# 1 GENERAL INFORMATION

## 1.1 INTRODUCTION

In this section, we shall give some background information of the 4 point probe techniques, the applications, CDE ResMap's role in this field and other semi-technical information.

### 1.1.1 What is a 4 point probe?

A 4 point probe [4pp] resistivity measurement tool is a precision instrument for measuring resistivity in a conductive media (usually a thin film the semiconductor applications), called sheet resistivity, Rs. The unit expressed is generally called Ω/□ or 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 area (compared with the dimension of a probe).

The 4 point probe has 4 pins [#1, 2, 3 & 4] in contact with the conductor 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 (typical 1-mm). The pins are made of metal, typically Tungsten Carbide, with a pointed tip. The tips have typical radii of between 40 µm (0.0016" or 1.6 mils) to 500 µm (20 mils). The pins are located in a housing called a probe. It is loaded axially with springs, with forces of typically 100 gms. When the pins are pressed onto the sample, the spring is compressed so the pins are retracted (pushed) into the housing in order to make a good electrical contact for measurement. Later, we will show that this contact is very important.

If one puts a current $I_{14}$ between pins 1 and 4, the measured voltage between pins 2 and 3 is $V_{23}$, then the sheet resistivity is,

$$Rs = \pi/\ln 2 \ . \ V_{23}/I_{14} = 4.532 \ V_{23}/I_{14}$$

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

### 1.1.2 Types of measurements

The 4 point probe measures sheet resistivity Rs directly for many applications such as implant film, metal film, etc. one either adopt or forces to adopt Rs as the native unit.

However, one can derive other units such as film thickness w, media bulk resistivity ρ or other types of measurements.

### 1.1.2.1 Film thickness

Since the thickness of a metal film cannot be measured optically like a dielectric film because it is, in general, not transparent to light, so the resistivity measurement can be used to calculate film thickness. If one assumes the film behaves like a bulk (or the electrical and mechanical properties do not change in the film), then one can express the thickness, $w = \rho\ Rs^{-1}$, where ρ is the bulk resistivity. However, many films do not behave nicely and ρ is not a constant within the thickness of the film. If we assume that ρ decreases as a function of thickness buildup (typical within the first few hundred Angstroms) then one can express $w = \rho'\ Rs^{\beta}$. As an example for CVD W film, the thickness can be expressed as $w = 1950.1\ Rs^{-0.65567}$, over certain ranges of thickness [w in Å, and Rs in Ω/□]. Following is a table of commonly used parameters as provided by Sematech, after much characterization:

| **Film** | $\rho'$ | $\beta$ |
|---|---|---|
| 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 |
| | $w = \rho'\ Rs^{\beta}$ | |

Although people are used to expressing Rs as basic measurement unit for metal films, for film removal such as etch back or CMP process, if one wants to find out removal rate and uniformity, one cannot subtract Rs directly. One need to first convert the measurement to film thickness before subtracting.

### 1.1.2.2 Bulk resistivity.

Other applications of the four point porbe are for measuring the bulk resistivity, ρ, since ρ = Rs x w.

For manufacturers of doped bare Silicon wafers, w, the thickness of the wafer, can be measured mechanically, then one can calculate ρ when Rs is measured.

For EPI films, one can also measure ρ. In this case the EPI thickness w is measured typically with an FTIR type instrument.

## 1.2 ResMap Models

The CDE ResMaps are a series of automatic resistivity mapping systems for various applications. The models and specifications are listed in the following table:

# CDE ResMap 4 Point Probe Product Comparisons

| **Model** | **ResMap 168** | **ResMap 178** | **ResMap 273** | **ResMap 268-SMIF** | **ResMap 188** |
|---|---|---|---|---|---|
| **Feature:** | Auto Cassette Load | Manual Load "Baby" | Manual Load 12" ('Big') | Integrated 8" SMIF | Flat Panel |
| **Wafer Size:** | 4" - 8" C-C<br>2"- 8" Manual | 2" - 8" | 2" - 12" | 8" Auto SMIF,<br>2"-8" manual | 22" x 26"<br>550mm x 650mm |
| **Max Dia. Round Sample:** | 8.2" | 8.2" | 12.1" | 8.5" | |
| **Max Square Sample:** | 5.8" x 5.8" | 5.8" x 5.8" | 8.5" x 8.5" | 6" x 6" | |
| **Typical Measurement Time:** | 1-sec per site | 1-sec per site | 1.5-sec per site | 1-sec per site | 2-sec per site |
| **Typical Wafer Transport time (each way):** | 10-sec | N.A. | N.A. | 10-sec | N.A. |
| **Throughput** | 40 wafers/hour 49-sites | 1-min per wafer 49-sites | 1.5-min per wafer 49-sites | 40 wafers/hour 49-sites | |
| **Measurement Range:** | 5mΩ/□ – 5MΩ/□ | 5mΩ/□ – 5MΩ/□ | 5mΩ/□ – 5MΩ/□ | 5mΩ/□ – 5MΩ/□ | 5mΩ/□ – 5MΩ/□ |
| **Repeatability [1σ]** | | | | | |
| **Same Spot:** | < ±0.02% | < ±0.02% | < ±0.02% | < ±0.02% | < ±0.02% |
| **Multiple Sites Nearby:** | < ±0.1% | < ±0.1% | < ±0.1% | < ±0.1% | < ±0.1% |
| **Accuracy:** | < ±0.5% | < ±0.5% | < ±0.5% | < ±0.5% | < ±0.5% |
| **Minimum Edge Exclusion:** | < 3-mm | < 3-mm | < 3-mm | < 3-mm | < 7-mm |
| **Size: Width x Height x Depth** | 12"W x 10"H x 28"D | 12"W x 11"H x 19"D | 15"W x 110"H x 19"D | 17"W x 68"H x 30"D | 26"W x 8"H x 343"D |
| **AC power:** | 100V to 240V | 100V to 240V | 100V to 240V | 100V to 240V | 100V to 240V |
| **Computer System:** | Pentium<br>75MHz<br>3.5FD >500HD<br>Color VGA<br>Color Injet Printer | Pentium<br>75MHz<br>3.5FD >500HD<br>Color VGA<br>Color Injet Printer | Pentium<br>75MHz<br>3.5FD >500HD<br>Color VGA<br>Color Injet Printer | Pentium<br>75MHz<br>3.5FD >500HD<br>Color VGA<br>Color Injet Printer | Pentium<br>75MHz<br>3.5FD >500HD<br>Color VGA<br>Color Injet Printer |
| **Mapping Patterns:** | Polar,<br>Rectangular,<br>Line,<br>User defined | Polar,<br>Rectangular,<br>Line,<br>User defined | Polar,<br>Rectangular,<br>Line,<br>User defined | Polar,<br>Rectangular,<br>Line,<br>User defined | Rectangular,<br>Line,<br>User defined |
| **Plots:** | Contour, 3D,<br>Linear,<br>Data on points,<br>Histogram | Contour, 3D,<br>Linear,<br>Data on points,<br>Histogram | Contour, 3D,<br>Linear,<br>Data on points,<br>Histogram | Contour, 3D,<br>Linear,<br>Data on points,<br>Histogram | Contour, 3D,<br>Linear,<br>Data on points,<br>Histogram |