "measurement image" should show just the defect. If other details show up with nearly as much contrast as the defect, then the measurement is probably not accurate. (The other details are contaminating the measurement).

5.4 Retaking an Invalid Measurement

- Retake the measurement, being more careful in marking the defect region. Try using the Zoom feature.
- If the red box is lined up wrong (not parallel to the adjacent line), click on the "Direction" menu and select the box direction that should be used.
- If there is too much clutter, use a reference feature: find a suitable reference, and then click on a spot that corresponds to the center of the defect that you're measuring.

5.5 After the Measurement

- Average multiple measurements to reduce noise: click on the [Rpt] button after a good measurement has been taken. The measurement will be taken the selected number of times with new images, and the mean, standard deviation, and range of the measurements will be displayed.
- Save measurement and image to database: Press F2 (or select "Database | Database Save") to display the “Save Measurement” screen, and click on “Save to Database”.
- Print a defect report: click the [Print Image] button.
- Send defect report via email: select "File | Send Defect Report”.
- Review images in the database: click on “Review”.

5.6 Testing with VeriMask and VeriThoro Masks

VeriThoro Masks (VeriMask x90: 690, 890, 1090, 1590) have a wide range of defects, beyond the usual spots, holes, edge defects, and linewidth defects. Here is how to measure them:

- When measuring VeriMasks, remember that most of the defects are square.
- A-D: Edge Defects: measure as described above.
- E-H: Corner Defects: measure a reference, use the VeriMaskMode, then measure the defects.
- I-L: Missing Chrome: same as corner defects.
- M-N: Contact Size errors: measure around the contact; Use the “Sqrt(Area)” display in the Defect Details screen.
- O-P: Contact Position errors: measure the “linewidth” between adjacent contacts.
- Q-R: Linewidth: Measure as described above
- S-T: Isolated defects: Measure as defined above. Note that 690 and sometimes 890 masks require you to take reference images first. Be sure to save the reference images so you can re-measure the images in the database.

6 Measurement Procedures

6.1 Getting the Best Measurements

- Defects near geometry (within about 0.5 micron) need a reference image, which is an image of a “correct” feature without the defect. That image may be a new one from a different region, (typically an adjacent die), or it could be the same image, using a similar, but non-defective feature.

- When measuring several defects with the same reference (as when measuring VeriMasks or doing a repeatability study on a singe defect), use the VeriMask Mode

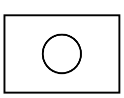
  To do this: mark the relevant spot in the reference image, ignore the measurement, and then turn this mode on. Now each time you mark a feature to measure it will use that specified reference image Note: this checkmark is enabled by the “Show Verimask Chk” item in the system setup menu.

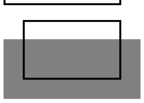
- With isolated holes or spots with no geometry nearby, there can be an issue of determining the actual system contrast. For example, an image with a totally isolated spot has the intensity of “full white” but not “full black”. In this case the AVI will use the most recently measured “full black” value.

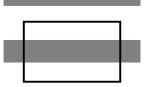
- Be sure that you have measured an image with significant chrome area recently (on the current mask). If not, you should move to a region with a chrome edge and measure it (ignoring the result). This will allow the AVI to measure the current intensity range. The intensity range is displayed in the bottom left of the screen, so you can see if there was any change.

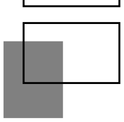
6.2 How the AVI Determines What You Want To Measure

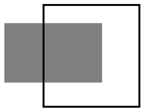
When you mark a region, the AVI uses the shape of the geometry in that region to determine the test to do.


Isolated defect or contact


Edge or edge defect. A square box requests a defect measurement


Linewidth or butting error, depending on selection at top

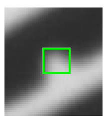

Corner radius: Geometry crosses two adjacent edges



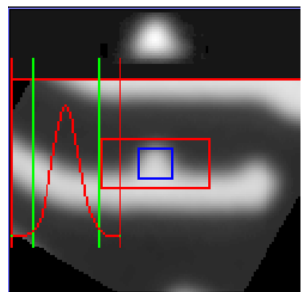
OPC: Geometry crosses one edge only

6.3 Spots, Holes, and Edge Defects

6.3.1 Measuring Defects



Marked Image



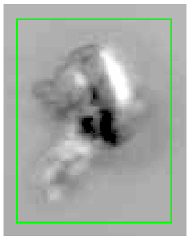
Measurement Image

- Mark the Defect by clicking and dragging diagonally across it. Start and end in the middle of the defect's edges. Do this carefully to reduce the frequency of retries.
- The defect will appear, with a box drawn around it, in the "measurement" image in the lower left corner of the screen.
- The defect size is displayed in the boxes above the "measurement" image if it measured successfully. A record of the five most recent measurements is displayed below the "Current" size display.

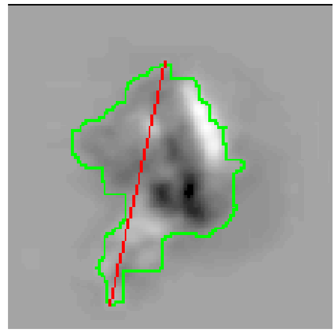
6.3.2 Using a Reference Image

- Use a reference image for defects near corners, or defects where the red box has a corner or angle in it.
- Mark the defect as usual (by clicking and dragging diagonally across it), but ignore the measurement.
- Find a similar pattern and CLICK (do not drag) on the spot corresponding to the defect location in this reference pattern. The click tells the AVI that you are giving a reference position, not a defect to measure.

6.4 Large Defects or Dirt



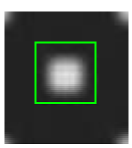
Marked Image



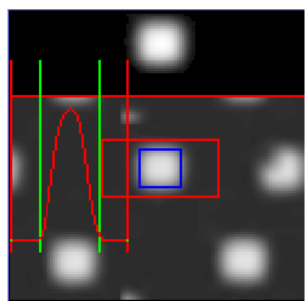
Measurement Image

Mark the defect as usual (by clicking and dragging diagonally across it). The perimeter of large defects (greater than 1 micron) are traced, and the maximum distance across the perimeter is measured and displayed. This is used for measuring large dirt particles, mostly on glass and pellicles. This measurement is not used for defects < 1 micron.

6.5 Contact Holes



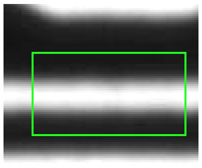
Marked Image



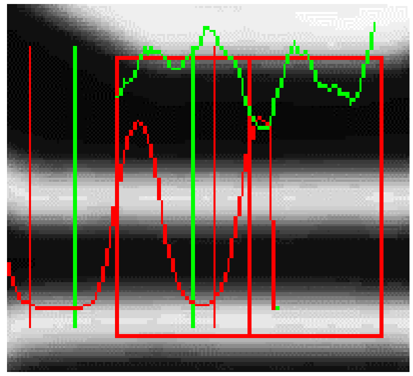
Measurement Image

Mark the defect as usual (by clicking and dragging diagonally across it). The defect size will be displayed above the “measurement image” - look at the "Sq" value below the "Dia" (Square Root of Area). This gives the effective size of square features, such as contact holes, VeriMask defects, or other defects designed to be compared to their edge-to-edge size.

6.6 Linewidth (Critical Dimension) and Line Uniformity



Marked Image

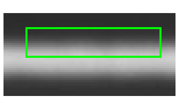


Measurement Image

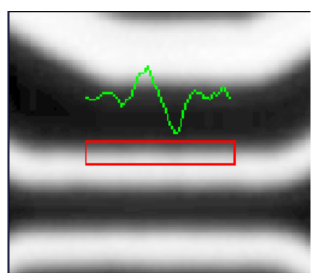
Linewidths (also called Critical Dimensions, or “CD”s) are measured by marking across the line. The average width in the marked area is calculated. Note that if one line is too close to another, then the reported measurement will be somewhat less accurate.

The linewidth uniformity is measured along the marked box. It is displayed as a standard deviation and a range. The linewidth profile is displayed on the measurement image in green. This helps you judge if a CD measurement is meaningful. For example, if the deviation in the area of the measurement is 30 nm, then the meaning of the least significant digits is questionable.

6.7 Edge Roughness / Edge Statistics



Marked Image

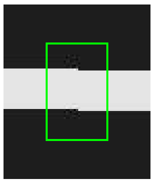


Measurement Image

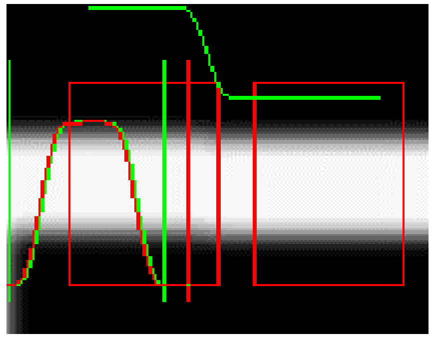
Mark a long segment of an edge. The roughness is measured and displayed as a standard deviation and a range, and the edge profile is displayed on the measurement image in green. The line must be exactly horizontal or vertical.

To measure an edge defect, make the box square. Although edge roughness offers another way to measure edge defects, the edge defect measurement’s “effective diameter” will correlate best to what prints on the wafer.

6.8 Butting Error and Line Position Uniformity



Marked Image

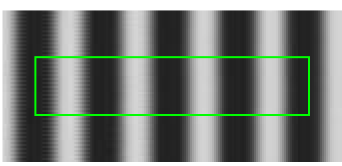


Measurement Image

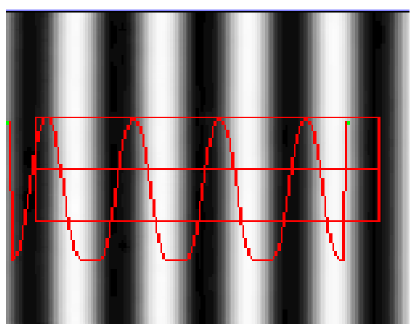
Select "Butting Error" from the drop-down selector above the main image, and mark the area around the butting error. When you select “Butting Error”, the two linewidth measurement boxes are offset by one “blur distance” (usually 0.5 or .036 microns), and the distance between their centroids is measured and displayed. The line must be exactly horizontal or vertical.

Butting error is the only measurement that requires selection, to distinguish it from linewidth measurement.

6.9 Pitch Measurement



Marked Image

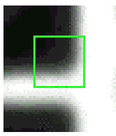


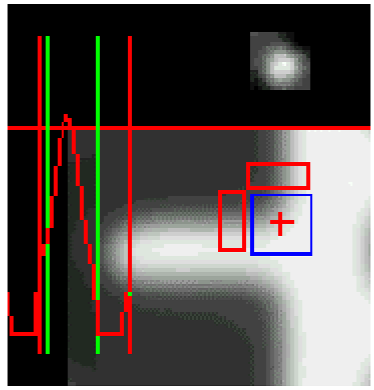
Measurement Image

Mark across several lines. The pitch (center-to-center spacing) between the lines will be measured and displayed. In addition, the width of the dark and clear parts are calculated based on the total (average) transmission, and displayed.

The pitch measurement is independent of mask processing parameters except scale, so it is frequently used to check system calibration.

6.10 Corner Radius



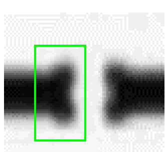


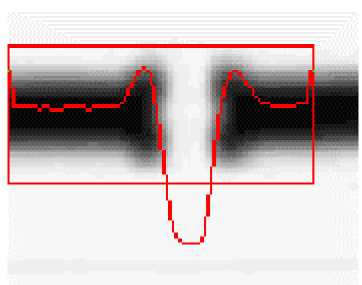
Marked Image Measurement Image

Mark a corner, and its radius and “missing area” are displayed. The actual light getting past the corner is compared to the amount expected from a perfect corner extrapolated from the edges. The top image in the measurement image is the difference between a perfect corner and the measured image after being blurred by the imaging system’s optics. Usually it appears as a simple blur because the radius of curvature is smaller than the blurring of the optics.

The difference is displayed as a radius or square root of the missing area. It is also displayed as the effective radius of the corner. If you then click on a “reference” corner, then the difference is simply displayed as an edge defect. (The absolute radius of a referenced corner can’t be calculated because the radius of the reference image is not known).

6.11 OPC (Optical Proximity Correction) Measurement



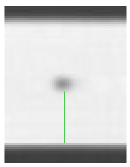


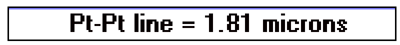
Marked Image Measurement Image

Mark around a line end with OPC Serifs. Three measurements are taken: 1) The “bulge area” - the area contained in the serifs - is displayed as an effective diameter; 2) The separation distance between the line end and the nearest line or line end. This is a flux-area measurement similar to linewidth, so it takes into account any kind of excess chrome or dirt; 3) Asymmetry, the net shift of the line end (up or down in this image) due to excess or missing chrome on one side. It is the distance the line end is shifted relative to the rest of the line, in microns.

To measure an OPC Serif on a simple corner, measure the corner, and use the corner radius measurement. That corresponds to the effective serif area.

6.12 Point-to-Point





Marked Image Sample Measurement Display

Point-to-point measurement is an assist for manual measurement. **Right** click and drag between the points to measure. The distance will appear in the box above the large image. The distance is corrected with the XY Ratio calibration.

7 Data Export, Reports, Database, and Image Files

7.1 Data Export

- **Copy Measurements to Clipboard (Ctrl-C)** Select “File | Copy Measurements”. The measurement history is copied to the clipboard. This is the easiest method to get measurements into a spreadsheet. Only the displayed measurements are saved. Use “Save Measurements to File” to save all the measurement parameters. If you do not have a spreadsheet program available, then paste the values into a text file using ‘Notepad’ or ‘WordPad’.

  Press ‘0’ to clear the history before each set of measurements. Click the “Average of …” label to change the maximum number of measurements in the history.

- **Save Measurements to File (Ctrl-V)** Select “File | Save Measurements”. You are prompted for a file name and then a data description. The measurement history is written to a CSV file for use by any spreadsheet program. This includes complete information for each measurement, including type, size, and intensity range.

- **Pixel Value Report (‘v’)** Select “View | Pixel Values”. The current measurement, intensity range, and pixel values inside the measurement box are saved to the clipboard. If you have a copy of AVI’s DATALOG.EXE program in the C:\Photo32 or the C:\Windows directory, then Datalog will be displayed, and you can save the data to a text or CSV file. Datalog.exe is provided with its simple Visual Basic (VB) source code so that you can quickly customize it to your needs. Customization typically takes 15-60 minutes for a someone who has used VB before. The executable and source are available from the AVI website: http://www.aviphotomask.com/datalog.zip This file is 10 KB, including executable and source.

7.2 Defect Report

The Defect Report contains both large and measurement images, the inspection summary, and the detailed measurements.

- **Printing the Report**: Click the [Print] button on the "Main" screen or select "File | Print". For printer setup, select "File | Printer Setup".

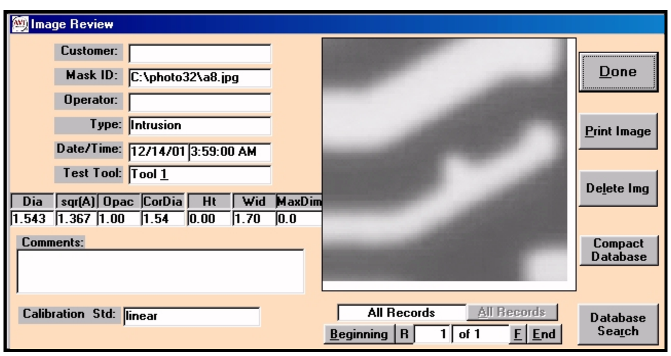
- **Sending the Report via E-mail**: Select "File | Send Defect Report", and a screen capture will be put in your mailer, ready for you to type in the address and a comment. This requires that the AVI system be connected on your network and that your company's mail program is installed on the AVI system.

7.3 Database: Save, Search, and Output Data

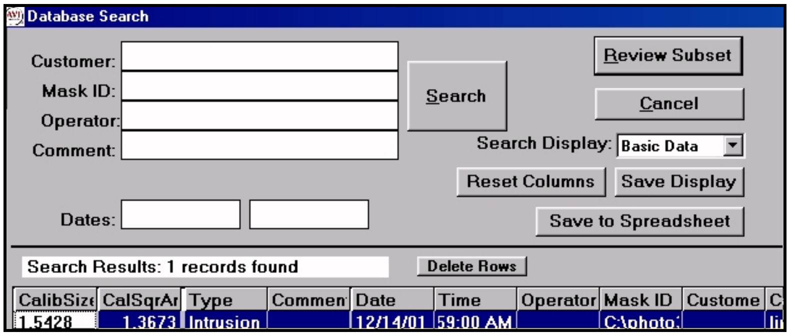
The AVI system includes a defect database which allows you to save defect images and their measurements for later review and statistical analysis.

- **Save a measurement to the database**: press [F2] or "Database | Database Save" to bring up the database save screen. Enter your comments and press [Save to Database]. Note that this box will come up automatically after each measurement when the [Database | Database Auto-Save] is checked.

- **Move through database**: Press the [Review Images] button to see the Review screen. Press the [f] key to move forward quickly, and press the [r] key to move in reverse quickly. You can also press [b] to move to the beginning of the database, and [e] to move to the end.



- **Search Database**: On the Review screen press the [Database Search] button. Enter any search parameters you want in the left side, and press [Search]. Select the data types to display in the "Search Display" selection box (Basic Data, All Data, Calibration Data, or Custom Data). You can modify any display by dragging the line between columns in the title row, and pressing the [Reset Columns] resets the display to its default. You can save your modification for reuse by pressing [Save Display].



- **Save selected database data to Excel file** (CSV format, readable by any spreadsheet program). Display selected data in the "Search" screen (see above). You can now save the display to a spreadsheet file by pressing [Save to Spreadsheet]. You will be prompted for the file name and location When reading this file into a program such as Excel you may need to specify the file type as "CSV". Usually you can just select "all files" and Excel will recognize the CSV format.

- **Printing database image and information**. In the 'Review' screen, click the [Print] button.

7.4 Saving and Recalling Images

- **Saving Images to Disk**: Select "File | Save Image File", or type Ctrl-S. You will select the image type (JPG is the most compressed format, thus easiest to copy to floppy. The compression will not detectably affect images from Reticle Inspection Systems). Then give the image a filename.

- **Recalling Images from Disk**: Select "File | Open Image File", or type Ctrl-O. This allows you to read in an image that wasn't saved to the database. Note that if the image is from another system, the calibration may be incorrect.

8 Setup and Troubleshooting

8.1 Hardware Connections

8.1.1 Standard computer connections:

- Monitor, keyboard, mouse, and power. These are the same as with any PC. Be sure that the voltage switch on the back of the computer (and sometimes the monitor) is set properly to 120V or 220V. If there is any doubt, start at 220V.

8.1.2 Video Input.

- Standard NTSC or RS-170 video is received from the inspection tool via a BNC coax cable.
- The cable connects directly into the BNC connector on the AVI PC.
- On KLA Terastar and Lightning, tools take the signal off the video filter box. Four of the five outputs are connected to the monitor (3 RGB plus "Sync"). The signal to AVI is "T"ed from the one remaining output.
- On ETEC Aris-I tools, take the video out from the video monitor.
- If an older KLA has a video output connector on the back panel, use that. If not:
    - Connect a BNC ‘T’ to the video input going through the bulkhead to the Sun. There are 2 BNC’s going through that panel: The thin one is the video. They’re both labeled. This cable is often accessible at the back of the main chassis. On some units the cable is accessible inside the lower center panel at the back.
    - Route the video cable: If the AVI will be on the right side of the KLA, then open the right side door too and thread the cable across the floor of the KLA.
    - Use 3-5 cable ties inside the KLA to attach the cable neatly to the chassis.
    - In most cases you will run the cable out the door, where it will get slightly pinched. Sometimes you can find a hole to run it through.

8.1.3 Ground Transformer

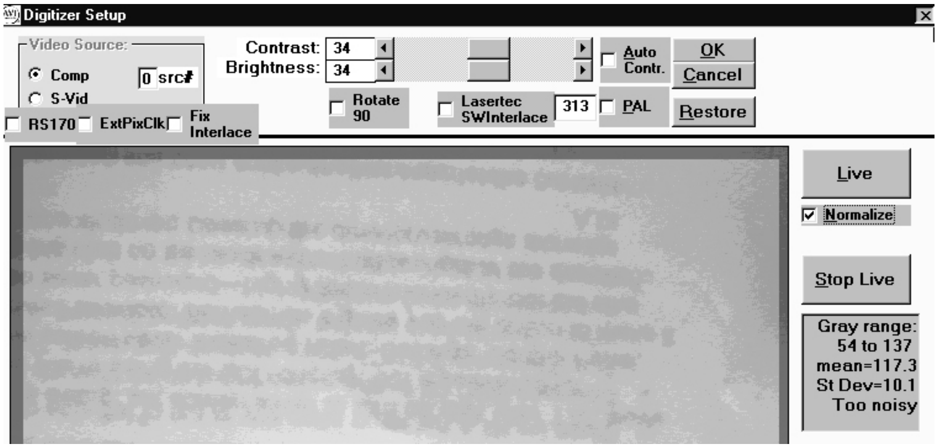
- In many cases a Ground Isolation Transformer is required (if there is too much noise on that input due to a long ground loop between the AVI and the inspection tool). This can be seen in the “Digitizer Setup” screen. When the “stdev” value is above 1.5, with a uniform image, and a small (1/2”) active area, then you should consider using a ground transformer.
- Ground transformer connection: The signal is passed through the ground transformer using a short cable. Either connection on the ground transformer can be input or output.

8.2 Computer Setup

- Make sure there is a Photo32 icon on the desktop.
- Copy the Photo32 icon to the Start | Programs | Startup folder.

- Set the computer's display properties to 800x600 or 1024x768, and 24, 32, or 16 bits/pixel (in that preference order). Using higher resolution makes the text and images too small for most users.

8.3 Digitizer Setup



8.3.1 Select “File | Digitizer Setup” or [Ctrl-D].

8.3.2 Display a mask edge near the center of the image, with large clear and chrome areas. On KLA systems, be sure the system is in review mode because alignment mode uses different video levels.

8.3.3 Click on [AutoContrast], and wait for the contrast and brightness controls to stop changing. The Gray range should end up around 16-240.

8.3.4 Click [OK] to save this setting.

8.3.5 You will need to enter the system password, “camera” after you click on [OK]. The password will remain active for the next 30 minutes, or until you quit out of the Photomask program.

8.3.6 Note that the image will display light blue where the digitizer is overflowing. If you see blue or yellow areas in an image during operation you should return to the Digitizer Setup screen and click on [AutoContrast] to adjust the contrast.

Restore allows you to recall the hardware standard, or previous contrast and brightness values.

Video Source is normally set to Comp. src# 0.

Rotate 90 rotates the live image 90 degrees. This is used for Lasertec and Nikon systems.

PAL and **Lasertec 9MD83** are normally off. PAL is enabled for Lasertec systems, and Lasertec 9MD83 is a software interlace designed for old Lasertec systems.

8.4 Field Correction Procedure:

1. **Decide if field correction is required**: Laser scan systems (KLA and Lasertec) don't require field correction. Camera based systems, such as the ARIS-I and CD microscope systems usually require field correction. Find a clear field of view on a mask. Press Shift-F for high-resolution false color. Normally the image will be a uniform color. If you can easily see regions where the color shifts (typically brightest in the center of the image), then field correction will be required. Perform the following steps:
2. **Take a bright field image**. Use the clear field you found in step 1, and select "Calibrate | Field Correction | Take Bright Field Image" or Ctrl-F7. The software will average images for 12 seconds and then save and display the correction image.
3. **Test the correction**. Press F7 to capture a new image and correct it. View it in false color—it should be totally uniform. If not, capture a new image (Ctrl-F7) and try again.

8.5 Other Setup Parameters

Tool Name: Tool name. Displayed on main screen if there are multiple calibrations, and saved in database and defect report.

Instructions: Reminder information. Typically "4x2700 Transmission" for KLA3xx at 4x. Displays above the main image.

Target Dia (microns): List of diameters of circular targets (in microns, using Pixels per Micron value below. For concentric circles, separate values by commas (for example, "4,10,15"). Some installations on Nikon inspection tools use target circles, to help the operator position a defect in the same position each time. To enable them, enter a value, such as "2" in this entry and then check the "display target" check box on the main screen, below the "measurement image". Then click on "Live".

Smoothing: Smooth image: set to 4 for KLA 4x Electronic Magnification. Set to 1 for other tools without “electronic magnification”. On Lasertec systems, set to 2 to reduce the affect of the edge enhancement used in those systems.

Pixels per Micron: Scale factor. Used to convert computed pixel sizes into microns. The second parameter, "height" is normally set to .5, larger values (.8) are used with very low magnification, around 7 pixels/micron.

XY Ratio: Ratio of scale factors in X and Y directions. Normally set close to 1.0. The XY ratio will vary from 1.0 if the source video signal timing is not exactly the NTSC or PAL standard. Most easily set in the “Linear Calibrate” menu. Values of 1.02 to 1.05 are common on KLA installations.

Blur Microns: Amount of blurring in image. Usually 0.5 or 0.36 microns, according to illumination wavelength. Primarily affects "red box" size. Second parameter specifically adjusts the red box height. Always set to 0.5 unless image quality is very poor. Third parameter is used to optimize dense line measurement.

Blur Pixels: Used in opacity correction and XY measurement. This is set with the “Calibrate | Opacity” command after measuring a 0.3-0.5 micron chrome defect. The defect size should be within 0.2 microns of the illumination wavelength. This is approximately equal to Blur-microns times Pixels per Micron.

 # Frames to Average: Average images to reduce noise from vibration and noisy images. Usually set to 10. The averaging occurs at 30 frames/second, so averaging 15 takes 0.5 second. You may want to increase this when measuring very small defects, or suffering from severe vibration.

Guard Band: Amount added to defect measurements. Used to assure that no overspec defect is passed due to mis-measurement.

Spec: Min. Iso. Dist: Used with "Show Specs" below. Determines when a defect is considered “isolated” instead of “edge”. Defects farther than this from an edge are considered "isolated" for Show Specs assessment. Size is in microns.

Show Specs: Display pass/fail sizes on the main screen. Both edge and isolated defects sizes may be set.

Show Height: Display computed height and width on the main screen.

Show Opacity: Display computed opacity and corrected height on the main screen.

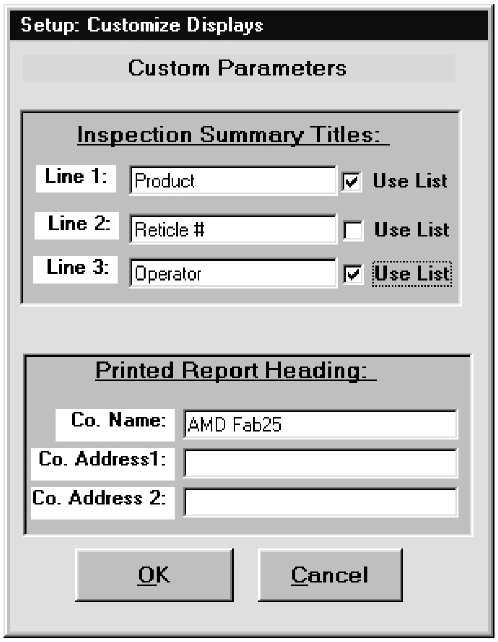
Full Menus: Display Review shortcut menus, plus non-linear calibration items.

Field Correction: Display field correction options in Setup menu.

Right Half Only: Only display the right half of a live image. For KLA3xx with database image on the right side only.

Show VeriMask Chk: Show VeriMask Mode checkbox on main screen.

Customize: Displays "Custom Parameters" screen. Enter company information for printed defect report, and titles for each line in the Inspection Summary box and in the defect report.



8.6 Trouble Shooting and Diagnostics

No image from the inspection tool (KLA or other).

- Check all video connections, try swapping cables. 90% of video problems are caused by bad connectors.
- Run the test program, "C:\Flashbus\FBG\FBG32.exe". If you see an image here, but not in Photo32, then check the Digitizer Setup.
- If the video connections are good and even FBG32.exe doesn't show an image, then try swapping the video capture board (Contact AVI).

Can't see dim holes, even when using "contrast" command.

- Increase the brightness of the AVI monitor.

Measurements are erratic.

- Make sure you are marking the defects correctly.
- Make sure that the Reticle Inspection System contrast and brightness are set to their defaults.
- Make sure that the RIS is operating at the proper magnification and that the Pixels per Micron is correct in the System Setup.

Measurements have started coming up wrong.

- Check that magnification is correct
- If a maintenance operation was performed on the inspection tool, then AVI may need recalibration.
- Make sure that the contrast and brightness on the inspection tool are being set to “normal” for all measurements.

Error message comes up on the AVI screen or the computer hangs (doesn’t respond).

- Ignore it: press [OK].
- Reboot the computer. Win98 should be rebooted at least weekly.
- If it returns consistently, then reboot the computer. If it still comes up consistently, contact your local PC maintenance team.
- If your PC expert says the PC is ok, then contact AVI.

9 Installation and Calibration Procedure/Checklist

9.1 Parts List

- AVI PMS Computer with software security key
- Monitor (or monitor switch box and cables if multiplexing existing monitor)
- Keyboard, mouse, power cord for appropriate country.
- Printer (if purchased)
- CCD Camera (KLA-219, DRS, Nikon AM6, plain video)
- User Manual, plus training page on cleanroom paper
- Video isolation transformer
- Video cables: 75 ohm:1’, 3’, 10', 15’
- BNC barrel connectors (2), BNC 'T' connector
- S-Video to BNC cable if 2 camera inputs (KLA-219, DRS, plain video)
- Backup floppy disks
- AVI Tool Kit
- Small monitor for adjusting focus & rotation (KLA-219, DRS, plain video)

9.2 Installation Procedure

- **Install computer**, monitor, keyboard, mouse, make sure it starts
- **Install camera** (KLA-219, DRS, Nikon AM6, plain video): gain/offset range should be 16-240 +/- 10. Nikon AM6: adjust focus (Typical adjustment is to screw on just one thread, with out the 5mm C-mount extender), rotation.
- **Load a VeriMask** plate into the KLA or other system, get it to “review mode”.
- **Connect the video cable and Video isolation transformer** as described in the section on hardware setup.
- **Adjust digitizer gain** with image of an edge, in review mode.
- **Take Bright field image.** For Aris-I and microscope based systems only.
- In the **System Setup** screen, click on the setup for the inspection tool, type in the machine name, verify the “Instructions”, and customize the displays ([Customize] button). See "Other Setup Parameters" for details.
- **Validate calibration using lines of known pitch**.
- **Set up non-linear calibration as needed.**
- Perform **Opacity Calibration:** Measure a 0.4-0.6 micron defect, then select “Calibrate | Opacity Calibration”
- Perform **repeatability test**: 20 measurements of a 0.3 - 0.4 micron defect. One sigma deviation should be .002 micron (2 nm) or less (1.2 nm is expected). Try increasing # of images to average in the system setup menu if deviation is too high. To change the # of measurements included in the

measurement statistics, click on the “Average of __” label and enter a new number.

- **Complete Windows setup**: Set a password for Windows and/or the screen saver if desired (Start, Settings, Control Panel, Passwords, Windows Password. Sometimes it gives you the option to make it the same as screen saver password—highly recommended!). Set the time and time zone (double click on the clock at the bottom right of the desktop). Remove NetBeui network driver, clean up the desktop, remove icons for network services.
- **Backup calibration**: keep one copy, make another copy for the customer.
- Acceptance testing: measure all the edges, spots, holes in a VeriMask. Compare to design size. Demonstrate repeatability on defects bigger than .2 micron.

9.3 Training Procedure/Checklist

Each of these items is explained in the manual.

- Digitizer setup
- Field Correction: Only for Aris-I and camera-imaged systems.
- Linear Calibration, using known pitch
- Perform Measurements
  - Spot, Hole, and Edge Defects
  - Spot, Hole, and Edge Defects using a Reference
  - Large Defect or Dirt
  - Contact Hole
  - Linewidth / CD
  - CD Uniformity
  - Edge Roughness
  - Pitch Measurement
  - Corner Radius
  - Butting Error and Line Position Uniformity
  - Point to Point
- Non-linear Calibration
- Save and Restore Calibration backup to floppy
- Measurement Statistics
- Use the defect database: save, review, search, output to Excel file

10 New Features

10.1 Version 4.0 July 1, 2002

10.1.1 Stepper Simulator.

10.1.2 Improved non-linear calibrations: added corner and separate X- and Y-linewidth calibrations

10.2 Version 3.2; June 30, 2001

10.2.1 Save Measurements to Spreadsheet. You can quickly save data to a spreadsheet: after a measurement you can save the history of measurements (3 or 5 or whatever you have it set to) to a CSV (comma separated values) spreadsheet file using the File | Save Measurements (Ctrl-M) command.

10.2.2 Pixel Value Display. The intensity under the cursor is displayed in a box below the left corner of the main image.

10.2.3 Improved Contact Statistics. The contact offset and area loss is displayed along with the contact size above the measurement image. When the variation of reference contact sizes is above 3%, a yellow warning message is displayed.

10.2.4 Vibration Tracking. Vibration in the live image is tracked and reduced. This also operates during image averaging before taking a measurement. This can be disabled by setting the “Align Pixels” value in the extended setup menu to zero.

10.3 Version 3.1; March 15, 2001

10.3.1 View menu This provides options for viewing pixel statistics in the selected region, viewing the image with contrast normalized in the region, or in false color. Also provides a command to turn off the yellow warnings that intentionally obscure the measurement image. Each of these commands has a key for easy access: "s" for statistics, "n" for normalize, "f" for false color, "y" for turn-off-yellow message.

10.3.2 Reference Menu Allows you to mirror or rotate the image, especially for aligning a corner for use as a reference. The "Restore" command is used for restoring the original image, especially after field correction of saved images

10.3.3 Non-linear calibration menu Allows you to set up a SEM correction or other more complicated correction. A button is visible above the measurements when there is a correction set up. Clicking that button will toggle the correction on all the visible values. Use Calibration | Non-Linear Calibration to set up the correction. See the help in the screen.

10.3.4 Contact Position and Statistics. Selectable from the drop down measurement type menu. When selected a larger region is analyzed, allowing a contact's size and position to be compared to the ones around it. The relative area and offset compared to the contacts around it, or a reference image are displayed in the box above the main image. The statistics of the surrounding contacts (Area range and standard deviation) is displayed in the box below the main image.

10.3.5 Isolated Defect Distance from edge. When an isolated defect is within 1 micron of an edge the distance from the center of the defect to the edge is displayed in the box below the main image. Note: edge-to-edge distance is not used because the edge of a small defect (compared to the wavelength of the illumination) is not really measurable.