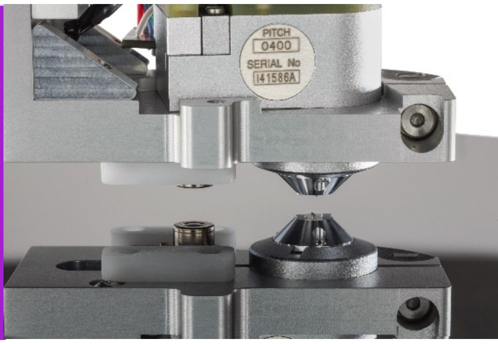
Application Note

Metal Film Sheet Resistance and Thickness Mapping

Filmetrics® R50 Series



Introduction

Most metal traces used to create electrical connections in devices such as semiconductor chips, start out as blanket metal films that are subsequently patterned and etched to form conductive connections between elements of a device.

The KLA Instruments™ Filmetrics® group offers industry standard film resistance measurement systems for semiconductor, PCB, FPD, solar applications and R&D metrology. Our customers measure metal layers for conductive films, adhesion layers and other conductive layers. Each of these applications offers a unique set of challenges, and Filmetrics has developed the software, hardware, and applications knowledge to deliver the right solution.

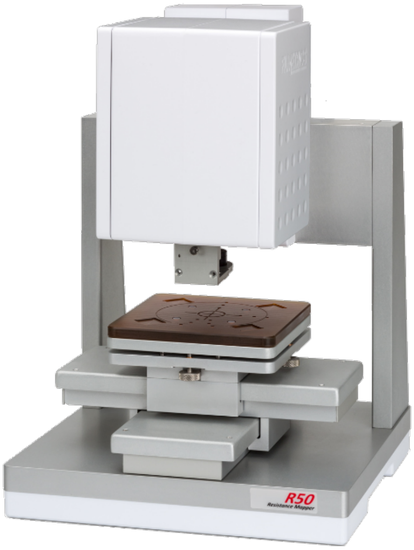


Figure 1. The R50-EC sheet resistance mapping system.

Background

The R50, shown in Figure 1, represents a culmination of over 45 years of resistivity innovation. The first KLA resistivity system was the ADE 6035 eddy current (EC) system introduced in by ADE Corporation. The first four-point probe (4PP) system was introduced in 1984 with the launch of the Prometrix® OmniMap®, which was the first 200mm-capable sheet resistivity measurement system. Although there are capability overlaps between the two measurement techniques, there are significant advantages to each, depending on the specific application. This application note presents an overview of the four-point probe and eddy current techniques for metal film measurement, as well as a discussion on converting a resistance map to a film thickness map.

An example R50 resistance contour map is shown in Figure 2. This color contour map of a thin chromium layer provides quantitative insight about the deposition process, where the measured resistance is higher at the outer edge of the wafer and lowest at the center. This “bullseye” pattern indicates thinning of the chromium wafer from center to edge. Reliable output data is also highly dependent on measurement repeatability, which will also be discussed.

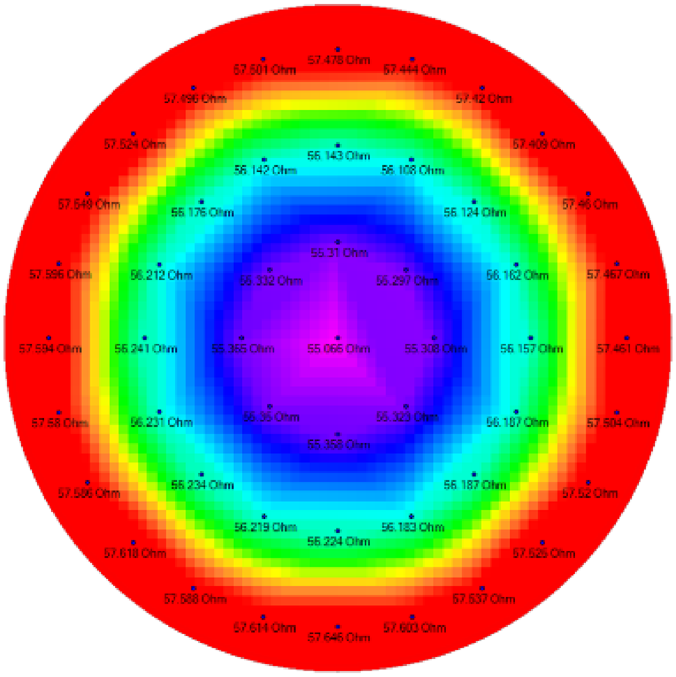


Figure 2. The R50 map of a thin chromium layer shows a typical bullseye map where a significant increase in resistance is observed as the layer thins from center to edge of the wafer.

Four-Point Probe Measurement Technique

The 4PP technique has been around for over 100 years and has maintained popularity due to its basic simplicity and inherent accuracy. In a four-point probe design, electrical current is passed between two pins in contact with a conductive surface while the voltage is measured between two additional pins also in contact with the surface, as shown in Figure 3. Typically, the pin arrangement is either a linear or square array, with this discussion focusing on the linear array used by the R50 probes. For most applications, the standard measurement configuration (Figure 3, left) is used, but the alternate measurement configuration (Figure 3, right) may be used as part of the R50 Dual Configuration method, in cases of current crowding at the edge of a film or for correction of pin spacing variations. The measurement results presented here utilized the standard configuration only.

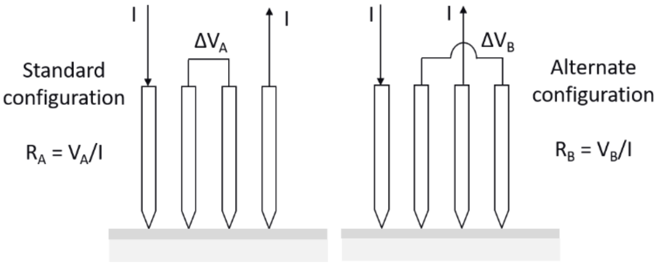


Figure 3. Four-point probe pin schematic for both the standard (left) and alternate (right) linear configurations. The alternate configuration is used as part of the R50 Dual Configuration measurement method, which is typically used in cases of current crowding at the edge of a film or when pin spacing variation requires correction.

Eddy Current Measurement Technique

The EC technique measures the amount of eddy current induced in a conductive layer by an applied alternating magnetic field, as shown in Figure 4. A time-varying drive current through a coil creates a time-varying primary magnetic field around the coil. As the probe coil approaches the conductive surface, time-varying (eddy) currents are induced in the conductive material. These eddy currents create their own time-varying secondary magnetic field that couples to the coil, creating a signal change proportional to the sheet resistance of the sample. The more conductive the layer, the greater the induction of eddy currents and the greater the change in the real and imaginary impedance of the driving coil.

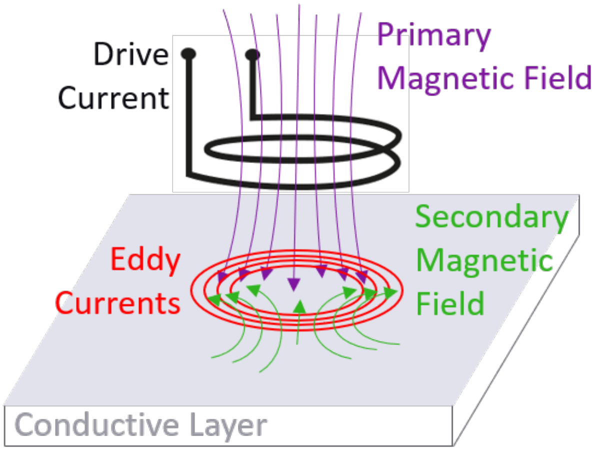


Figure 4. The eddy current (EC) technique a time varying current through a coil creates time varying eddy currents in the conductive layer. These time varying eddy currents in turn create a magnetic field which modify the impedance of the driving coil which is inversely proportional to the sheet resistance of the layer.

R50 Sheet Resistance Data Analysis and Visualization

Once either 4PP or EC measurements are made and the sheet resistance (Rs) is calculated, the R50 data is handled similarly for either method. Depending on user preference, sheet resistance values can be exported directly, or the data can be converted to film thickness using the conversion function in the RsMapper software:

$$Rs = \rho / t$$

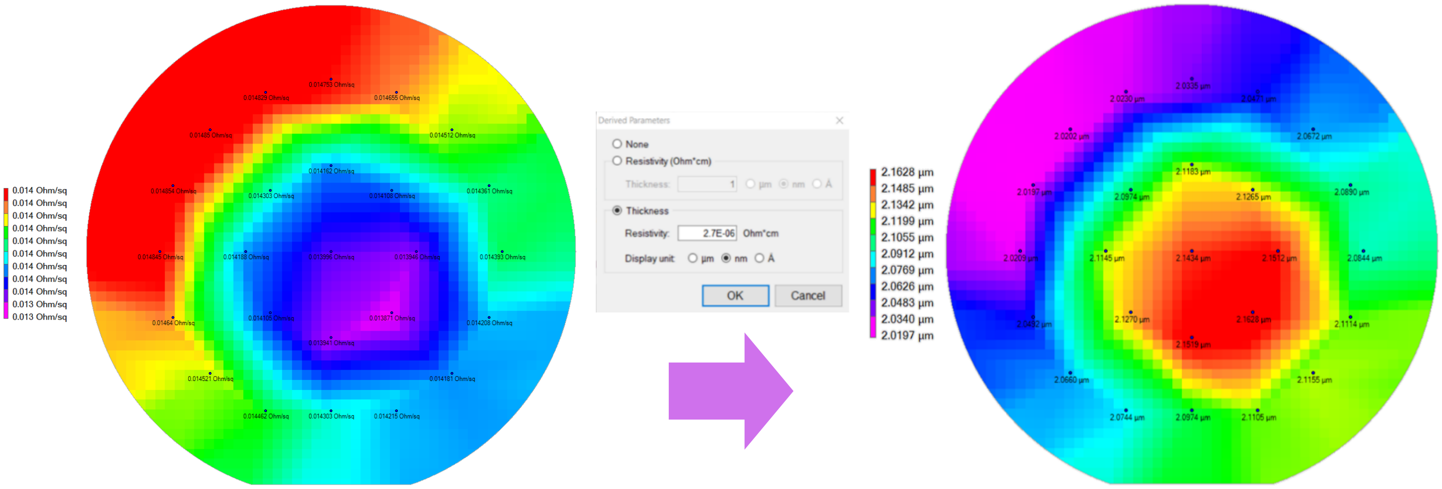
where ρ is the resistivity and t is the film thickness.

Figure 5 shows both a sheet resistance map and a film thickness map of a 2µm nominal thickness aluminum film. From the sheet resistance data (Figure 5, left), a nominal resistivity is applied (Figure 5, center) to convert the data into a film thickness map (Figure 5, right). Displaying the data as a film thickness map may be more useful and visually meaningful for some applications. The RsMapper software also provides Difference Maps, where mapped data from two specified wafers are plotted as a single map showing the difference between them. This feature is especially useful for evaluating the sheet resistance before and after etching or polishing processes, for example.

Choosing the Appropriate Technique

The R50-4PP has a maximum sheet resistance of 200MΩ/sq., which makes it ideal for the thinnest of metal films. For very thick metal films, the voltage drop (between pins 2 and 3 in Figure 3, left) becomes very small, effectively limiting the 4PP technique to measuring metal films less than a few microns, depending on the resistivity of the metal.

The EC method is limited to about 100nm of metal thickness (or about 10Ω/sq., depending on the type of metal) for sheet resistance measurement, due to the minimal eddy currents



○ None
○ Resistivity (Ohm*cm)
Thickness: 1 ○ µm ● nm ○ Å
● Thickness
Resistivity: 2.7E-06 Ohm*cm
Display unit ○ µm ● nm ○ Å

Figure 5. A 2µm thick aluminum layer is mapped for sheet resistance (left). The RsMapper software enables the derivation of film thickness (center) to produce the derived film thickness map (right). The thickness map exhibits an off-center mound, which may be due to an offset in the deposition system. Other possible causes include misalignment of the wafer to the metal target or a slight tilt in the wafer, which will also produce similar

produced by very thin metal films. This limitation is due in part to the very small spot size of the R50-EC.

For very thick metal films, the EC signal increases such that there is no practical limit to the thickness of metal film that can be measured. For films below 1mΩ/sq., please contact your local KLA representative.

In the range where both 4PP and EC techniques can be used, one deciding factor may be to avoid damage or contamination from the pins touching the sample. For these types of sensitive surfaces, the EC technique is recommended. If the film to be measured is on a conductive substrate that could produce additional eddy currents, the 4PP technique is recommended, assuming an insulation layer that blocks the 4PP DC current.

Other Metal Film Applications

Some applications require measurement of buried or backside metal layers. For buried layers, any non-conductive layer blocking contact of the 4PP with the conductive layer will negate the 4PP technique. A buried layer can be measured using EC If the resistance of the buried layer is < 10Ω/sq. For backside layer applications, this layer can be measured by 4PP if the sample can be placed face down on the platen. If this configuration is not possible, the EC technique can often measure through the face up sample to the characterize the backside metal layer.

Conclusions

The Filmetrics R50 series enables measurement of a wide range of metal layers. The R50-4PP is recommended for thinner films, due to their higher resistance and the large measurement range capability of the 4PP. The R50-EC is recommended for very thick films, or for flexible/soft and/or sensitive films where non-contact measurement is required.

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