Four-Point Probe Operation

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Thin Film Deposition
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1 INTRODUCTION

1.1 Purpose

This document describes the procedure for measuring sheet resistance on substrates using the Alessi Four-Point Probe.

1.2 Scope

This document describes substrate metrology using the Alessi Four-Point Probe. Parameters such as film thickness, sheet resistance, and bulk resistivity can be evaluated using the Four-Point Probe.

1.3 Definitions

Angstrom	(Å) A unit used to measure very small lengths, such as wave length. Equal to 10^{-10} m
Substrate	The material of which something is made. In this case, a Si wafer or glass slide.
Wafer	A thin slice of semiconductor (such as silicon) used as a base for an electronic component, or substrate.

OVERVIEW

1.4 Four-Point Probe Overview

The Four-Point Probe can be used to measure film thickness, but is usually used to measure the sheet resistance of shallow layers (as a result of epitaxy, ion-implant, diffusion or sputtering) and the bulk resistivity of bare wafers. The schematic representation of the Four-Point Probe is shown in Figure 1. The theory behind this is a fixed current is injected into the wafer through the two outer probes, and a voltage is measured between the two inner probes. If probes with uniform spacing s are placed on an infinite slab material, then the resistivity, ρ, is given by

$$\rho = 2\pi s V/I \text{ μOhm-Centimeters for } t>>s$$

and

$$\rho = (\pi t/\ln 2)V/I \text{ μOhm-Centimeters for } s>>t,$$

with *t* representing the thickness of the thin film. For shallow layers, the above equation gives the sheet resistance as

$$R_s = \rho/t = (\pi t/\ln 2)V/I = 4.53V/I \ \mu\text{Ohm-Centimeter for } s >> t.$$

The approximation used in the above equations is easily met for shallow layers in silicon.

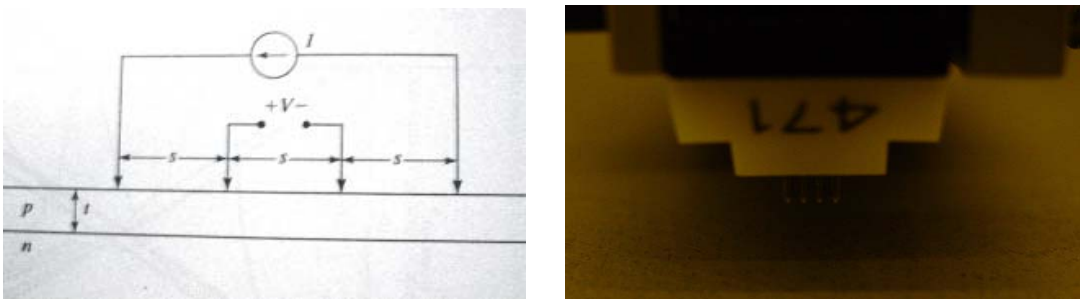

Figure 1 – Four-Point Probe schematic (left) and actual (right).

1.5 Limits of Measurement Capability

1. The probes must be able to make ohmic contact with the material. Gallium Arsenide cannot be probed with this particular model.
2. Very low resistive material (e.g. aluminum, gold, platinum) requires the maximum current from the current source to achieve a reading on the display. Only very thin films (100's of Angstroms up to 1 micron thickness) can be measured. The current through the probe is best restricted to 10 mA because of heating effects and excessive current density at the probe tips.
3. High sheet resistivity material (e.g. ion implanted silicon wafers, silicon on sapphire) can be measured using very low currents (values of 1 μA or less) and avoiding a greater voltage indication than 200mV.
4. Low level measurements are negatively affected by various sources.
5. Know your substrate. An unclean sample or a sample that has surface doping will lead to inaccurate figures due to an impeded ohmic contact or current leakage.

2 Film Thickness Measurement

1. Powering On the Four-Point Probe

1.1 Turn on the power strip located below the Four-Point Probe (Figure 2). This will activate the vacuum pump, which should be heard, and the top Keithley 2400 source meter display will illuminate.

Figure 2 – Power Strip on

2. **Configure the Keithley 2400 Source Meter**

2.1 If the Keithley is not illuminated after the power strip is turned on, assure that the power switch, located on the lower left of the source meter, is in the "on" position.

2.2 Press the "CONFIG" key on the front of the instrument.

Figure 3 – Select "CONFIG"

2.3 Press the "Ω" key.

Figure 4 – Select "□"

2.4 Use the "right/left" arrow keys to select "SENSE-MODE." Press "Enter" to select and the following screen will appear.

Figure 5 – Select "4-WIRE"

2.5 Select "4-WIRE" using the "right arrow" key and pressing "ENTER."

2.6 Exit this menu by pressing "EXIT."

2.7 The upper right portion of the LCD display should read "4W AUTO." If not, repeat this procedure.

Figure 6 – Resistance measurement display

2.8 Press the "Ω" key to set the instrument to measure resistance.

3. **Measure a sample**

3.1 Place the sample under the probe head. To get an accurate measurement, the substrate must be placed such that the probe contacts are in the center of the substrate.

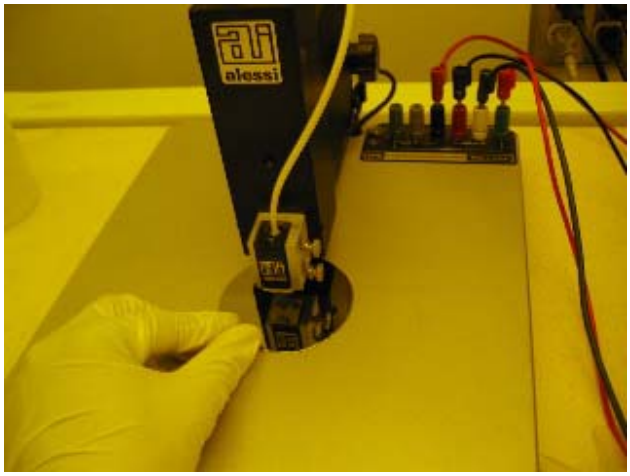

Figure 7 – Place wafer under probe

3.2 Press and hold the button on the right front side of the probe platform. This will move the probe tips onto the sample.

Figure 8 – Lower the probe onto the wafer

3.3 Press the "Output" button on the right side of the Keithley display, while holding the button on the probe platform. The display will show the resistance measured.

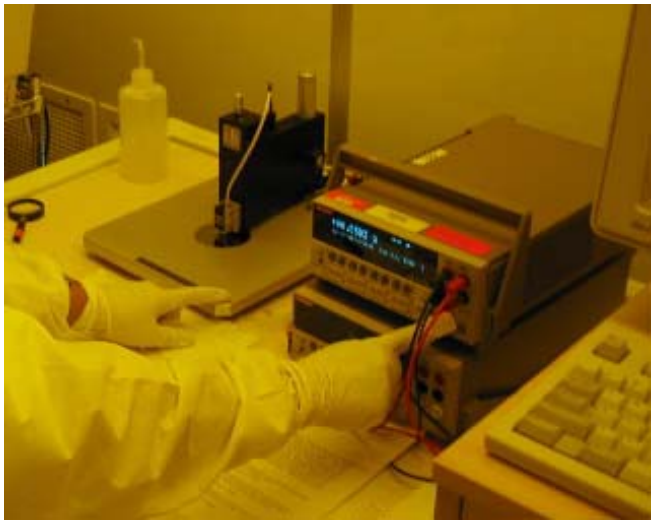

Figure 9 – Measure resistance of the sample

3.4 Press the "Output" button again to turn off the output. **NOTE:** This step must be followed in order to avoid arcing from the probe tips to the substrate. Arcing will damage the equipment as well as the sample being measured.

3.5 Release the button on the probe stand. The probe head will raise.

3.6 Multiply the recorded measured resistance by 4.532. This product is the sheet resistance, in Ω/square, of the film under measurement.

3.7 Multiply the sheet resistance by the film thickness, in cm. This will be the resistivity of the film, in Ω-cm.

3.8 Repeat 3.1 through 3.7 for additional samples.

4 **End of Procedure**

4.1 Turn off power strip beneath the table.