Four-point probe measurement of semiconductor sheet resistance

In a sheet resistance measurement, several resistances need to be considered, as shown in Fig. 1 (a). The probe has a probe resistance R_p. It can be determined by shorting two probes and measuring their resistances. At the interface between the probe tip and the semiconductor, there is a probe contact resistance, R_{cp}. When the current flows from the small tip into the semiconductor and spreads out in the semiconductor, there will be a spreading resistance, R_{sp}. Finally the semiconductor itself has a sheet resistance R_s.

The equivalent circuit for the measurement of semiconductor sheet resistance by using the four-point probe is shown in Fig. 1 (c). Two probes carry the current and the other two probes sense the voltage. Each probe has a probe resistance R_p, a probe contact resistance R_{cp} and a spreading resistance R_{sp} associated with it. However, these parasitic resistances can be neglected for the two voltage probes because the voltage is measured with a high impedance voltmeter, which draws very little current. Thus the voltage drops across these parasitic resistances are insignificantly small. The voltage reading from the voltmeter is approximately equal to the voltage drop across the semiconductor sheet resistance.

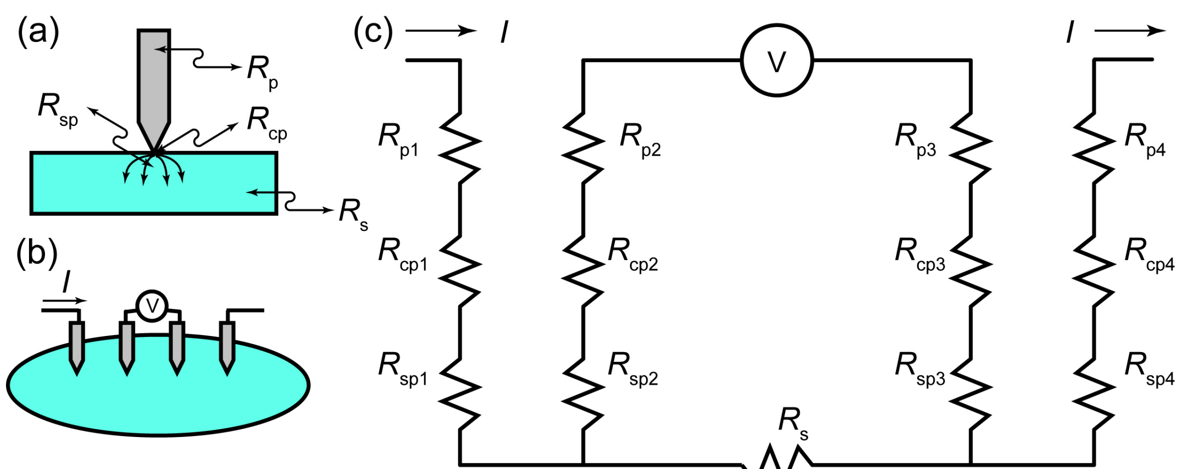

Fig. 1: Four-point probe measurement of semiconductor sheet resistance

By using the four-point probe method, the semiconductor sheet resistance can be calculated:

$$R_s = F \frac{V}{I},$$

where V is the voltage reading from the voltmeter, I is the current carried by the two current-carrying probes, and F is a correction factor. For collinear or in-line probes with equal probe spacing, the correction factor F can be written as a product of three separate correction factors:

$$F = F_1 F_2 F_3$$

F_1 corrects for finite sample thickness, F_2 corrects for finite lateral sample dimensions, and F_3 corrects for placement of the probes with finite distances from the sample edges. For very thin samples with the probes being far from the sample edge, F_2 and F_3 are approximately equal to one (1.0), and the expression of the semiconductor sheet resistance becomes:

$$R_s = \frac{\pi}{\ln 2}\frac{V}{I}$$

The four-point probe method can eliminate the effect introduced by the probe resistance, probe contact resistance and spreading resistance. Therefore it has more accuracy than the two-point probe method.

References:

Schroder Dieter K., *Semiconductor Material and Device Characterization*, 2nd Edition, (John Wiley & Sons, New York, 1998)