Operations Manual

for the

R50

Automated Resistance Mapper

Revision 1.2.1.0

Welcome

What is the R50 used for?

The Filmetrics R50 is used to measure the sheet resistance of conductive and semi-conductive films using either a contact (4PP) or non-contact (EC) method. The standard automated X-Y stage allows for easy mapping of sample surfaces and can make measurements as quickly as one point per second. Samples up to 300 mm in size can be measured, over an area up to 200 mm (-200 model required for larger samples).

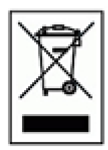
Commonly measured films include various semiconductor substrate materials such as wafers, glass, and plastic substrates, as well as PCB patterned features, solar cells, flat panel display layers and features, and metal foils.

Warning: Accurate measurements require suitable recipe settings. Improper system setup may lead to errors. It is the user's responsibility to ensure this instrument is being used properly andfor its intended purpose. Please contact Filmetrics support for assistance with any questions.

Safety, Maintenance, and Care

This symbol indicates information or instructions that must be read and carefully followed to prevent hazards, injury to the operator, or damage to the instrument.
Ce symbole indique des informations ou des instructions qui doivent être lues et suivies attentivement pour éviter les dangers, les blessures de l'opérateur ou les dommages à l'instrument.

This symbol indicates a potential shock hazard. Areas marked with this symbol should be serviced by a trained service technician.
Ce symbole indique un risque d'électrocution. Les zones marquées de ce symbole doivent être réparées par un technicien de maintenance qualifié.



This symbol indicates that the product conforms to the WEEE (Waste in Electrical and Electronic Equipment) Directive 2002/96/EC. For further details contact:
Ce symbole indique que le produit est conforme à la directive DEEE (Déchets dans les équipements électriques et électroniques) 2002/96 / CE. Pour plus de détails, contactez:

Filmetrics Europe GmbH
Hauptstr. 42
82008 Unterhaching
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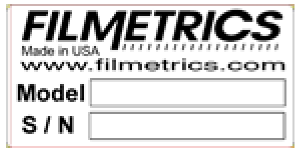
This symbol indicates that the product meets the applicable EU safety, health and environmental protection directive requirements.

Ce symbole indique que le produit est conforme aux exigences de la directive européenne en vigueur sur la sécurité, la santé et la protection de l'environnement.



This label indicates the Model Number and Serial Number of the instrument. This information may be necessary when contacting Filmetrics for assistance.
Cette étiquette indique le numéro de modèle et le numéro de série de l'instrument. Ces informations peuvent être nécessaires lorsque vous contactez Filmetrics pour obtenir de l'aide.

Disclaimer: Use of this instrument in a manner inconsistent with the information and directions included in this manual may impair the product's built-in protection resulting in danger to the operator or damage to the instrument.
Clause de non-responsabilité: L'utilisation de cet instrument d'une manière non conforme aux informations et aux instructions incluses dans ce manuel peut altérer la protection intégrée du produit, ce qui peut entraîner un danger pour l'opérateur ou endommager l'instrument.

Disclaimer: Protective Personal Euipment (PPE) provided with this tool must be used in accordance with the instructions provided by the supplier. Failure to do so may result in danger to the operator.
Clause de non-responsabilité: l'équipement de protection individuelle (EPI) fourni avec cet outil doit être utilisé conformément aux instructions fournies par le fournisseur. Le non-respect de cette consigne peut entraîner un danger pour l'opérateur.

Installation Location: Install the instrument in a well-ventilated location. Enclosing the unit or blocking the vent holes may impair the performance of the instrument or damage the internal components.
Emplacement d'installation: installez l'instrument dans un endroit bien ventilé. Le fait de fermer l'appareil ou de bloquer les orifices d'aération peut nuire aux performances de l'instrument ou endommager les composants internes.

Cleaning: Periodically clean the system based on the cleanliness of the environment in which the system is installed. Only the external surfaces should be cleaned. Cleaning and maintenance of all internal components is to be performed by a trained service technician. Do not use aerosol or spray cleaners as they may contaminate the sensitive optical surfaces on the instrument.
Nettoyage: nettoyez périodiquement le système en fonction de la propreté de l'environnement dans lequel le système est installé. Seules les surfaces externes doivent être nettoyées. Le nettoyage et la maintenance de tous les composants internes doivent être effectués par un technicien de maintenance qualifié. N'utilisez pas de nettoyants en aérosol ou en aérosol car ils peuvent contaminer les surfaces optiques sensibles de l'instrument.

Disconnect the main power before performing any service on the instrument.
Débranchez l'alimentation principale avant d'effectuer tout entretien sur l'instrument.

Cleanroom or low lint wipes should be used to wipe down the system. A mixture of Isopropyl Alcohol (IPA) and De-ionized Water (DI H_2O) at 70% DI H_2O: 30% IPA should be used for cleaning. Undiluted IPA may be used, if the 70:30 DI and IPA mixture is not available, but extra care must be taken. Avoid using stronger solvents such as acetone, as these may compromise the surface finish.

Avoid excessive pressure on any surface when cleaning. Excessive force may bend a component which would damage the system or cause the system to be out of alignment.

When cleaning, start with the top of the system and work down. Use slow motions, in a straight line, from the back to the front of the surface being cleaned. Change the cleaning wipe periodically to avoid re-depositing material back onto the surface being cleaned. Allow all cleaned surfaces to dry completely before restoring power to the system.

Une salle blanche ou des lingettes peu pelucheuses doivent être utilisées pour essuyer le système. Un mélange d'alcool isopropylique (IPA) et d'eau désionisée (DI H2O) à 70% DI H2O: 30% IPA doit être utilisé pour le nettoyage. L'IPA non dilué peut être utilisé si le mélange 70:30 DI et IPA n'est pas disponible, mais des précautions supplémentaires doivent être prises. Évitez d'utiliser des solvants plus puissants tels que l'acétone, car ils peuvent compromettre la finition de la surface.

Évitez toute pression excessive sur toute surface lors du nettoyage. Une force excessive peut plier un composant, ce qui endommagerait le système ou provoquerait un désalignement du système.

Lors du nettoyage, commencez par le haut du système et descendez. Utilisez des mouvements lents, en ligne droite, de l'arrière vers l'avant de la surface à nettoyer. Changez périodiquement la lingette de nettoyage pour éviter de re-déposer le matériau sur la surface à nettoyer. Laissez sécher complètement toutes les surfaces nettoyées avant de remettre le système sous tension.

CE Mandated Warnings

Please read the following instructions carefully to prevent potential shock or fire hazards. This manual should be retained for future use

Bitte lesen Sie die nachstehende Anleitung sorgfältig durch, um Stromschlag und Feuergefahr zu vermeiden. Diese Betriebsanleitung soll für späteren Gebrauch sorgfältig aufbewahrt werden.

Preghiamo di leggere accuratamente, le sequenti Instruzioni, per evitare Prossiomi Incendi e Correnti.

Shock Hazard - Do Not Enter
Achtung Hochspannung - Nicht Berühren
Attenzione Corrent-Forte - Prego non toccare

The power cord should be removed after use.
Das Stromkabel soll nach Gebrauch aus dem Gerät herausgezogen werden.
La Corrente viene.

Never expose the unit to water or liquids. Avoid direct sun.
Bringe das Gerät nicht mit Wasser oder anderen Flüssigkeiten in Berührung. Vermeide direkte Sonneneinstrahlung.
Evitare contatto con acqua oppure liquidi Infiammabili al Macchineggio. Auche entrate di Sole.

Do not insert any objects into the unit.
Keinen Gegenstand in das Gerät einbringen. Do non inseriamo any obietta into gli unità.
Non mettere ogetti dentro la Macchina.

Do not use near open flame or heat.
Das Gerät nicht in der Nähe einer offenen Flamme oder Hitze benutzen.
Non mettere la Macchina vicino a fuochi oppure Riscaldamenti.

The unit should never be enclosed or blocked.
Das Gerät darf nicht eingeschlossen oder blockiert werden.
La Macchina non chinderla per nessun motivo.

Connect unit only to a properly measured supply with a reliable earth ground. Use only the which is provided with the unit.
Schließen Sie das Gerät nur an eine ordnungsgemäss vermessene Stromsversorgung an. Verwenden Sie nur ein , wie es auch mit dem Gerät ausgeliefert wird.
Montare solo con misura normata. Adoperando solo cosi come e fornita la Macchina.

Table of Contents

1. Software Overview

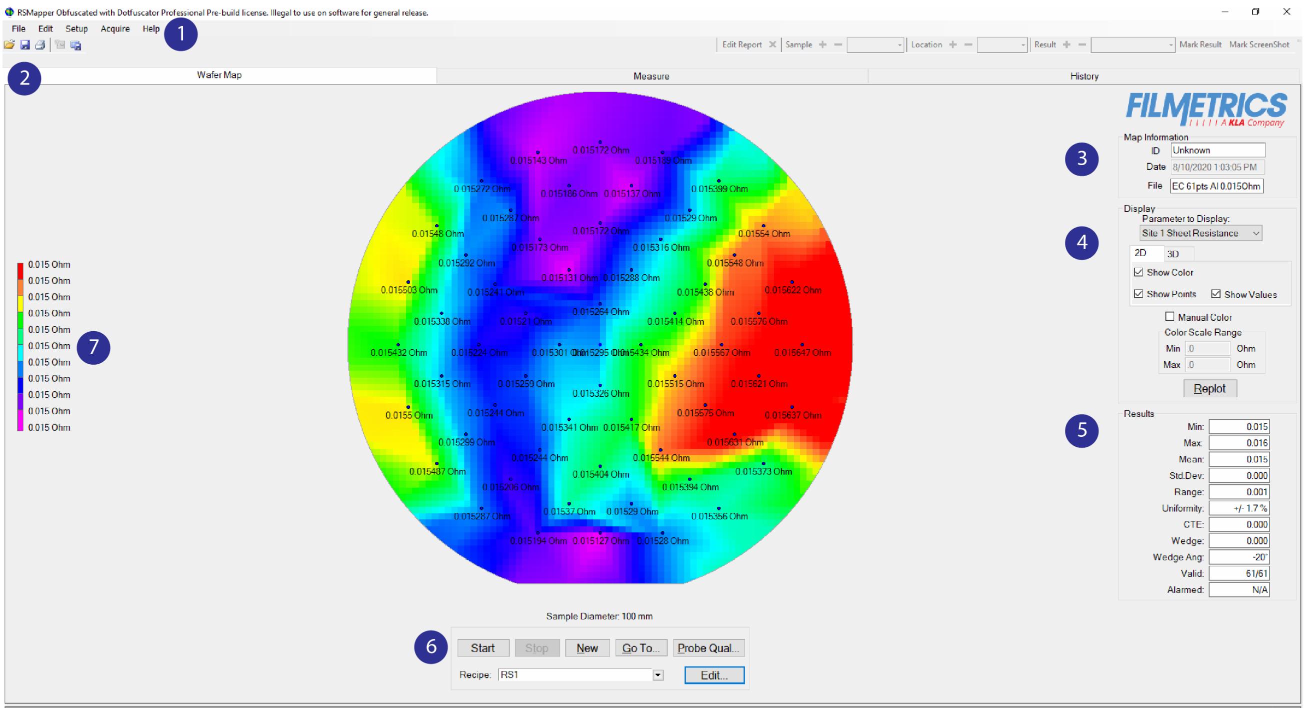
Sheet resistance is the resistance of a square sheet of material of arbitrary size. It is designated as Rs, and measured in units of Ohm/sq. The R50 is measures sheet resistance of a sample directly, either by four-point probe (R50-4PP, R50-200-4PP), or by eddy current (R50-EC, R50-200-EC).

For four-point probe systems, this analysis is made by bringing the probe in contact with the sample and measuring the voltage drop between a current supplied from the outer pins.

For eddy current systems, this analysis is made by measuring the induced eddy currents from the sample surface when a time varying current is passed through a probe coil.

Most of the features of the R50 operation software - RsMapper - can be divided into data acquisition and data analysis functions. The following pages outline the main features of the RsMapper software.

1.1 The Wafer Map Tab



1. Standard menus: **File**, **Edit**, **Setup**, **Acquire**, and **Help.**

2. Select between the **Wafer Map**, **Measure**, and **History** windows.

3. Information about the *Operator* can be entered here for tracking purposes.

4. This section is used to determine how the map is displayed. The **Replot** button will enact any changes selected.

   i. **Parameters to Display**: Allows the user to select which parameter (Rs, Ra/Rb, Ra, Rb) to display on the map. Only parameters currently being solved will be listed.
   ii. **2D/3D**: Allows the user to select between two-dimensional and three-dimensional maps.
   iii. **Show Color**: Enables or disables the color bar on the left-hand side of the map.
   iv. **Show Points**: Enables or disables display of the measured points on the map.
   v. **Show Values**: Enables or disables display of the measured values at each point.
   vi. **Manual Color**: Allows the user to input a manually selected color scale.

5. Statistical analysis for the set of measurements taken.

   i. **Min**imum parameter value recorded for selected wafer, xmin.
   ii. **Max**imum parameter value recorded for selected wafer, xmax.
   iii. **Mean** (average) parameter value of all measurement locations.
   iv. **Std.Dev.** (Standard Deviation), or 1σ, is calculated using the following equation: $= \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$

where $\bar{x}$ is the mean and *n* is the number of measurements.

v. **Uniformity** as a percentage. The equation used in the uniformity calculation is determined under Setup > Options > Map.

vi. **CTE** is the center-to-edge thickness variation calculated using a least squares linear fit of the average thickness of 10 radial regions. If the CTE is positive (> 0), then the thickness is greater around the wafer edge. If the CTE is negative (< 0), then the thickness is greater near the center of the wafer.

vii. The **Wedge** value is the product of the slope at the angle specified by the **Wedge Angle** and the sample diameter (for rectangular samples the length of the longest edge is used in place of diameter).

viii. The direction of maximum positive slope (increasing measured values) is given by the **Wedge Angle** where x=1, y=0 is 0° (3 o'clock) and x=0, y=1 is 90° (12 o'clock).

ix. **Valid** indicates how many locations have valid results out of the total number of measurement locations based on the minimum valid GOF set under **Alarms** in the recipe.

6. These options control the wafer map process.

i. **Start** or Restart the mapping cycle. Not available if there is no valid baseline or a map in progress.

ii. **Stop** the mapping cycle.

iii. **New** clears the measurement results and displays the points to be measured as determined by the settings in **Edit Recipe > Wafer Map** tab.

iv. **Go To** a specified location on the wafer.

v. **Reanalyze** the current map if the recipe has been changed or a new recipe has been selected.

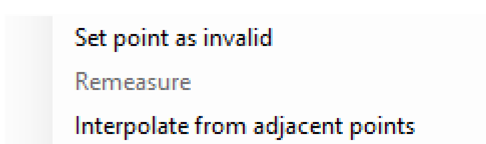
vi. **Probe Qual**

vii. Select previously saved recipes from the drop-down menu.

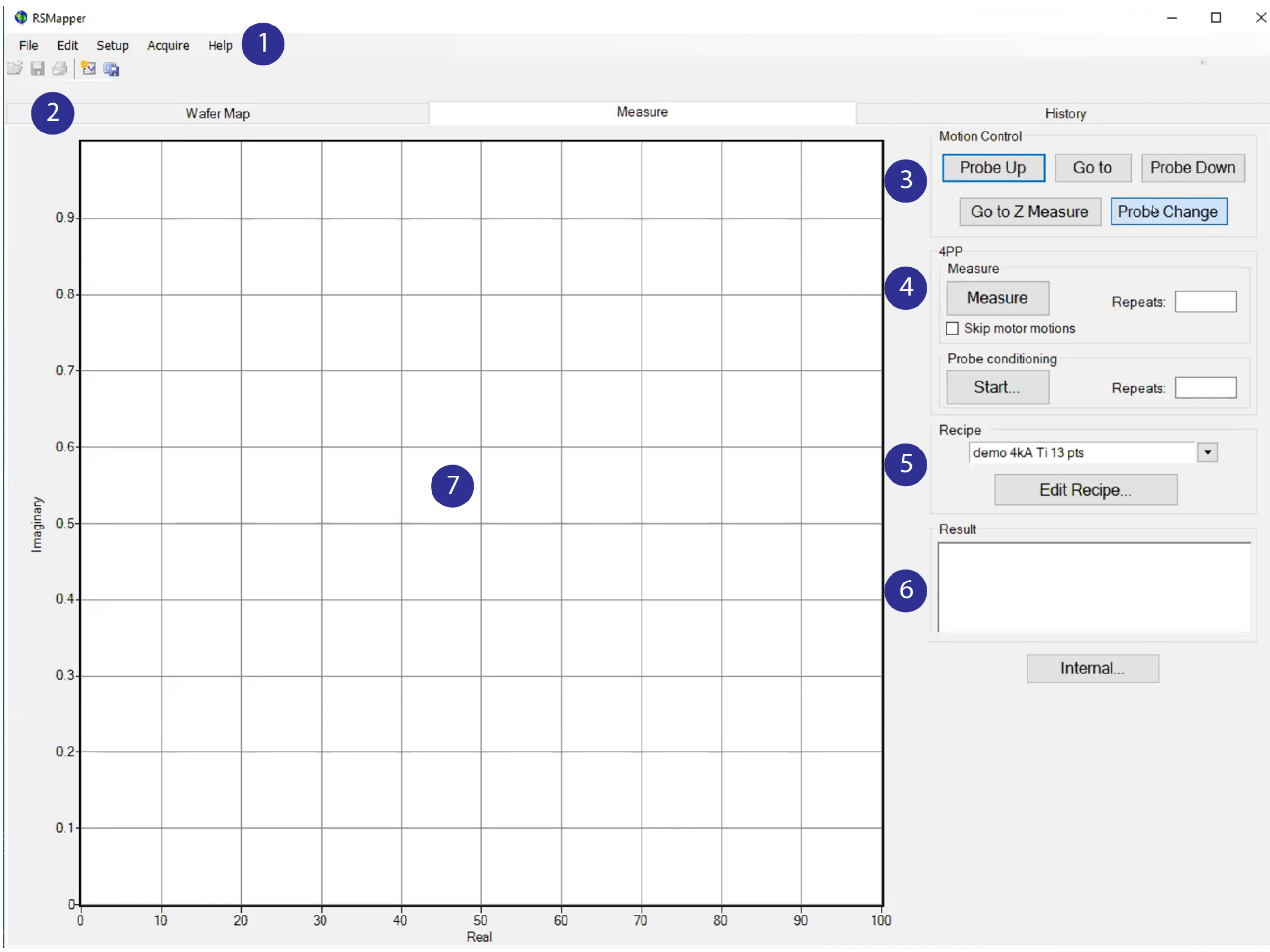
viii. Opens the **Edit Recipe** window.

7. Graphical display of the wafer with points of measurement as well as a color scale for thickness summary.

Based upon the options selected, left clicking on a point will either move the stage to that exact location or the nearest point on the map. Right clicking opens the following menu, which allows you to either mark a currently measured point as invalid, remeasure an individual invalid point using the current recipe, or interpolate the value of an invalid point using adjacent values.



1.2 Measure Tab



1. Standard menus: **File**, **Edit**, **Setup**, **Acquire**, and **Help.**

2. Click on these tabs to select between the **Wafer Map**, **Measure**, and **History** windows.

3. Controls the motion of the stage and the probe head.
   i. **Probe Up** lifts the probe away from the stage.
   ii. **Go To** provides motion controls for the stage and measurement head.
   iii. **Probe Down** brings the probe down into measurement position.
   iv. **Go To Z Measure** brings the probe to a preset height for measuring the sample. Set this value via **Z Height Measure Calibration**.
   v. **Probe Change** moves the head up to allow easier access for changing out the connected probe.

4. **Measurement Controls**. Available controls will be dependent on the measurement mode available (4PP or EC). See **Making Measurements** for further information.

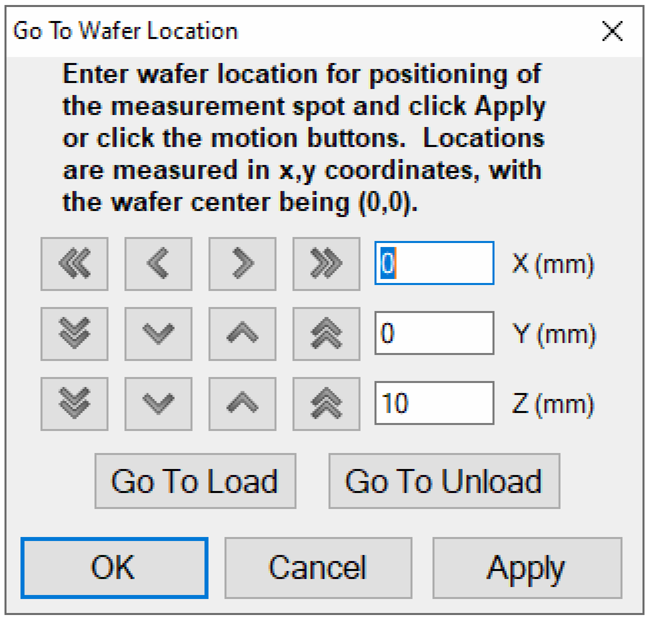
5. Select an existing recipe by clicking on the drop-down menu, or open the **Edit Recipe** dialog for the current recipe.

6. Results are displayed here.

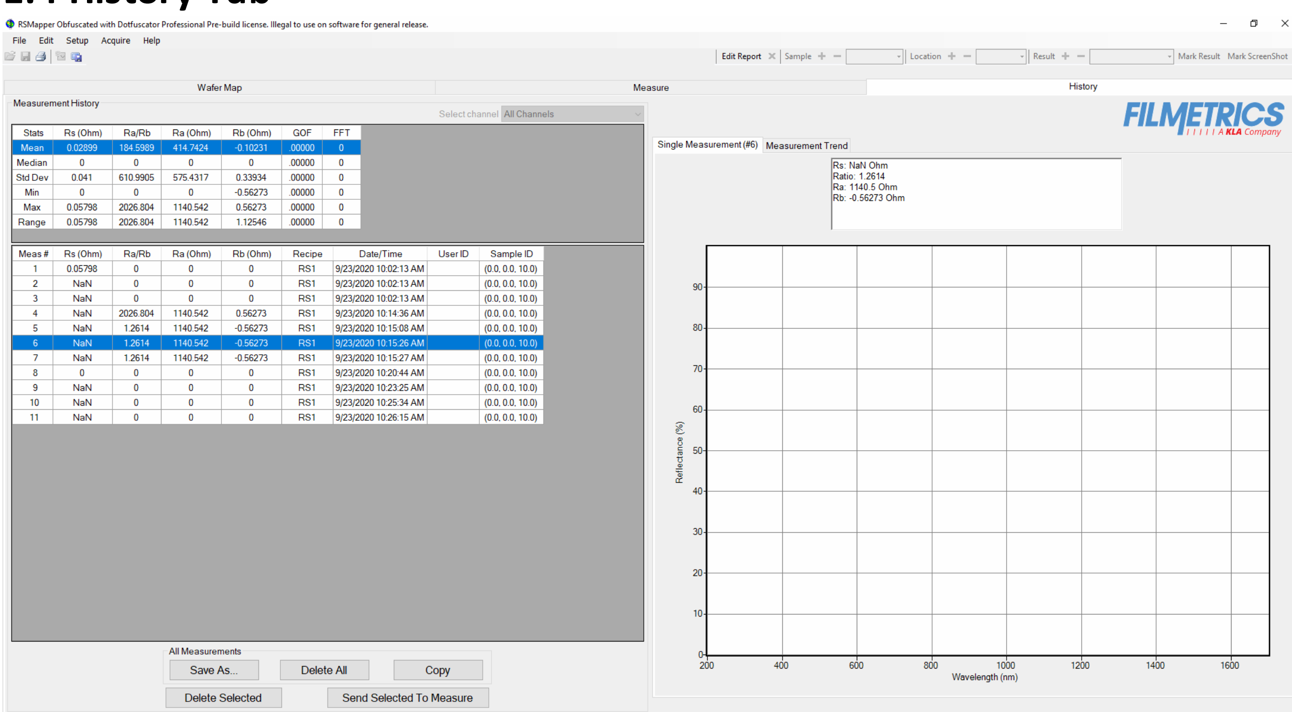
7. For EC measurements, the liftoff curves are displayed here.

1.3 Go To

The **Go To** function allows the user to manually locate the system in the x, y directions, and with capable systems, the z direction. Measurements may be entered as discrete coordinates or by clicking on the arrow keys to move the stage accordingly. When using the arrow controls, the single arrows allow a slower movement speed while the double arrows are for faster motion.



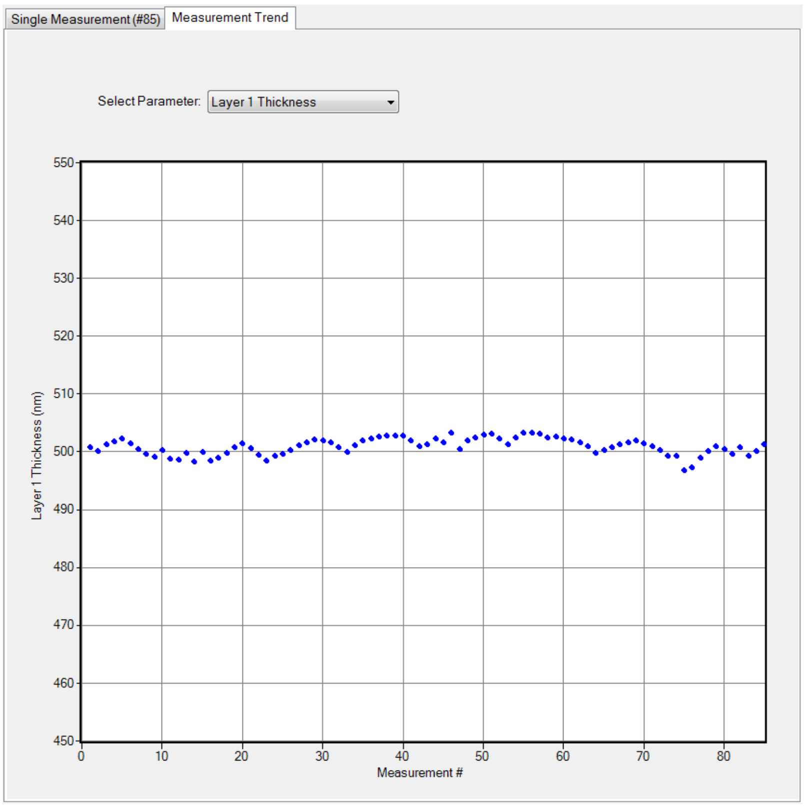
1.4 History Tab



1. Standard menus: **File**, **Edit**, **Setup**, **Acquire**, and **Help.**

2. Click on these tabs to select between the **Wafer Map**, **Measure**, and **History** windows.

3. Used to alternate between the **Single Measurement** and **Measurement Trend** tab. Selecting the **Measurement Trend** tab will allow the user to see a plot of the measurement results versus measurement number. A drop-down list allows the user to select between which parameter is displayed.



When the **Measurement Trend** tab is selected in the **History** window, the right side of the screens graphs the results.

4. Shows the results for the selected measurement (must be in **Single Measurement** mode).

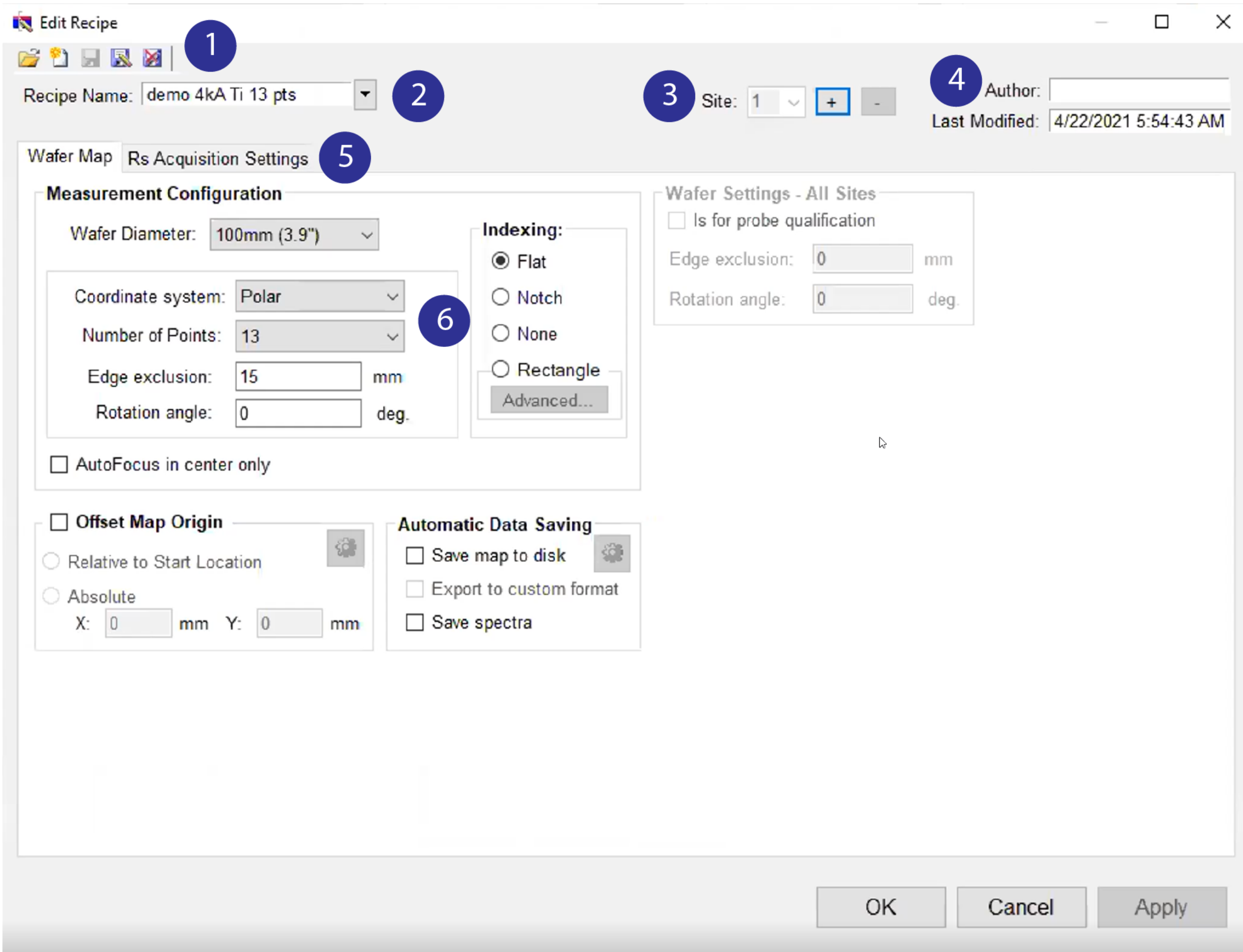
5. Displays the liftoff curve for -EC tools in **Single Measurement** mode, or the measurement trend plot in **Measurement Trend** mode.

6. Displays statistics for all measurements included in the history file. This data can be selected for copying and pasting outside of the software.

7. This list contains all results currently included in the history file. Left-click on a column header to re-sort the data in ascending or descending order based on the selected column. Right-click anywhere in this box to allow the user to open the **Edit Columns** control panel.

1.5 Edit Recipe Window

The **Edit Recipe** window is used to define the wafer map and to set acquisition parameters. More information on how to configure the recipe is included in the Editing Film Recipes section.



1. These buttons allow the user to (in order from left to right):
   i. Open a saved recipe.
   ii. Start a new recipe.
   iii. Save the current settings.
   iv. Save the current settings as a new recipe.
   v. Delete the current recipe.

2. Opens a drop-down list for quick access to saved recipes.

3. Select or add additional Sites to your measurement.

4. **Author**, defined by user login name and recipe modification date, is indicated here.

5. Allows the user to select between the Wafer Map and Rs Acquisition Settings tabs.

6. This is where the various parameters are defined, further explained in **Making Measurements**.

1.6 Menu Controls

This section describes the various functions available through the standard menus.

File Menu

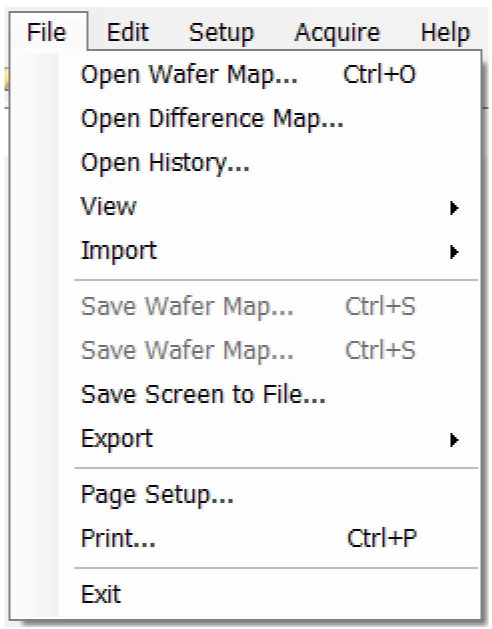
Edit Menu

Setup Menu

Acquire Menu

Help Menu

1.6.1 File Menu



Open History…
Load previously saved **History** data containing measurements and statistics.

Open Wafer Map… (Wafer Map Tab only)
Open stored wafer maps, which are then displayed and can be analyzed for sheet resistance.

Open Difference Map… (Wafer Map Tab only)
Display resistance differences between two maps (Map2-Map1). Film structure and map pattern must be the same for both map recipes. Press the **Select Map** button to browse for the map files.

Import: Recipe…
Import recipes that were previously exported or created with an older version of RsMapper.

Import: Material…
Import materials not currently in the software either, created by the user or provided by Filmetrics.

Import: License…
When the user purchases an upgrade for the system, Filmetrics will send a license file to the user. The license must be imported into the software before upgrades are effective.

Save Screen to File… (Measure Tab only)
Take a screenshot of the RsMapper window.

Save Wafer Map… (Wafer Map Tab only)
Save measured wafer maps for export or later analysis. Files can be saved in two different formats:

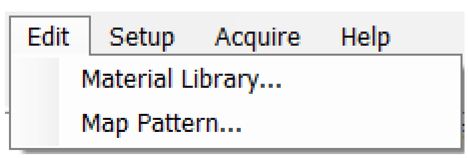
*.fiwmc: This file is the preferred way to save maps. This file will contain all data captured in measurement process.

*.fimap: This file can be opened in all versions of RsMapper.

Export: Recipe…
Recipes can be exported for use on other computers running RsMapper. The exported file automatically includes any material files required by the recipe. Duplicate an analysis on any other computer running RsMapper using the exported recipe and the spectrum being analyzed.

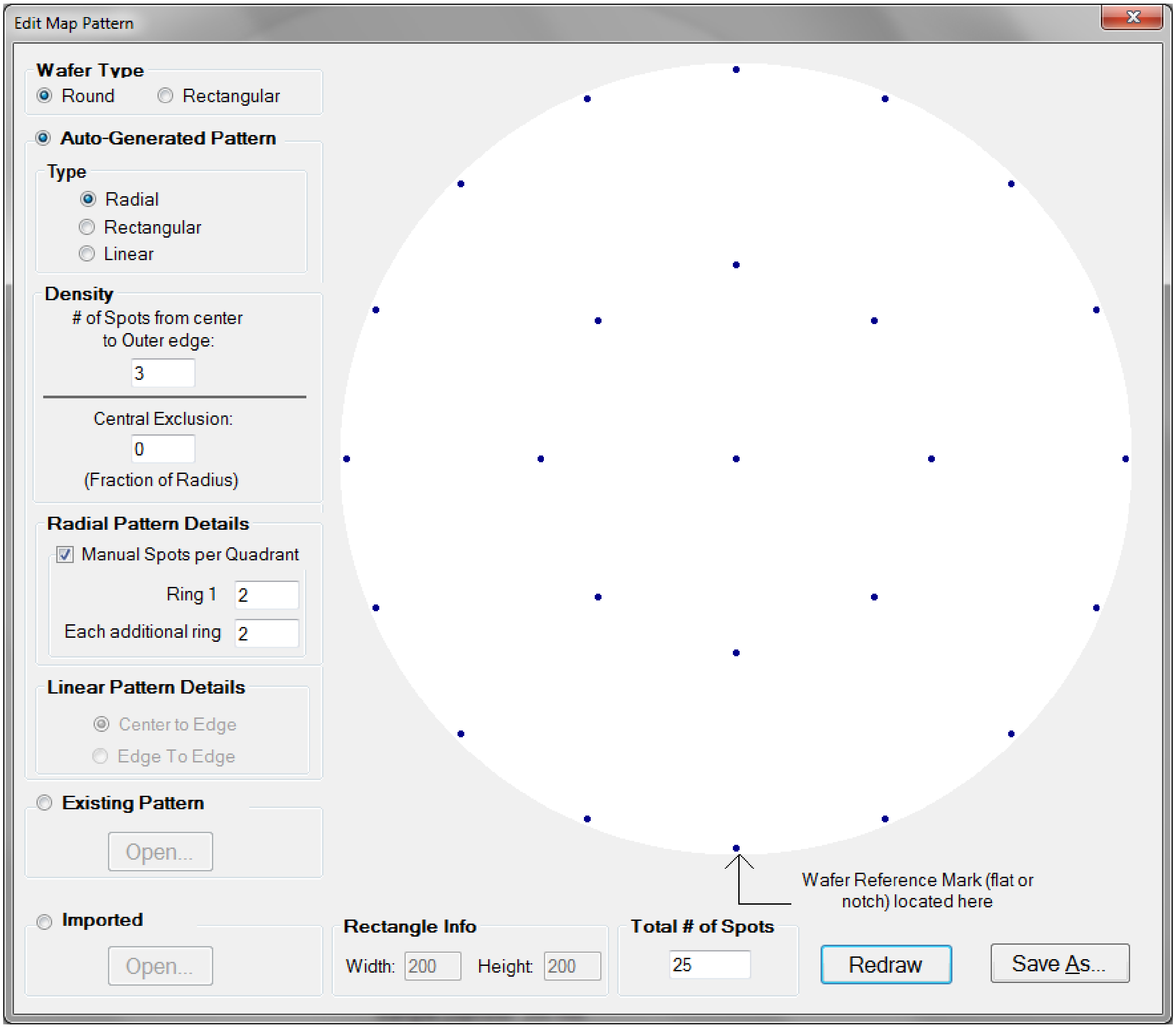
Export: SystemInfo File…
For certain software upgrades the user is required to send the SystemInfo file to Filmetrics which can be exported using this command.

1.6.2 Edit Menu



This menu allows access to the **Map Pattern** editor.

Map Pattern…(Wafer Map tab only)



The **Edit Map Pattern** dialog is used to specify the measurement pattern on the wafer. Patterns can be generated automatically through the dialog, or pre-existing patterns can be opened or imported for review.

When generating patterns automatically, first determine if the wafer shape is round or rectangular under the **Wafer Type** option. The pattern type specifies the pattern geometry within the wafer shape. If *Round* is selected, enter the expected wafer diameter into the **Round Info** text box at the bottom of the dialog window. If *Rectangular* is selected, the **Rectangle Info** allows the input of both height and width data of the sample. All measurements are assumed to be in millimeters. RsMapper will automatically scale the wafer map to match other wafer sizes if a different wafer size is input during recipe creation in the **Edit Recipe > Wafer Map** dialog.

The pattern density and central exclusion features specify the exact distribution of the measurement points on the wafer. A greater density leads to an increased number of measurement spots and can only be increased in whole numbers. **Central Exclusion** can be used to set an exclusion zone in the center of the wafer where no points are placed. The exclusion must be <1 in order to function properly. The **Radial Pattern Details** options are only enabled when the type is set to **Radial**. Enabling the *Manual Spots per Quadrant* option will allow for further modification of the number of measurement spots even further by increasing the number of spots per each concentric ring.

Rectangular patterns are used to modify spot density, and with the additional **Fixed** option allow the manual entry of the number of spots per each row and column.

Linear patterns, by default, are set to measure from **Center to Edge**, but can be set to **Edge to Edge** using the *Linear Pattern Details* options.

Display an updated version of the map pattern by clicking **Redraw** after changing any of the above values. **Save as** will save the new map pattern in the RsMapper\Patterns\Custom folder under a user-determined name.

If the x-y coordinates for a specific pattern are known, RsMapper software will recognize a text file of these coordinates. See **Editing Map Files Using Excel** for more details on creating custom maps.

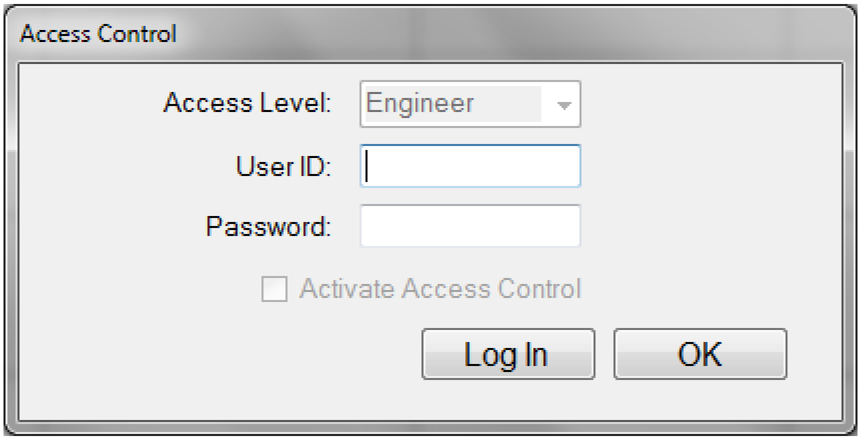
All custom patterns must be saved in RsMapper\Patterns\Custom folder. To select the new pattern in the **Edit Recipe > Wafer Map** tab, select the **Custom Coordinate System** and the name of the pattern from the drop-down box.

1.6.3 Setup Menu

This menu contains the settings for **Display** options and the **Raw Signal** dialog. This is also where user access can be set through the **Access Control** option, as well as modifying some system **Options**.

Access Control

RsMapper incorporates password protection to limit access to the measurement software and settings. When the software is initially installed, access control is turned off. The software automatically starts with *Engineer* level access that enables access to all features of the program except turning on and off access control and adding and deleting users.



Turning on access control requires Supervisor level access. The software is delivered with one user, a supervisor, in the list of authorized users as shown below:

UserID: filmsuper

Password: filmetricsfff

To turn on access control, log in as filmsuper using the password shown above. Select the **Activate Access Control** checkbox to enable access control functions. *User ID* and *Password* are case-sensitive.

To add an operator level user, select operator from the **Access Level** list box, type a username and an initial password, and then click the **Add User** button. To add an engineer or a supervisor user, use the same procedure as above, then select the appropriate access level from the list box before clicking the **Add User** button.

To delete a user, enter the **UserID** and press the **Delete User** button.

Operator and Engineer level users passwords can be changed while logged in by entering the password into the password box and pressing the change button. Supervisor-level user passwords, or the password of any other user, can be changed by selecting the appropriate access level, entering the appropriate **UserID** and new password, then pressing **Add User**. If the software finds that a user already exists, the old entry for that user will be deleted and a new entry created.

We recommend creating a new supervisor level user, then deleting the filmsuper user for maximum security. If all supervisor level users forget their passwords, it will be necessary to re-install the software and add all the users again.

Options

The **Options** menu allows the user to enable, disable, or modify several different settings within RsMapper.

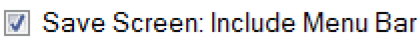
General Settings

[**Data Recording**]

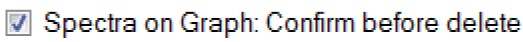
[**Calibration**]

General Settings

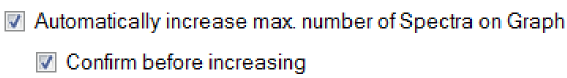
The **General Settings** tab is used to enable, disable, and modify various options in the software.



Hide or show the menu bar when using *Save Screen to File*.



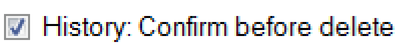
Enable or disable whether the software displays a warning before clearing all spectra on the screen when the *Clear Graph* button is pressed.



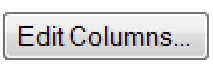
Enable or disable automatically increasing the number of spectra displayed on the graph when opening multiple saved spectra.

You can also set whether to show a confirmation message before increasing the number of spectra.

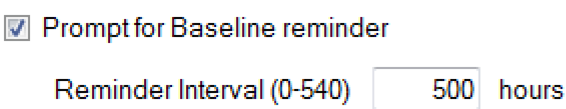
Toggle whether the software prints out all currently loaded spectra, or only the active curve when using the *Print* feature.



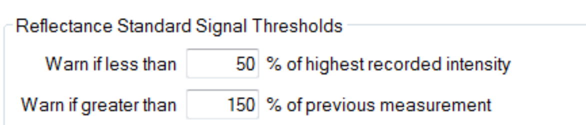
Enable or disable whether the warning dialog before you delete entries in the history file.



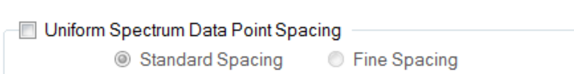
Open a dialog that allows you to control which columns are visible in the **History** tab.



Enable or disable the baseline reminder feature, and if enabled to set the reminder interval.

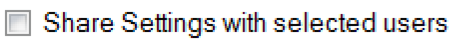


Set your *Reflectance Standard Signal Threshold* values. These determine at what percentage of the initial signal intensity the software will display a warning during the process. This feature is used to track lamp health, proper baseline procedure, and other parameters.



Enable or disable the *Uniform Spectra Data Point Spacing* function. When enabled, saved spectra will have their values set to a multiple of 1, 2 or 5. *Standard Spacing* sets the spacing equal or greater than the smallest interval in the data, while *Fine Spacing* sets the spacing to shorter than the smallest interval.

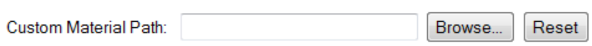
For systems with multiple user accounts, enable or disable sharing settings across all users. A folder to store the settings file may be selected.



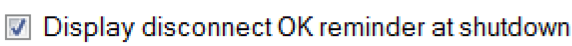
For systems with multiple user accounts, enable or disable sharing settings across any users who have slected this option. A folder to store the settings file may be selected. This option is only available if *Share Settings with all users* isn't enabled.

This feature allows the user to select a different location for their *Recipes* folder, for example to a shared network drive. This can be useful for syncing recipes across multiple instruments in varying locations.

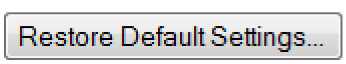
Selecting **Reset** will instruct the software to look in the default location for the *Recipe* folder.



This feature is similar to the one above, only it allows you to choose a different location for your *Materials* folder.



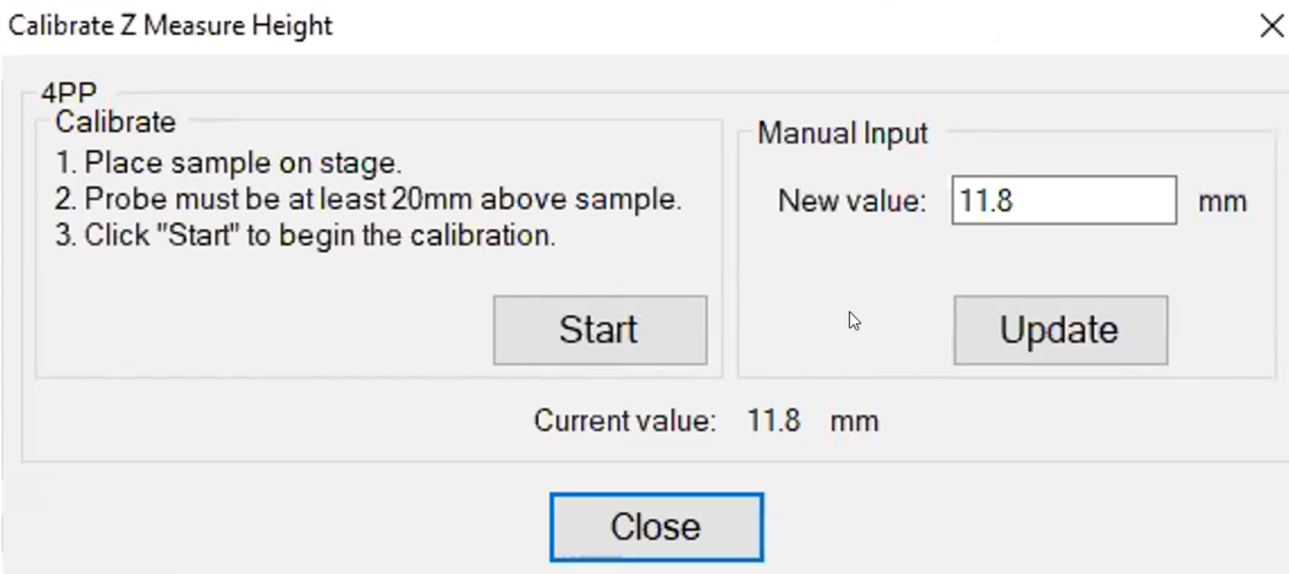
Enable or disable whether the software prompts you when it is ok to disconnect the instrument at software shutdown.



Click to restore all settings to their default values.

Calibrate Z Measure Height.

This dialog sets the position for the **Go To Z Measure Height** button to insure rapid measurements and that the probe doesn't crash into the sample. This value is set in two ways; an automated calibration or by manual entry.



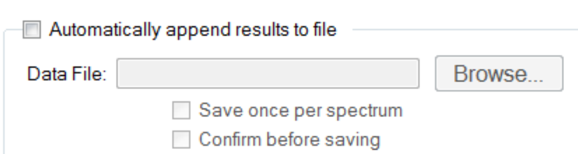
If the appropriate z-height is already known, enter that value into the *New value:* text box under *Manual Input* and then click **Update**.

To have RsMapper automatically determine the appropriate height, first use the **Go To** command to raise the measurement head at least twenty mm above the sample surface before launching the **Z-Height Measurement Calibration** via the *Setup > Options > Wafer Map* menu.

With the head positioned an adequate distance above the sample, click **Start** to begin the calibration. The head will step down to find the sample, updating the *New value* and *Current value* fields when complete. Click **Close** to exit the calibration. After calibration, clicking **Go to Z Measure** moves the head to the calibrated height in preparation for measurement.

Data Recording

The **Data Recording** tab contains controls for the various methods by which RsMapper may automatically save collected data.

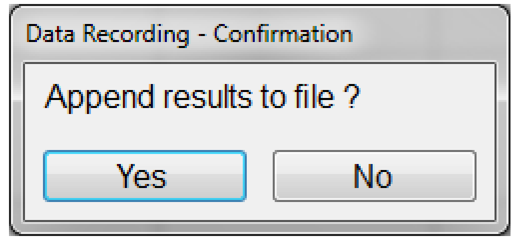


Enabling *Automatically append results to file* will instruct the software to create an excel file at a specified location in which a running tally of measured results are kept.

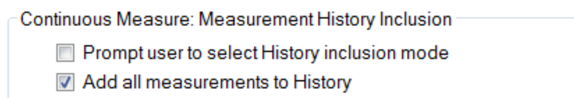
This feature is different from the **History** tab in that it only records results, not the spectra files as well. It does not however have an upper limit on the number of spectra that can be recorded.

Enabling *Save once per spectrum* will only append results when the **Measure** button is pressed or a saved spectra is opened in the software. Any changes in the recipe applied to existing spectra will not be recorded. When this feature is disabled, any time a spectra is analyzed the result is entered into the file.

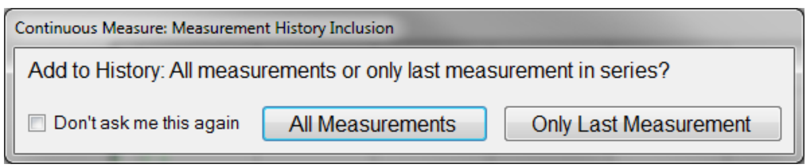
When *Confirm before saving* is turned on, the software will provide a prompt before appending data to the excel file.



Continuous Measure: Measurement History Inclusion controls which spectra are included in the **History** tab when the **Acquire > Measure Continuously** feature is used.

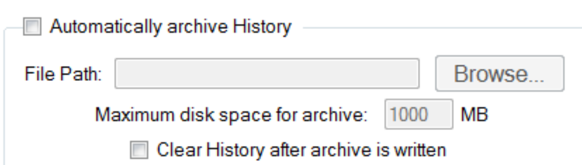


If the software is set to *Prompt user to select History inclusion mode*, a dialog will pop up prior to beginning the continuous measure asking the user whether to save all measurements while measuring continuously, or only the last measurement. The only last measurement feature can be useful on less ideal surfaces (rough, non-uniform, etc.) where the user may have to search around the sample surface for a spectrum capable of being analyzed.



Clicking **Don't ask me this again** will disable the prompt, and the user will have to navigate back to this menu to re-enable the feature.

The user can also select between having the software provide a prompt for which data to include in the history file when using **Acquire > Continuous Measure** or to record all measurements to the **History** tab.



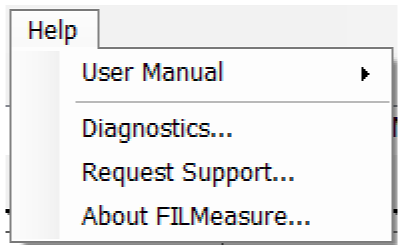
The *Automatically archive History* feature can be used to have the software save a copy of the history file whenever it hits 1000 measurements.

The history files are saved in the following format (YYYY-MM-DD-X) where YYYY is the year, MM is the month, DD is the day, and X is a serialized number based on how many history files have been saved on a given day.

A value can be entered in megabytes for the maximum disk space to be allocated for the saved archives. This will keep the software from using up all available hard disk space if the feature is enabled and then forgotten. Should the software hit the allocated max, it will delete the oldest files in the selected folder until enough space is available for the new history file.

Clicking **Clear History after archive is written** will instruct the software to automatically clear the history results after 1000 measurements have been reached, and then begin counting towards the next group. When it is disabled the history feature will work in the normal mode upon reaching 1000 measurements (newest measurement is added as Meas #1000, Meas #1 is deleted). It will write the next history file upon reaching 1000 measurements again, not each time the *Meas#* counter shows 1000.

1.6.4 Help Menu



Help > About RsMapper
Information about the hardware and software versions and the system serial number can be found here. Please have this information available when calling Filmetrics for technical assistance.

Help>About RsMapper... window

2. Editing Film Recipes

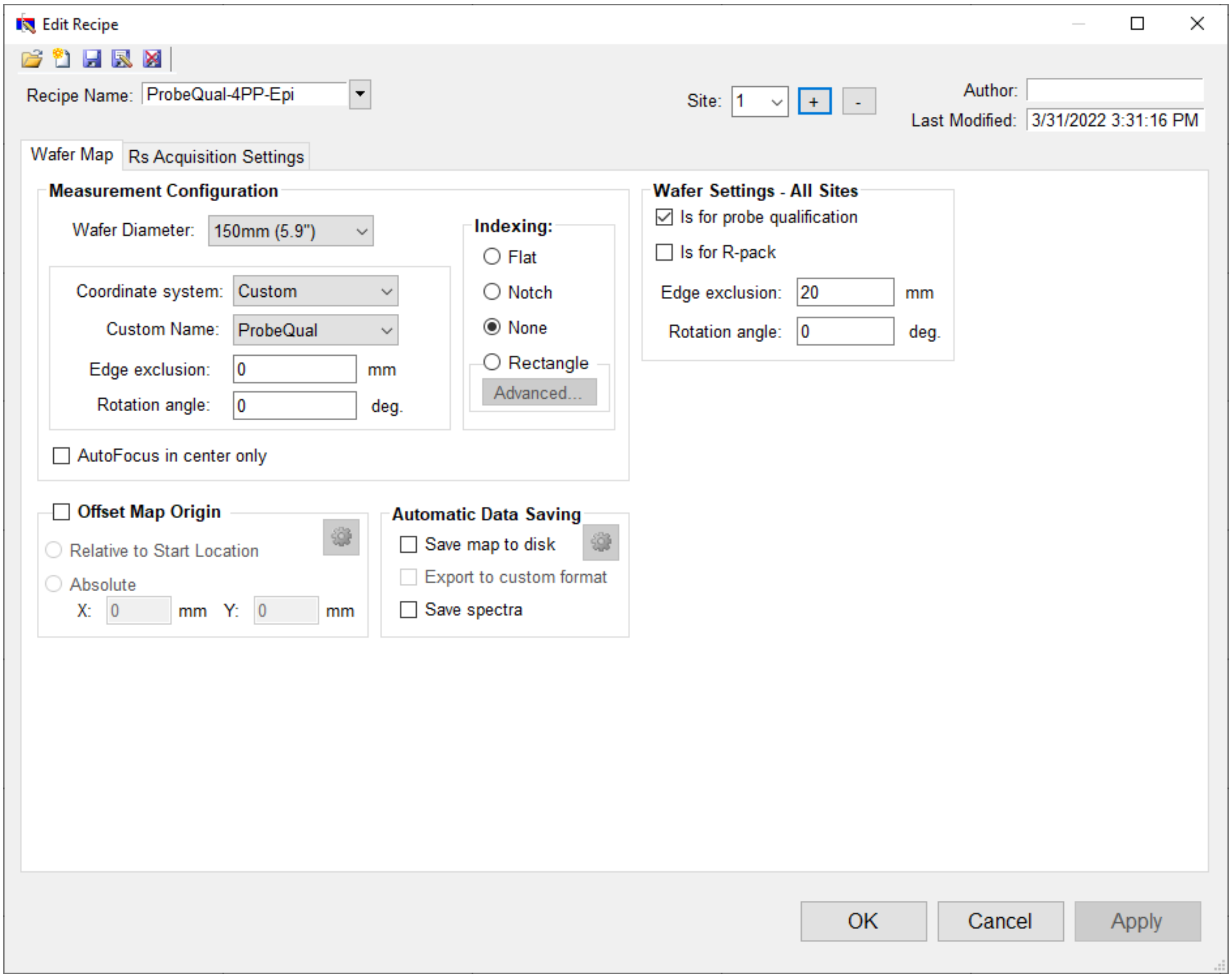
Recipes are used to configure the film stack, measurement map, and acquisition settings for the system. If varying samples or processes are being measured, multiple recipes can be saved to quickly switch settings as appropriate.

The **Edit Recipe** dialog box is accessed with the **Edit Recipe...** button on the **Measure Tab**, or the **Edit…** button on the **Wafer Map Tab**.

2.1 Adding, Changing, or Deleting a Structure

When the **Edit Recipe** dialog box is opened, it shows the stored specifications of the structure selected from the **Recipe Name:** list, along with any changes made since the recipe was loaded. Changes to the selected structure can be permanently stored by making the desired changes and clicking **Save**. Changes can also be stored as a new recipe by clicking **Save As**. A structure may be deleted (removed from the **Recipe Name:** list) by clicking the **Delete** button. Recipes can be moved between computers using the **File > Import > Recipe** and **File > Export > Recipe** commands.

2.2 Wafer Map



This wafer map tab allows various settings to be specified in relation to how the map is generated. This includes the size and type of wafer to be analyzed, the configuration of the measurement spots, as well as data saving protocols.

2.2.1 Measurement Configuration

Wafer Diameter: Diameter of wafer to be measured – choose from the list. When using rectangular patterns, this option will switch to **Width** and **Height**, with text boxes to enter the appropriate values.

Coordinate System: Polar, Rectangular, Linear, or Custom.

Number of Points or Custom Name: Number of points to be measured or select the name of the custom pattern file.

Edge Exclusion: Distance from outermost points to the edge of the wafer.

Advanced Settings: When using a rectangular map, the advanced rectangular map settings option is enabled for use. This menu allows the user to define the sample origin point in one of five locations; top-left, top-right, center, bottom-left, or bottom-right. **Automatic Alignment** can be used to help find the edges of the sample.

Rotation Angle: Sets a fixed angular offset to all measurements in the map.

2.2.2 Offset Map Origin

This feature is intended to allow the origin point location used for the measurement map to be specified. If no option is selected, the software defaults to centering all maps around the (0,0) measurement location. Once selected there are two options available:

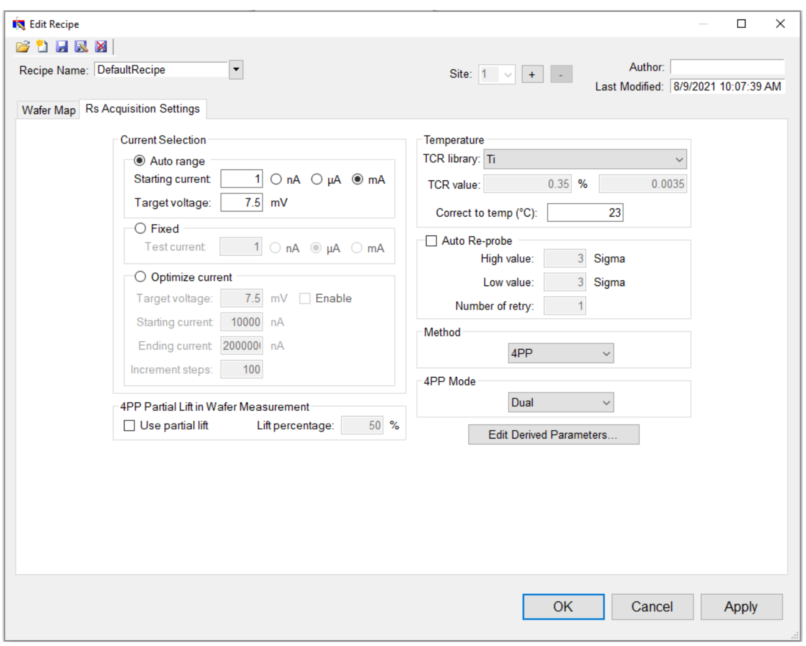
1. **Relative to Start Location** - When the **Start** button is clicked, the software uses the current (x,y) position as the origin for the map. This position is not saved as part of the recipe.
2. **Absolute** - Set a specific (x,y) location as the origin of the map.

2.2.3 Automatic Data Saving

If a filename is entered in the upper right corner of the **Wafer Map View>Map Information** field, a new folder with that name will appear in the RsMapper\Map Results folder. If no name is specified, all saved data will appear in the Map Results folder.

Save Results to Disk: Automatically saves the map after completion of measurement. Depending on the settings in Setup>Options>Wafer Map, maps are saved as an .fimap or .fiwmc file.

2.3 Acquisition Settings



Control **Current Selection**, **Partial Lift**, **Temperature** correction, enable **Auto Re-probe**, select the measurement **Method**, select the **4PP Mode** used or which **Liftoff** curve to analyze when using eddy current, and open the **Edit Derived Parameters** dialog.

Current Selection

Toggle through the different radio buttons to select how the current is generated for testing.

NOTE: These features are still in development. Descriptions and functionality may change in future software releases.

Auto Range: Allows the software to find the best current range when measuring the sample. Select a starting current in nA, µA, or mA, as well as a target voltage in mV.

Fixed: Set a fixed current in nA, µA, or mA.

Optimize Current: Allow the software to select the best current range based on data from the sample. Click **Enable** to set the values.

Partial Lift

When enabled, this feature shortens the lift distance of the probe head during the mapping procedure as a percentage of total lift height. This allows for quicker measurements on the R50.

Note it is recommended to test the minimum *Life percentage* required in single measurement mode to insure clearance with the sample surface before mapping. Failure to provide enough lift may result in damage to the sample, probe or both.

Temperature Correction

The temperature correction option allows for adjusting measurement results based on the temperature of the sample. To set the correction factor, select the material to be measured from the drop-down menu. The TCR value populates automatically. Next, enter the temperature the sample should be corrected to in the text box. Click **OK** to exit the dialog. The correction will be applied to future measurements.

Auto Re-Probe

When enabled, if there is a measurement failure at a given location a short series of measurements will be taken in nearby locations to attempt to complete a good measurement. Limits can be set as a function of sigma of standard deviation high and low, as well as the number of measurement retries that should be attempted.

Method

For systems with both the four-point probe and an eddy current detector, use the drop-down menu to select which probe is currently in use.

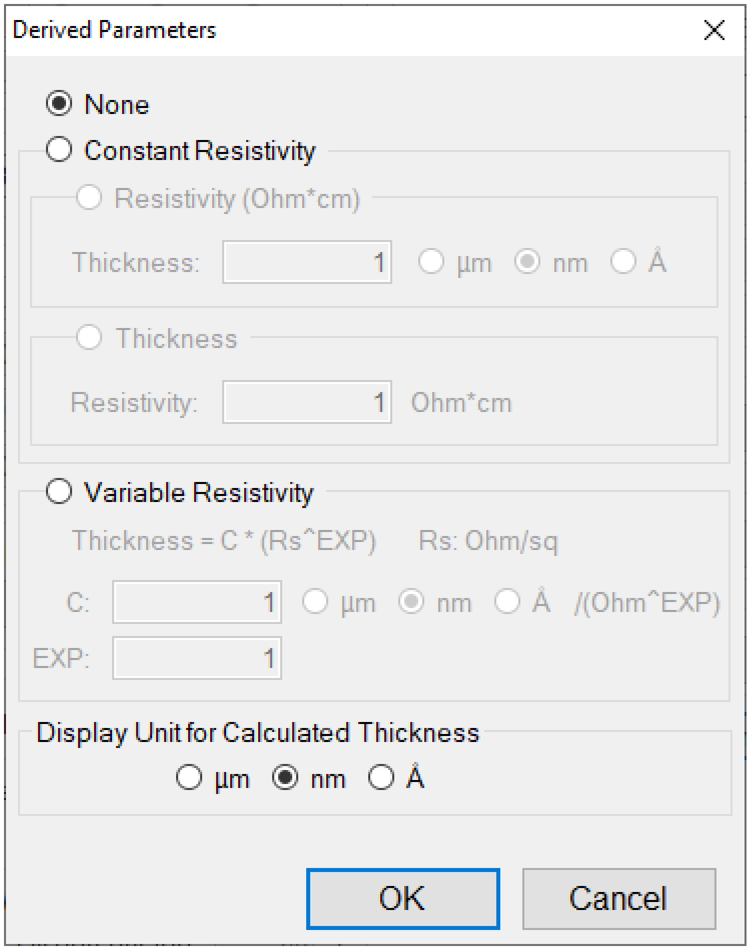
Liftoff

NOTE: This feature is still in development. Descriptions and functionality may change in future software releases.

Select where in the motion of the eddy current probe the liftoff curve is measured when making a full measurement. Select *Drop* to measure on the down motion, and *Lift* to measure on the upward motion.

Edit Derived Parameters

Enable the display of thickness or resistivity in the Results box and completed wafer maps via the controls in this dialog.



If either thickness or resistivity of a film is known, the other can be measured by the R50 by selecting the appropriate radio button and entering the known value. Thickness units available are µm, nm, and Å.

These controls are split into *Constant* and *Variable* resistivity sections. *Constant* assumes the values for thickness or resistivity are the same at all locations measured, while *Variable* allows for changes across the surface using the equation *Thickness = C*Rs^EXP*. It is assumed that the end user knows the constant (C) and exponential (EXP) values to be entered for this equation.

3. Making Measurements

Accurate measurements with the R50 rely on using the proper measurement setup. The basic steps for any R50 measurement are:

1) Selecting and/or editing the **Recipe** to be measured.
2) Loading the sample.
3) Clicking on the **Measure** button to acquire and analyze the data.

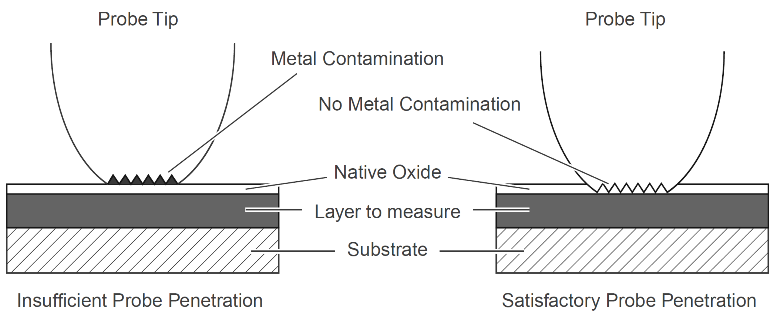
The examples below further explain this sequence of steps. In each example, it is assumed that the hardware has been set up as described in the **Quick Start Guide**and that the user has read the**Software Overview** section and is familiar with the basic controls.

3.1 Probe Head Selection

Many users use the same probe head to measure a variety of wafers. This practice can produce erroneous readings or cause electrically-noisy measurements. The table below describes the probe heads typically used by application.

Probe Type	Part Number	Description (radius, loading, material, spacing)	Application
A	4PP-TypeA	1.6 mil, 100 gm, Tungsten Carbide, 40 mil (1 mm)	For measuring metals
F	4PP-TypeF	1.6 mil, 100 gm, Tungsten Carbide, 25 mil (0.6 mm)	
B	4PP-TypeB	4.0 mil, 100 gm, Tungsten Carbide, 40 mil (1 mm)	General purpose head for implantation, doped poly, silicides, epitaxy, and diffusion
G	4PP-TypeG	4.0 mil, 100 gm, Tungsten Carbide, 25 mil (0.6 mm)	
C	4PP-TypeC	8.0 mil, 100 gm, Tungsten Carbide, 40 mil (1 mm)	Specifically designed for high impedance surfaces such as low implant dose, shallow junctions, doped poly
H	4PP-TypeH	8.0 mil, 100 gm, Tungsten Carbide, 25 mil (0.6 mm)	
D	4PP-TypeD	20.0 mil, 100 gm, Tungsten Carbide, 40 mil (1 mm)	For very difficult implant and high impedance surfaces beyond 8.0 mil
I	4PP-TypeI	20.0 mil, 100 gm, Tungsten Carbide, 25 mil (0.6 mm)	
E	4PP-TypeE	1.6 mil, 200 gm, Tungsten Carbide, 62.5 mil (1.6 mm)	Probe head specific to substrate measurements; i.e bulk

Remember to use different probes to measure metal films and silicon wafers. For example, aluminum is a soft metal and oxidizes easily. As the probe repeatedly contacts an aluminum film, some of the aluminum collects on the probe tips. This excess aluminum can smooth over and insulate the surface of the probe tips. If you were to use this probe tomeasure a highly polished and oxidized (native oxide) silicon wafer, there would be very little penetration or electrical contact by the probe tips as illustrated below.



For more information on how probes wear, see the Probe Monitoring section in the appendices.

3.2 Example A: Measuring Sheet Resistance Using the Four Point Probe

Measuring Sheet Resistance of a Ti film.

In this example we will cover the basics of making a four point probe measurement of a Ti film on the R50-4PP. While this application is specific to Ti films, the basics covered can be applied to most any material that can be measured on the R50-4PP.

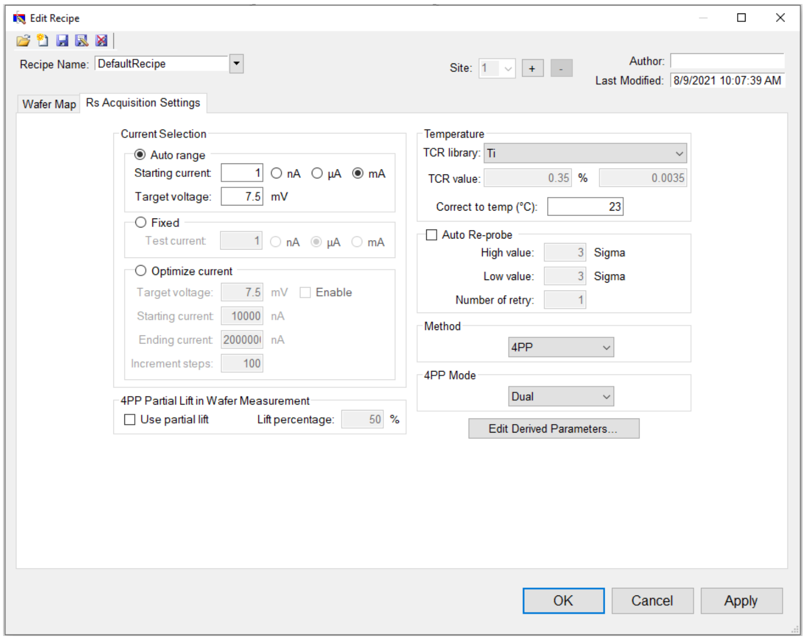
It is assumed that the **Go To Z Measure** height has already been calibrated before starting the measurement. If this hasn't been completed, see **Calibrate Z-Height Measure** for details.

Continue to step 1.

Example A: Preparing for Measurement.

Before taking a measurement, a basic recipe must be configured.

First, click on **Edit Recipe** and select the **Rs Acquisition Settings** tab.



Select *Auto Range* under *Current Selection* with a *Starting Current* of 1 mA and a *Target Voltage* of 7.5 mV. This method is slower than the *Fixed* or *Optimize Current* options, but is best used when optimal values are not yet known. See **Current Selection** for more details on modifying these values for other applications.

Next, click the drop-down menu next to *TCR library* and select the Ti correction file. Enter the current room temperature into *Correct to Temp (°C)*.

This example will not include a map, so *Auto Re-probe* should be left disabled.

This example assumes an R50-4PP, so the *Method* should be preselected to **4PP**. Select the **Dual** *4PP Mode* from the drop-down list. When all values have been updated, click **OK** to apply the changes and close the dialog.

Continue to Step 2.

Example A: Making the Measurement.

Click the **Go To** button to open the stage motion control dialog. Click **Go To Unload** to move the stage to the unload position. Place the sample on the stage, then click **Go To Load** to move the stage to the (0,0) point. Click **OK** to exit the dialog.

With the sample in position under the head, click the **Go To Z Measure** button to move the measurement head into position. Once the head is in position, click **Measure** to take a single point measurement. The head will drop down to the sample and take a measurement, and then lift back up off the sample. Results are displayed in the *Results* window, including additional parameters enabled via **Edit Derived Parameters**.

See **Editing Film Recipes > Wafer Map Tab** for more details on configuring the map settings to run a map of the sample surface. Additionally, faster measurements can be completed by changing to a fixed current in the recipe using the calculated current shown in the *Results* window.

3.3 Configuring Current

Selecting the proper current is imperative to get high quality measurements on the R50. The following guide covers how to best set current through the **Acquisition Settings** section of the recipe.

To configure the measurement parameters, select a target voltage or a fixed current. When *Auto Range* under *Current Selection* is selected, the value in the *Target Voltage* text box is usually set at 7.5 mV (directing the system to search until it finds a current that results in a measured voltage of 7.5 mV). The system then uses this current to measure wafers.

The optimum current is achieved by testing the sample by using various currents:

- If sheet resistance remains constant, the highest current usually gives the most consistent results.
- If sheet resistance decreases at higher currents, the probable cause is substrate leakage. The current should be reduced.
- If sheet resistance increases at higher currents, and the layer has a positive temperature coefficient of resistance, the probable cause is local heating. The current should be reduced.

Occasionally, a high resistance layer requires only very small current to meet the default voltage requirements. Additionally, if the substrate resistivity is very low, the potential for substrate leakage may be high. Under these circumstances, the leakage current may be an appreciable proportion of the measurement current, and the apparent sheet resistance will be low. Therefore, the highest substrate resistivity that can be practicably obtained should be used in conjunction with the lowest reasonable current.

The minimum noise is usually achieved with a trial-and-error method: several measurements are taken at a *Fixed Test Current*, and the standard deviation is noted. The current is then increased, the measurements are taken again, and the standard deviation at the new current is noted. This process is repeated at several different currents until the current producing the minimum standard deviation is determined. (The current should, of course fall within the acceptable current range as determined above.) This process should be employed when trying to measure a problem wafer which you have been unable to measure successfully or when a problem occurs with a known measurement process.

3.4 Troubleshooting

Most errors encounter on the R50 tools can be solved using by power cycling the system. See the document below for step-by-step instructions.

Power Cycling

Power Cycling

Over the years, we've found that about a third of support issues can be resolved with a simple power cycle of the Filmetrics system and computer. Follow the steps below to power cycle your instrument. Further assistance may be received by contacting us. See the **Contact Information** section.

Step 1: Shut down RsMapper (if unable to shut down, continue to Step 2).

Step 2: Turn off power at the back of the system.

Note: If the system is being powered down without a proper software shutdown, support the probe lift mechanism manually to allow for a controlled drop.

Step 3: Unplug all electrical connectors from the back of your Filmetrics system.

Step 4: Restart the computer, allowing time for all drivers to load.

Step 5: Reconnect the electrical connections to your Filmetrics system. Ensure the power cord is getting power, and that any switches near the power connector are turned on.

Step 6: Restart RsMapper.

3.4.1 Software Reinstallation Guide

Follow the steps below to reinstall RsMapper. Contact Filmetrics for further assistance. See **Contact Information** section. *Warning: Upgrading software versions may result in slightly different (<1%) measurement results due to continual improvement of our solving algorithms and material files.*

Step 1: Shut down RsMapper (If unable to shut down, continue to Step 2).

Step 2: Turn off power at the back of the system.

Step 3: Unplug all electrical connectors from the back of your Filmetrics system.

Step 4: Are you installing this software on a computer which already has RsMapper installed?

Yes: Go to Step 5.
Yes: Jump to **Step 7.**

Step 5: Make a backup copy of your recipe and material files:

On Windows 7/8/10: Backup the directory `C:\Program Data\Filmetrics\`
Note: The Program Data folder may be hidden by default.

Step 6: Uninstall the current version of software:

On Windows 7/Vista: Click the Start orb > Control Panel > Programs and Features > RsMapper > Uninstall
On Windows 8: Control Panel > More settings > Programs and Features > RsMapper > Uninstall
On Windows 10: Control Panel > Programs and Features > RsMapper > Uninstall

Step 7: Run the software installer and follow installer instructions.
Note: you will need administrative privileges to install the software.

Step 8: Reconnect your Filmetrics system.
Note for Windows 7/8/10: An Information balloon may appear over the taskbar while drivers are being installed. Please wait until the balloon indicates the drivers have been installed before starting RsMapper.

Step 9: Run the software to verify the installation was successful.

Verifying Tester Electronics

This procedure employs resistor networks (also called resistor packs) to help confirm that tester electronics are functioning properly. The resistor packs are installed in place of the probe head. Using resistor packs ensures that measurements are not influenced by probe contact problems or by probe arm mechanical movement. Use the set of resistor packs that shipped with the system.

WARNING

ELECTRIC SHOCK HAZARD: Type 3 - Equipment is energized and live circuits of less than 30 Vrms, 240 VA, or 20 joules are exposed to accidental contact.

Any work done on areas using 24 VDC or 24 VAC, if the power is left on, qualifies as a Type 3 task.
• The 24 VDC areas include
  – The interlock logic PCA
  – The theta interconnect PCA
  – The probe up sensor PCA
  – The Radial sensor PCA

Verifying the electronics:

1. Remove the probe head from the probe arm as described in **Changing 4-Point Probes**.
2. Insert the resistor pack.
3. Load the appropriate RPAC recipe.
4. Go to the **Map** tab.
5. Click **Start**.

The measured values shown should agree within the tolerances given on the resistor pack. If the measure value falls outside of the specified tolerance for a given current range, please contact Filmetrics.

4. Advanced Features

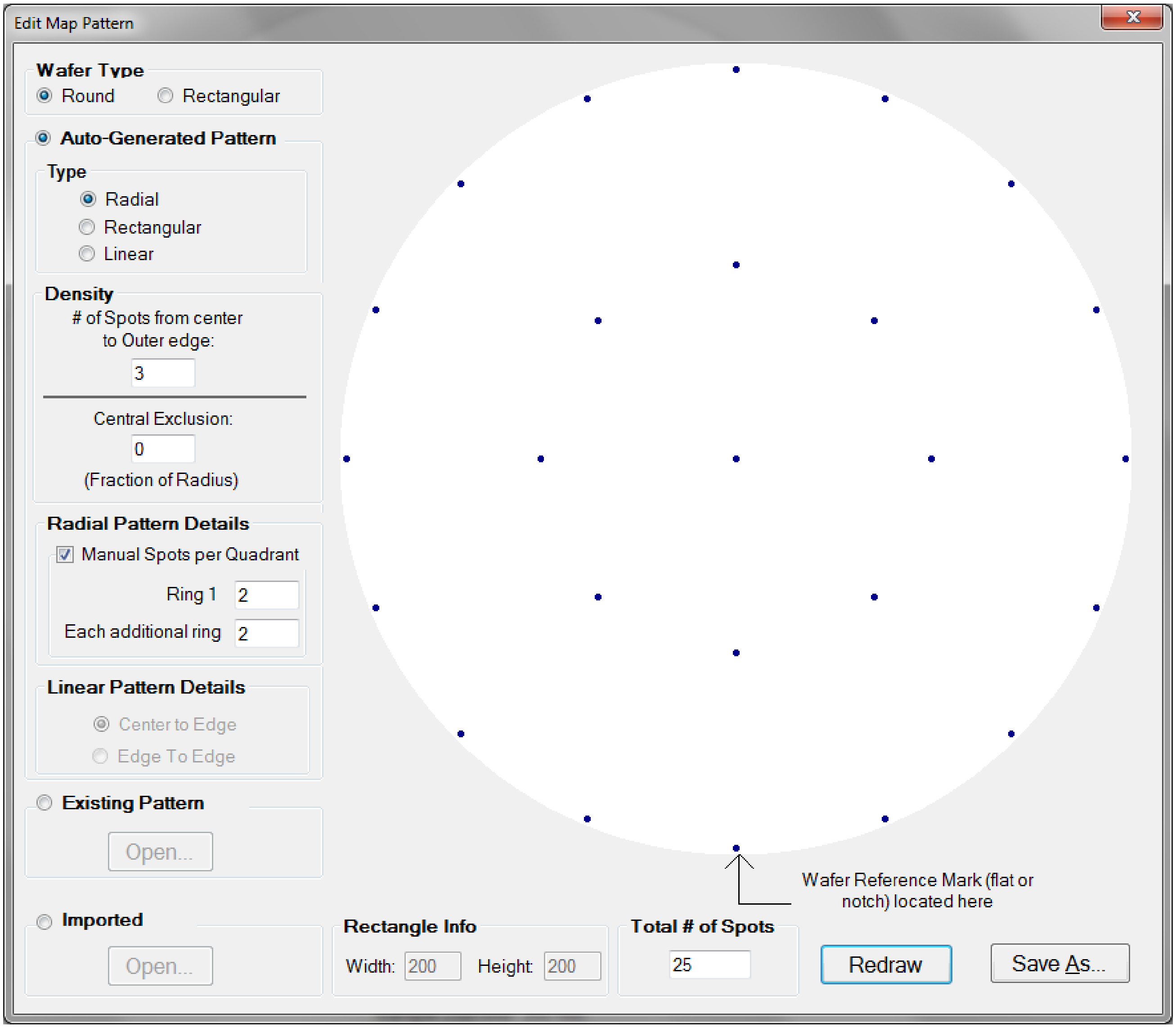
This section describes use of the map pattern generator and how to edit map files within Microsoft Excel.

Using the Map Pattern Generator

Editing Map Files Using Excel

4.1 Creating New Map Patterns

The **Edit Map Pattern** tool is best used for simpler maps on blanket wafers. To create a new wafer map pattern, go to the **Wafer Map Tab** and select **Edit > Map Pattern...** Once selected, a new window appears which allows parameters to be adjusted to create a custom wafer map.



1. Select the **Round** or **Square** wafer shape.

2. Select how the measurement points are distributed on the sample. The alignment can be **Radial (Polar)**, **Rectangular**, or **Linear**.

3. Control the measurement point density. The **# of Spots from Center to Outer Edge** specifies how many points are placed in a line between the center and the edge. The **Central Exclusion** specifies how much of the center (if any) should be excluded from measurement.

4. Select how many spots are in each quarter section of the ring (when the **Radial** pattern type is selected). When **Manual Spots per Quadrant** is not selected, **Ring 1** is automatically set to 1, and **Each additional ring** is automatically set to 2.

5. Select whether the measurement points should span the **Center to Edge**, or the **Edge to Edge** (only available when the *Linear* pattern type is selected).

6. Use **Redraw** to refresh the wafer map based on the current settings to verify the map is correct.

7. **Save** the wafer map to a file for subsequent use in a **Recipe**.

An **Existing Pattern** can also be opened for editing, or **Import** one that has been **created using Excel**.

4.2 Editing Map Files Using Excel

Map files can be further edited using Microsoft Excel in order to create more complex patterns. The .pat file created by RsMapper can be imported into Excel for editing and saved as a comma-delimited file (.csv). The newly edited file can then used in RsMapper to create more intricate map patterns. The example below shows how to create an “X” pattern starting with the default pattern.

Example: Creating an “X” map pattern starting with the default map pattern

Step 1: Create a new map file

In the map window, go to **Edit > Map Pattern…** Using a **Round** wafer type and a **Radial** pattern type, select 3 for **# Spots from center to Outer Edge**. Select **Manual Spots per Quadrant** and use 2 for **Ring 1** and **Each additional ring.**

Save this default map pattern as **Custom**.

Step 2: Import the map pattern into Excel

Using Excel, open the file **Custom.pat**. This file can be found in **C:\Program Files\RsMapper\Patterns\Custom**. (Note: If the file does not appear in the **Open** dialog box, choose **All Files (*.*)** under File Type.)

When prompted to import this file, select **Delimited**, click **Next**, then select **Comma** for the **Delimiters**.

Step 3: Edit map pattern in Excel

Starting in the fourth row, values are stored as x-y coordinate values, as a fraction of the radius of the wafer. When generating new maps, values can be entered as either a fraction of the radius of the wafer, or a discrete number, as long as all values are to the same scale. To create the “X” pattern, delete the highlighted rows shown in Figure below so that there are no empty rows between values. Delete the first two rows by selecting rows 1 and 2 and selecting **Delete** from the **Edit** menu.

	A	B	C	D	E
1	Version	1			
2	GUID	9edf4a33d97a4c2183ce5f2dfd471ca8			
3	25				
4	0	0			
5	0.5	0			
6	0.353553	0.353553			
7	3.06E-17	0.5			
8	-0.35355	0.353553			
9	-0.5	6.12E-17			
10	-0.35355	-0.35355			
11	-9.18E-17	-0.5			
12	0.353553	-0.35355			
13	1	0			
14	0.92388	0.382683			
15	0.707107	0.707107			
16	0.382683	0.92388			
17	6.12E-17	1			
18	-0.38268	0.92388			
19	-0.70711	0.707107			
20	-0.92388	0.382683			
21	-1	1.22E-16			
22	-0.92388	-0.38268			
23	-0.70711	-0.70711			
24	-0.38268	-0.92388			
25	-1.84E-16	-1			
26	0.382683	-0.92388			
27	0.707107	-0.70711			
28	0.92388	-0.38268			

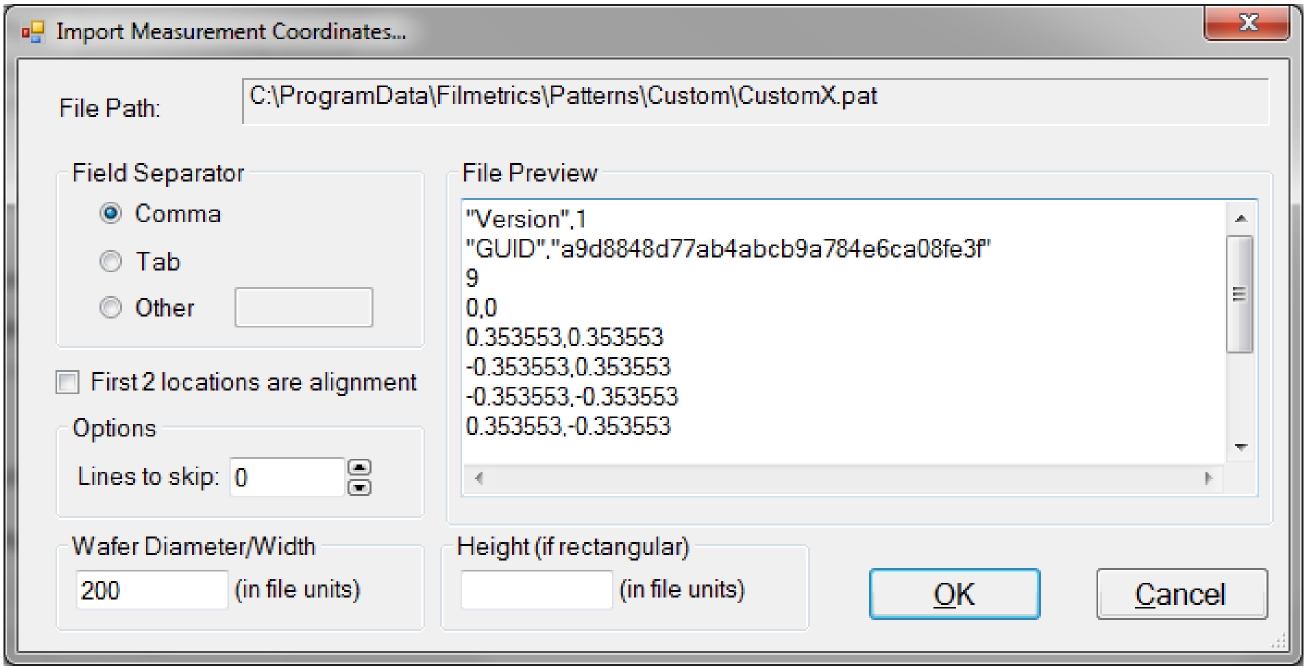
Delete the highlighted cells to leave the desired coordinates.

Step 4: Save map pattern

After the modifications have been made, select **File > Save**. Check that the **File Name** box is "**CustomEdit.pat**" (note: quotation marks must be used to enclose the filename in Excel to force the extension to **.pat**) and that the **File Type** is **CSV (Comma delimited) (*.csv)**. Click **Save**.

Step 5: Import the Map Pattern

In RsMapper, select **Edit >Map Pattern…**. Enable the radio button for **File-Imported Pattern**, and then switch to the **Imported Pattern** tab and click **Open…**. The following dialog will open:



Increase the **Options > Line to skip** value until the first value visible in the list is the first coordinate in the series. The **Wafer Diameter/Width** and **Height** is also set here according to the values used for the coordinate scale. If fractional values are used, set the Wafer Diameter/Width, and Height for rectangular samples, to 2 (-1 to 1). If whole values are used, enter the sample dimensions. Click **OK** when finished.

Step 6: Save the Pattern File

The new pattern file is displayed in the **Edit Map Pattern** window. Confirm it matches the expected pattern and save the new pattern using the **Save As** button.

Note: If the wafer map does not show up as described, open the file **C:\Program Files\RsMapper\Patterns\custom\Custom.pat** using a text editor, such as Microsoft Notepad. Check to see that the first row does not contain a comma. If it does, delete the comma and save the file.

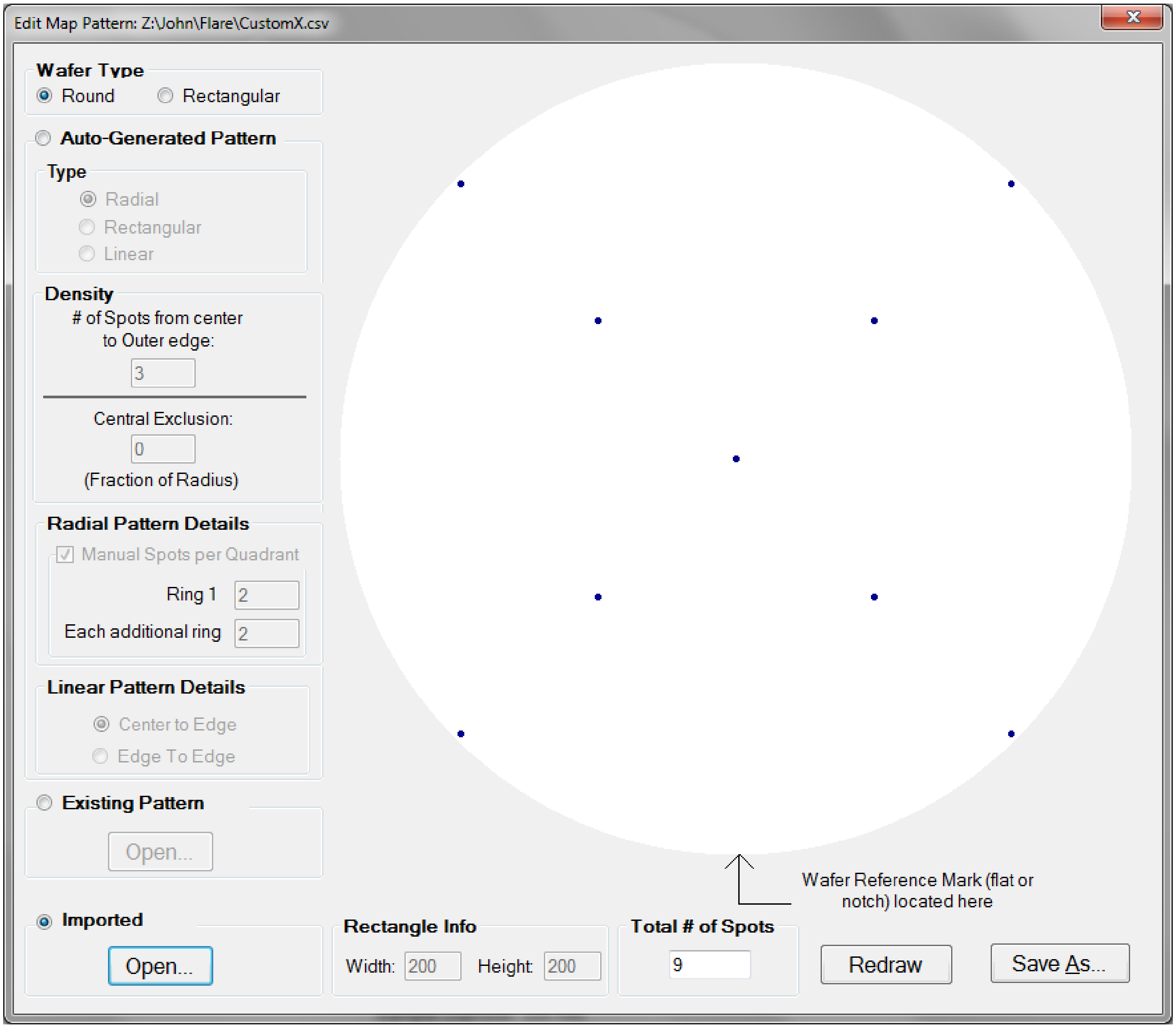


Figure: "X" pattern created using Excel.

Step 7: Load map pattern in RsMapper

In RsMapper, click the **Edit...** button next to the **Recipe** pull-down menu on the Wafer Map tab, or **Edit Recipe** if you are in the Measure tab. Click the Wafer Map tab in the recipe window and select **Custom** for the **Coordinate System**. All custome map file names will be listed under **Custom Name**. Here, select **Custom Edit**, and then click **OK**. In the Wafer Map Tab, you should now see the "X" pattern you created. RsMapper is capable of automatically resizing the map pattern after it has originally been created, so there is no need to create multiple versions of the same file. Simply adjust the wafer size in the recipe.

5. Theory of Operation

Resistivity, ρ, is a measure of the inability of a film to support the conduction of electrical carriers. In a metal layer, these carriers are electrons. For semiconductor layers, these carriers can be electrons (n-type material) or holes (p-type material). Resistivity, whose units are ohm-centimeters (Ω-cm), is a bulk property of the material. It is a function of the carrier concentration, n, and the carrier mobility, μ, as expressed in the equation.

$$\rho = \frac{1}{ne\mu}$$

where e is the electronic charge.

When characterizing thin films, it is useful to introduce the concept of resistance per unit area, or *sheet resistance*. The sheet resistance R_S of a homogeneous layer is defined as

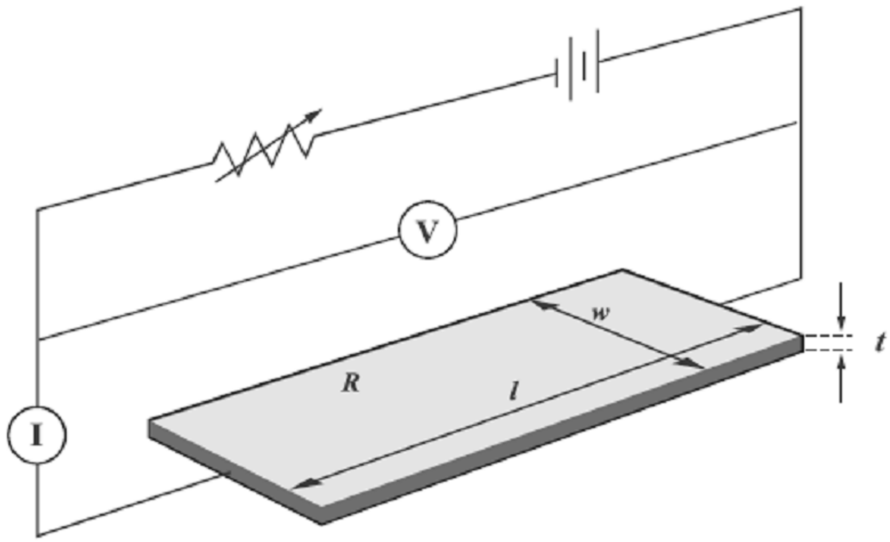
$$R_s = \frac{\rho}{t}$$

where t is the thickness of the layer. For example, a 2-micron thick epitaxial layer for which ρ = 0.1 Ω-cm has a sheet resistance of Rs = 0.1 Ω-cm / 2 x 10^{-4} cm, or 500 Ω/sq.

Resistance, R, is defined as

$$R = \rho(1/A)$$

where the cross-sectional area $A = t \cdot w$



Measuring the Resistance of a Rectangular Bar

Using Ohm's Law ($V = IR$), we can write resistance as

$$R = \frac{V}{I} = \rho\left(\frac{1}{A}\right)$$

and substituting for ρ, we get

$$\frac{V}{I} = R_s \cdot t(1/A)$$
$$\frac{V}{I} = R_s \cdot t\left(\frac{1}{t \cdot w}\right)$$

therefore

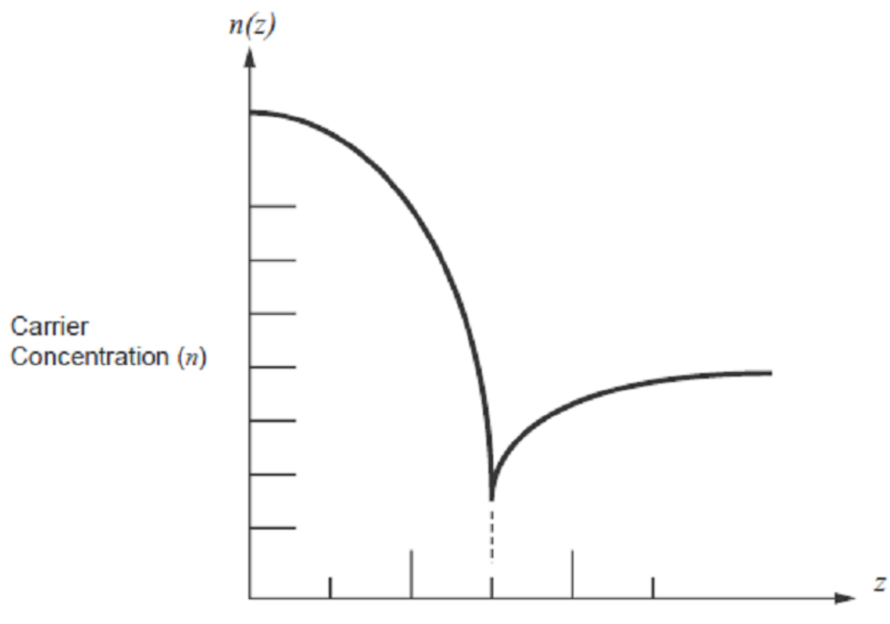
$$R = \frac{V}{I} = R_s\left(\frac{l}{w}\right)$$

Thus, a rectangular bar for which R_S = 100 Ω/sq., *l* = 100 mm and *w* = 10 mm, has a resistance (*R*) of 1000 Ω.

In most semiconductor applications, the carrier concentration, and therefore the resistivity, varies as a function of the depth *z* below the surface of the layer; that is,

$$\rho(z) = \frac{1}{n(z) \cdot e \cdot \mu(n)}$$

where the mobility μ is also a function of the carrier concentration *n*



Carrier Concentration as a Function of Junction Depth

Thus, the measured sheet resistance is a weighted average given by the equation

$$R_s = \frac{1}{\int^t n(z) e \mu(n) dz}$$

where the integration is performed over the full thickness of the film. For the case of a p-n junction isolated layer, the thickness *t* is equal to the junction depth z_j.

The sheet resistance of the conducting layers employed in semiconductor processing varies over a range of about 0.02 Ω/sq. (as with aluminum) to 1,000,000 Ω/sq (as with threshold adjust implants in MOS applications).

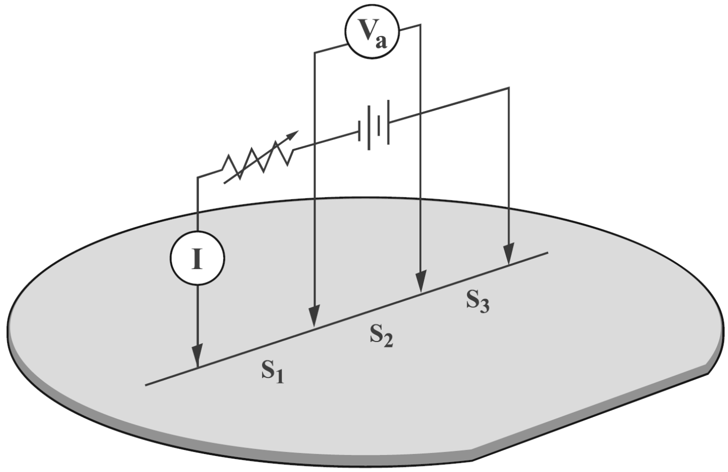
Sheet resistance measurements are routinely employed in semiconductor manufacturing facilities because of the accuracy, repeatability, and relatively low cost of the measurement equipment. In the case of semiconductor layers, they are frequently supplemented by various depth profiling techniques such as Secondary Ion Mass Spectroscopy (SIMS), spreading resistance measurements on beveled samples, and, for lightly doped layers, capacitance voltage techniques.

5.1 R50-4PP Hardware Operation

The four-point probe is commonly used to measure the resistivity of large-volume samples, such as ingots and wafers, and the sheet resistance of thin layers, such as epitaxial silicon and sheet diffusions. The resistivity and surface preparation of the material are important determinants of the accuracy of the measurements that can be made with the four-point probe. As discussed below, sample geometry must also be taken into account to ensure accurate readings.

Probe-tip spacings typically range from 0.025 inches to 0.062 inches. Precision four-point probe assemblies employ ruby guides and individually adjusted springs for each probe tip. Probe force, tip radius, and probe material must be selected with consideration for the resistivity, hardness, and thickness of the layer to be measured.

The sheet resistance Rs is obtained by introducing a current I through two pins and determining the voltage drop V across the two remaining pins. For the linear array, it is customary for the outer two pins to carry current and the inner two pins to measure the resulting voltage.



If the probe-tip spacing is equal (S1=S2=S3) and the sample area is large compared to the probe tip spacing,

$$R_s = \left(\frac{\pi}{\ln 2}\right)(R_a)$$
$$= 4.532 R_a$$

where $\mathbf{R_a = V_a/I}$.

NOTE: **R** and $\mathbf{R_a}$ represent the average of the two resistance values obtained by reversing the polarity of the current supply.

Geometric Effects in Four-Point Probe Measurements

As in the case of microelectronic resistor structures, four-point probe sheet resistance measurements are susceptible to geometric errors. Accurate measurements require compensation both for variable probe-tip spacing
and the influence of non-conducting wafer boundaries. If these effects are known, the sheet resistance is

$$R_s = k\left(\frac{V}{I}\right)$$
$$= \quad kR$$

where B is a correction factor (Cf) that takes into account geometric effects.

Self-Compensation for Geometric Effects Using Paired ResistanceMeasurements

Sheet resistance mapping of highly uniform layers, such as those obtained by ion implantation, requires a greater accuracy and measurement repeatability than can be achieved using the conventional measurement technique and the correction procedures previously discussed.

Fortunately, for the case of the linear array there exists a self-compensation technique (called dual configuration) for eliminating geometric sources of error, analogous to that used with van der Pauw sheet resistors. The standard (traditional) technique requires the four pins to be parallel to the radius of a circular wafer (β = 0). The enhanced technique is valid if the probe tip array is perpendicular (β = π/2) to the radius as long as $\mathbf{r - r_o > 1S}$, where B is the average probe tip spacing.

Two resistances are measured using one of these techniques. The first resistance, $\mathbf{R_a}$, is obtained in the conventional manner with the outer pins carrying current while the inner pins measure the resulting voltage drop. The second value, $\mathbf{R_b}$, is obtained by passing current between the first and third pins and measuring voltage across the second and fourth pins. Then, the sheet resistance is calculated as

$$R_s = k_\xi R_a \ \text{ for the standard technique}$$
$$R_s = j_\xi R_a \ \text{ for the enhanced technique}$$

where $\mathbf{k_\xi}$ and $\mathbf{j_\xi}$, the geometric correction factors for the standard and enhanced techniques respectively, depend only on the ratio $\mathbf{\xi = R_a/R_b}$

For the ideal case of equal probe tip spacing (S1=S2=S3) on an infinite sheet (r = ∞),

$$\xi = \frac{R_a}{R_b} = 1.2619, \quad k = \frac{\pi}{\ln 2} = 4.532 \text{ and } j = \frac{\pi}{\ln 2} = 4.532$$

Using paired-resistance measurements, one can achieve a measurement accuracy of about 0.5% and a 1σ repeatability of 0.1–0.2%.

6. Appendices

This section contains information on various topics as listed below:

Probe Monitoring

How to Replace a Four-Point Probe

Performance Specifications

Software License Agreement

How to Contact Us

For further support, or to report any EHS issues related to the equipment please use the contact details below.

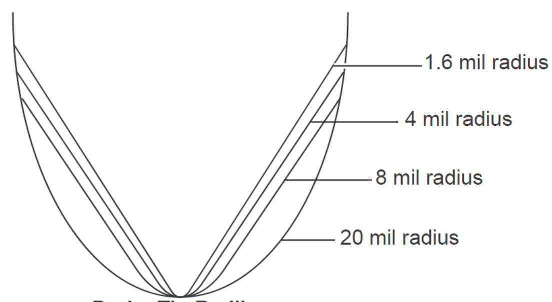
Reach us by phone at +1-858-573-9300, by fax at +1-858-573-9400, by the *Contact Us Now* form on **our website**, or by e-mail at **support@filmetrics.com**.

6.1 Probe Monitoring

As the 4-point probe is used, a certain amount of wear is expected to occur as a result of the repeated collision with the sample surface. The following section provides description of this wear and how it affects measurement, how to track it, and what can be done to maintain the probes.

Contact Resistance and Probe Tip Diameter

Since each probe is not a single contact point but has multiple contact points due to the rough surface of the tungsten carbide, there are multiple resistances all in parallel. The effective resistance is a function of the resistance of all the contact points. You can decrease the effective resistance by increasing the number of contact points. This is done by increasing the area of contact (i.e., the tip radius). The figure below shows the different probe tip types and their diameters.



Probe Tip Radii

Probe Tip Radius	Probe Head Type
1.6 mil (41 microns)	A, E & F
4 mil (102 microns)	B & G
8 mil (203 microns)	C & H
20 mil (808 microns)	D

A sharp probe, such as a 1.6-mil radius tip, works very well for metal layers where contact resistance and probe penetration are not a problem. Silicon wafers and wafers with implanted layers can have high contact resistance. For high dose implants (> 1E14 ions/cm2) or low-resistivity silicon (lower than 10 -cm), a 4-mil radius tip is recommended. For medium-dose implants (1E14 – 1E13 ions/cm2) and medium-resistivity substrates (1–100 Ω-cm), an 8-mil tip is more appropriate. For low-dose implants(< 1E13 ions/cm2) or high resistivity materials (> 100 Ω-cm), a 20-mil probe tip will probably work best.

When trying to measure a sawed or lapped surface, measurement problems are often experienced because this is a non-continuous surface and will reduce the number of contact points. In this case a higher probe loading or spring pressure is needed to make a positive contact to the surface. An increase to 200-gm loading from the usual 100-gm will usually solve contact problems on rough surfaces. Some bare silicon wafers may have a depletion region caused by the polishing process and may require a 10-minute bake at 200 ^{O}C on a hot plate, to replenish the surface, or a 1.6-mil, 200-gm probe to penetrate the layer. The table below shows a chart of preferred probe-tip radii for different wafers.

Probe Conditioning

Over a period of time, material collects on the probe tips and they will also wear down from repeated contact with sample surfaces. These factors prevent the probe from making good contact with the wafer leading to poor repeatability and measurement errors. The *Probe Conditioning* method employs a ceramic plate to remove these particles and roughen the surface of the probe tip to restore stable measurements.

Note: *Probe Conditioning* should only be performed when necessary. Routinely conditioning the probe at the beginning of every shift could lead to premature probe failure. Typically, condition a probe only if a Qualification (Qual) Procedure shows poor repeatability or measurement errors.

Qualifying the Probe

To qualify the probe for conditioning:

1. Place a known sample on the stage.
2. Select the appropriate **Recipe**.
3. Use the **Go To** command to move the sample under the probe.
4. Press **Probe Down** to bring the probe in contact with the sample.
5. Enable *Skip motor motions*.
6. Click **Measure**.
7. The standard deviation of the measurements determines the number of repetitions required when conditioning the probe.

Conditioning the Probe

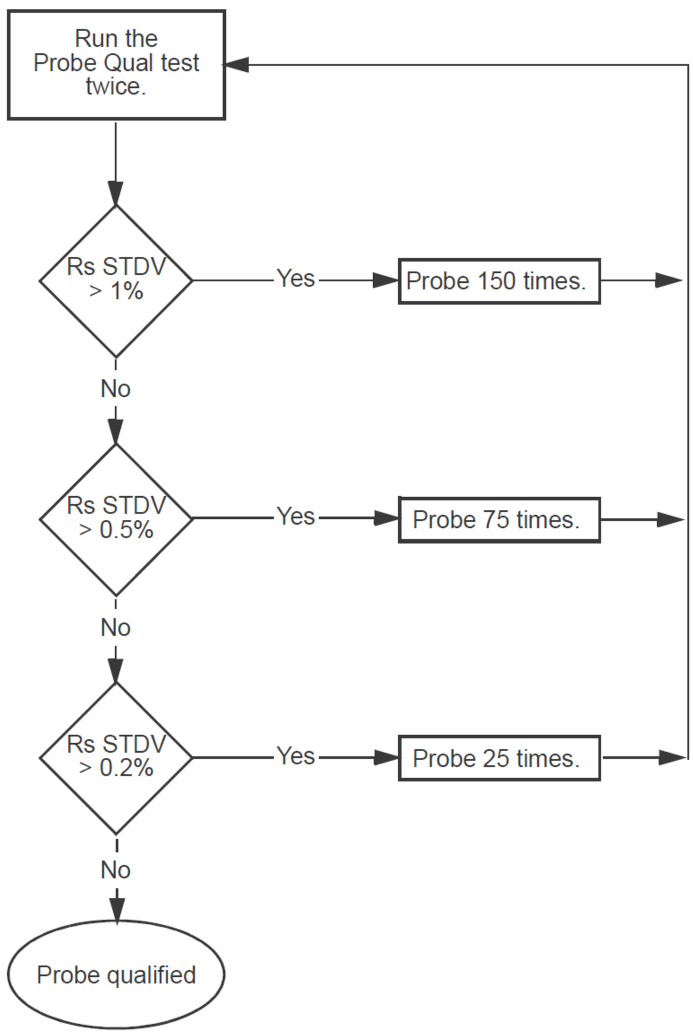
1. Place the ceramic plate (CondWafer-4PP, P/N:200-0639) onto the center of the stage.
2. Use the **Go To** command to move the wafer under the probe.

3. Enter the desired number of repetitions in the *Repeats* box.
   1. The number of repetitions depends on the monitor wafer and probe head types. Use the results of the qualifying test and the recommendations in the table below as general guidelines. Increase as required.

Standard Deviation (%)	Repetitions
0.2% to 0.5%	25
0.5% to 1%	75
> 1%	150

4. Click **Start…**
5. Perform two more probe qualifications.

The standard deviation values from the second test should be within specification. If the values are out of the specification, repeat the conditioning procedure until the results do not improve from at least two consecutive loops.



If repeated conditioning cycles do not improve the standard deviation results, contact Filmetrics for further corrective action.

6.2 Changing Four-Point Probes

The following steps can be followed to switch between different four-point probe heads as required. We recommend removing any samples from the stage prior to changing out the probe.

1. Click the **Probe Change** button to position the system head. Note that while the **Probe Change** button is selected, all other motion controls are disabled.

2. Pull open the locking lever on the probe assembly.

3. Lift the probe straight up out of the assembly. Note that twisting or turning the probe while removing it may damage the 6-pin connector.

4. Place the probe in the Filmetrics provided storage case for safe keeping.

5. Place the new probe into the probe assembly, being careful to align the 6-pin connector.

6. Push down gently on the top of the probe until set in place.

7. Close the locking lever on the assembly.

8. Click the **Probe Change** button.

6.3 Performance Specifications

General

Z Range:	100 mm
Z Stage Type	Automated
X-Y Stage Type	Automated
Sample Max Weight	2.5kg
Tip-Tilt Stage	+/- 5^{o}, Manual

Electrical Performance 4PP

Site Repeatability	<0.2%
Accuracy	+/- 1%
Measurement Range[1]	5mOhm/sq - 5MOhm/sq
Matching[1]	<0.2%

Mechanical Performance

X-Y Stage Range	100mm x 100mm
Sample Max Width	265mm
System Size, W x D x H	305mm x 305mm x 550mm
System Weight	15kg

X-Y Stage Range	200mm x 200mm
Sample Max Width	365mm

Electrical Performance EC

Site Repeatibility	<0.2%
Accuracy	+/- 1%
Measurement Range[1]	1mOhm/sq - 10MOhm/sq
Matching[1]	<0.2%

Mechanical Performance

System Size, W x D x H	406mm x 406mm x 550mm
System Weight	22kg

Electrical Performance EC

4PP (four-point probe)

Probes	Type A	Type C	Type E	Type F
Probe Spacing	1mm	1mm	1.625mm	0.625mm
Probe Contact Radius	40µm	200µm	40µm	40µm

[1] Typical value

6.4 End User Software License

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