Operation Instructions – CDE ResMap 168

What is a Four Point Probe?

A 4-point probe measurement tool is a precision instrument for measuring sheet resistance (or Rs) in a conductive media (usually a thin film for the semiconductor applications). The unit expressed is generally called ohms per square. The symbol □, or square, is not a unit like cm^2, it is just a way to express the measure of a sheet or semi-large (compared with the dimension of a probe) area.

The 4-point probe has 4 pins in contact with the sample. Two pins apply a current and the voltage is measured across the other two pins. For our applications, the 4 pins are in a straight line with equal spacing (typically 1-mm). The pins are made of metal, typically Tungsten Carbide, with pointed tips. The tips have radii of between 40 µm to 500 µm (0.0016" to 0.0200", or 1.6 to 20 mils). The pins are in a housing called a probe head. It is loaded axially with springs, with forces typically of 100g. When the pins are pressed onto the sample, the spring is compressed so the pins are retracted (pushed) into the housing to make a good electrical contact for measurement. Later, we will show that this contact is very important.
If one induces a current between pins 1 and 4, and measures the resulting voltage between pins 2 and 3, then the sheet resistance is

$$Rs = \pi/\ln 2 * V/I = 4.532\ V/I$$

Modern techniques allow measurement of Rs to a very high accuracy (± 0.5%) and very high precision (Repeatability±0.1%).

Types of Measurements

The 4 point probe measures sheet resistance Rs directly for many applications such as implant films, metal films, doped silicon, and epitaxial layers. One either adopts or forces to adopt Rs as the native unit. One can derive other units such as film thickness w, or bulk resistivity ñ from sheet resistance.

Film thickness

The thickness of a metal film cannot usually be measured optically like a dielectric film because it is, in general, not transparent to light. The sheet resistance measurement can be used to calculate film thickness. If one assumes the film behaves like a bulk material (or the electrical and mechanical properties do not change in the film within the thickness range), then one can express the thickness as

$$w = ñ / Rs$$

where ñ is the bulk resistivity. Many films, however, do not behave nicely and ñ is not uniform within the thickness of the film. If we assume that ñ decreases as a function of thickness buildup (typical within the first few hundred Angstroms) then one can express the thickness as

$$w = ñ' * Rs^{a}$$

As an example for CVD W film, the thickness in Å can be expressed as $w = 1950.1\ Rs^{-0.65567}$ (with Rs in Ω/□), within certain ranges of thickness. Following is a table of commonly used parameters as provided by Sematech, after much characterization:

Film	ρ′	β
Ti	3652.99	– 0.689
TiN	3233.58	– 0.629
W	1950.1	– 0.65567
Al	337.17	– 0.92041
Cu	479.13	– 0.75681
	$w = \rho' * Rs^{\beta}$	

In general, people often express Rs as basic measurement unit for metal films. In applications for film removal, such as etch back or a CMP process, one must first convert the Rs measurement to film thickness before subtracting to determine the removal rate and uniformity. One cannot subtract pre-Rs from post-Rs directly.

Bulk resistivity

Other applications of the four-point probe are to determine bulk resistivity ñ, since ñ = Rs * w.
The thickness of a doped bare silicon wafer, w, can be measured mechanically. With this, one can calculate ñ from a measurement of Rs.
For epi films, one can also determine the resistivity, ñ. In this case, the epi thickness w is typically measured with an FTIR type instrument.

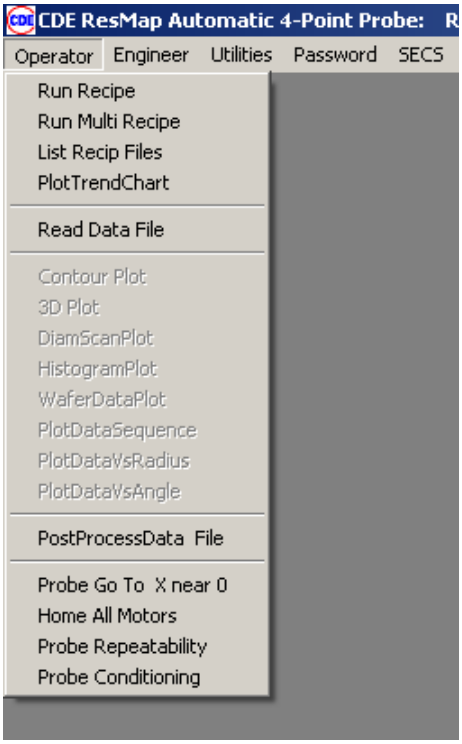
– *Operator Menu*

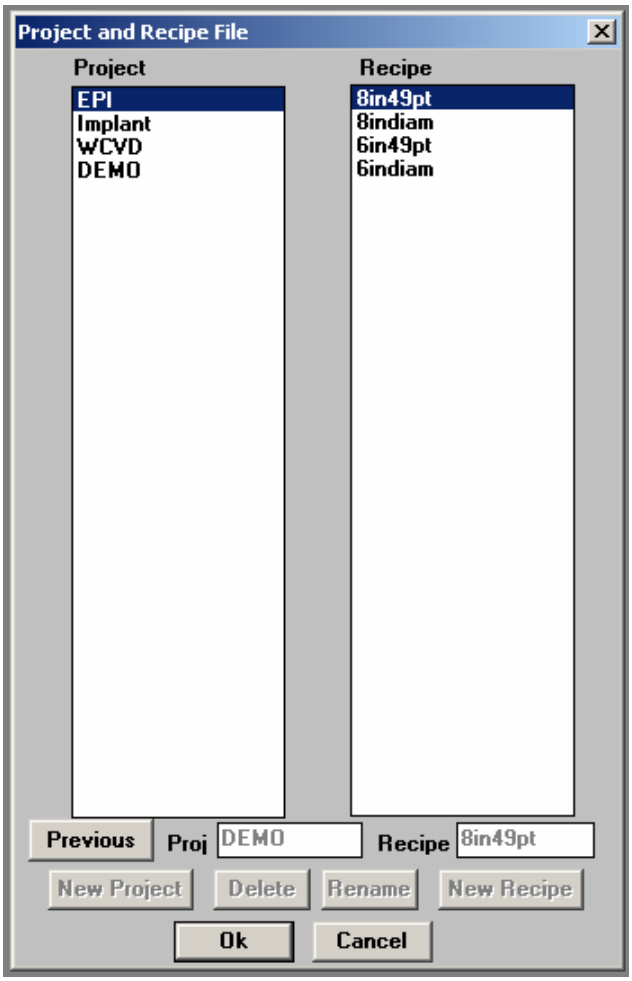
In this section, we will describe functions accessible through the Operator pull-down menu. These include all the routine tasks an operator might need to perform, such as how to make measurements using a recipe, how to display various graphics such as contour map, 3D map, trend charts, etc., how to monitor ResMap performance by measuring repeatability, and how to condition the probe. No password is needed to perform operator functions. The Operator pull-down menu is shown in the figure below. Each of the commands will be described in the order they appear.

Run Recipe

The simplest way for an operator to take data or map a wafer is to use a recipe. Recipes are created and modified in the Engineer menu and this is described in the next section. ResMap Recipes are organized in two levels: the upper level is a Project whose name is a folder, and the lower level is a sub-directory of the Project. Names for projects and recipes must be made of eight or fewer alphanumeric characters, like file names. We will describe these in detail.

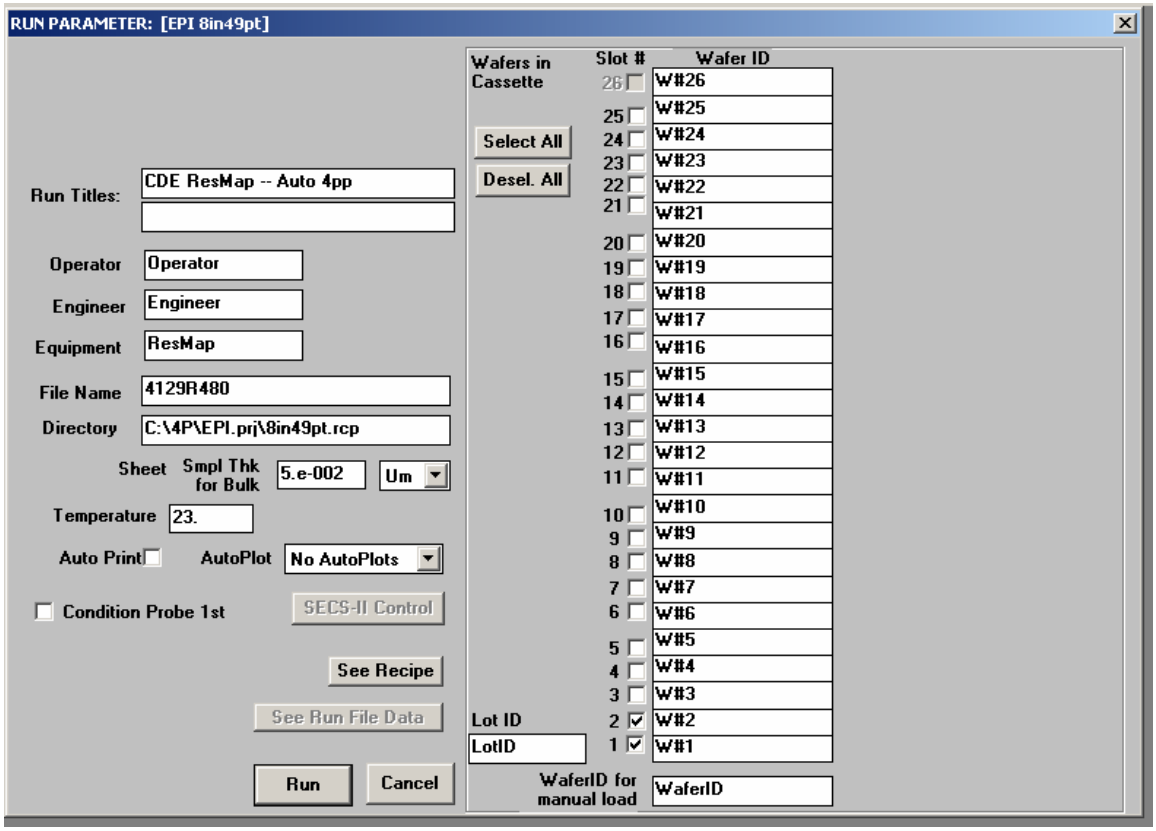
The operator selects **Operator… Run Recipe…** and then selects a **Project** and a **Recipe**, or clicks on the **Previous** button to repeat the previous recipe.





The operator enters run information in the **Run Parameter** screen shown below. Default example values are provided for all fields (see descriptions below) except which slot.

Here, the samples are loaded onto the stage manually so input the sample in the **WaferID for manual load** field and do not check any of the boxes that select wafers in a cassette. Click the **Run** button.



The fields **Run Titles, Operator, Engineer, Equipment** are all informational only and this information is included in the header of the data file.

A default **File Name** is provided, but any valid file name may be entered by the operator (see below). The **Directory** corresponds to the recipe name, and ordinarily should not be changed.

The Sample thickness is used only for bulk resistivity calculations; for **Smpl Thk**, the conducting layer thickness and units should be entered, which may be only the top layer, or the whole sample, depending on the type of sample. If temperature corrections are desired, and no sensor is present, the temperature may be entered.

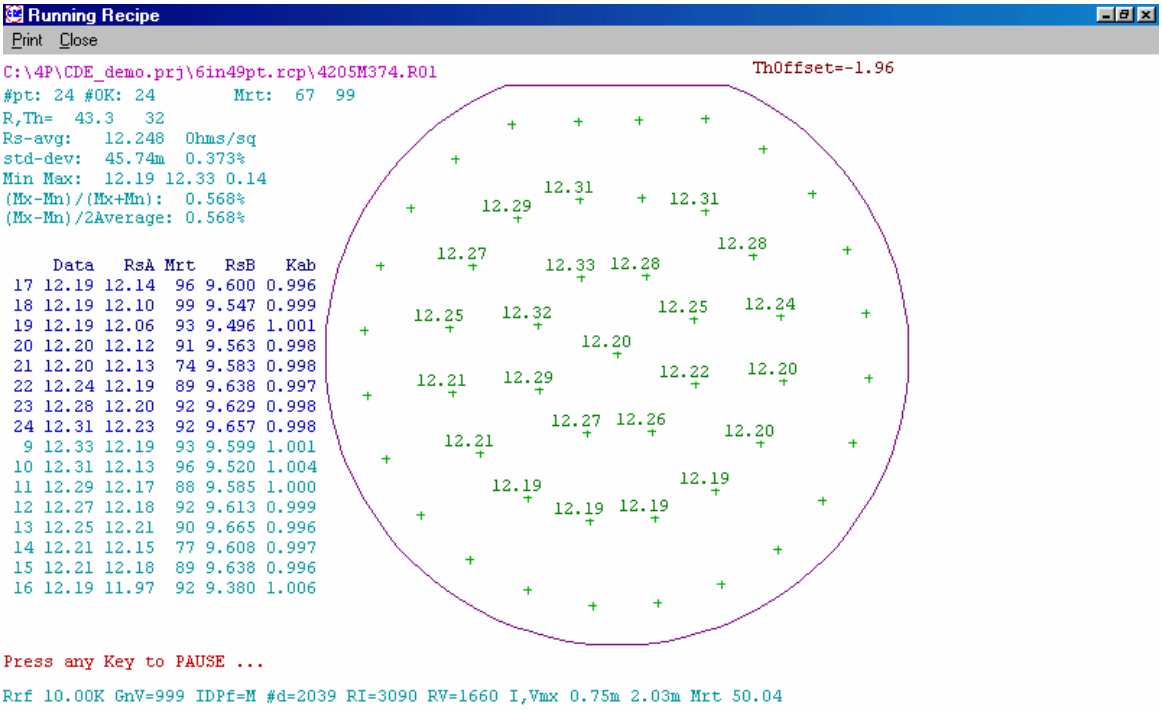
If **Auto Print** (text listing of the data values) or **AutoPlot** (contour/diameter, wafer data, or data sequence plot) is selected, the result will be printed automatically after the measurement is complete.

The operator can view the **Recipe Screen** by clicking the **See Recipe** button. The operator cannot make any changes to the recipe but can switch back to the run parameter screen by clicking the **Cancel** button.

The measurement data are stored in a file on the hard drive in the selected recipe subdirectory. By default, the file name extension is .r## (with ## the slot number) on autoloader measurements, and .RSM on manual measurements. There are three options for file names:

1. If the operator does not enter a filename, the system automatically gives an eight character date-time code of the form YMDDhmms, such as 4A23G108, where Y = the last digit of the current year (4 = 2004), M=month in Hex (A=10 or October), DD is the day of the month, h=hour in alphabet (A = midnight, B=1:00 am, etc.), mm=minute, s=second/6. Note this style of file name always increases in time, and it advances every 6 seconds.
2. A file name can be entered by the operator in an eight character alpha-numeric format, such as MyData. After the run the file name will be automatically incremented to MyData_2, MyData_3, etc. for convenience.
3. The operator may enter the character string “none”. In this case the data will be stored to a file named “none”. The next time the name will be “none” again and this will overwrite the previous “none”. This means only the most recent run will be saved and all previous measurements will be overwritten.

For the Auto Cassette Load ResMap models ResMap 168, ResMap 468, and ResMap 463 the wafers to be measured are selected by clicking the Slot # boxes. If no wafers are selected, the system selects Manual Load automatically. For ResMap models 178 and 273, the wafer is always loaded manually. A Wafer ID can be entered near the bottom of the screen.
During data collection for each wafer, the following screen is displayed:



The **Running Recipe** screen shows a map of the wafer, and posts each data value as it is collected, both on the map, and in a list that also includes other information useful for diagnosis. The running statistics and relevant file information are displayed in the upper left corner.

If the sample is loaded manually, after the data collection is complete, the operator is prompted to continue, at which point the sample may be manually unloaded. On Autoloader systems, the operator is not prompted. The appropriate map (contour map or diameter scan, or none if the number of mapping points is less than five) will be displayed.
If **AutoPrint** was selected, a listing of all the data will be printed automatically after each run. If **AutoPlot** was selected, the corresponding map will be printed. Note that the plotting of the contour map takes a few minutes, which may slow down throughput.

On Autoloader systems, the ResMap software will not prompt the operator to continue after every sample. Instead, after the entire cassette is finished, a wafer summary screen is displayed.