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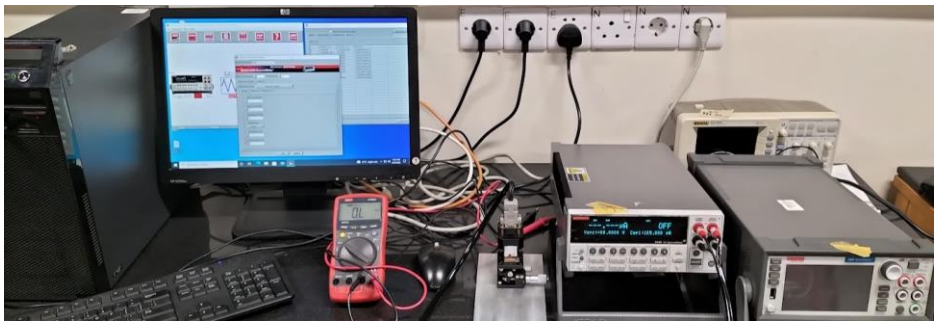
Four Probe Measurement Setup

Version:FPMS-2022-I

Physical Properties Measurement Lab.

Dr. Ghulam Sarwar Butt, Wardah Mahmood (Ph.D Researcher), Dr. Sabieh Anwar



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Four Terminal Sensing (Kelvin Sensing) uses separate pairs of current carrying and voltage sensing terminals for more accurate measurements than the two probe method. Separation of current and voltage electrodes eliminates the lead and contact resistance from the measurement. This is an advantage for precise measurement of low resistance values. LabTracer software runs on PC and communicates with Keithley 2440 sourcemeter using a GPIB interface. LabTracer2.0 may be used with 2400, 2410, 2420, 2425, 2430, 2440, 2601SMU, 2602SMU, 2611SMU, 2612SMU, 2635SMU, 2636SMU, 6430 Keithley sourcemeters. The probe tip size is 0.5mm and probe tip spacing is 1.5mm.

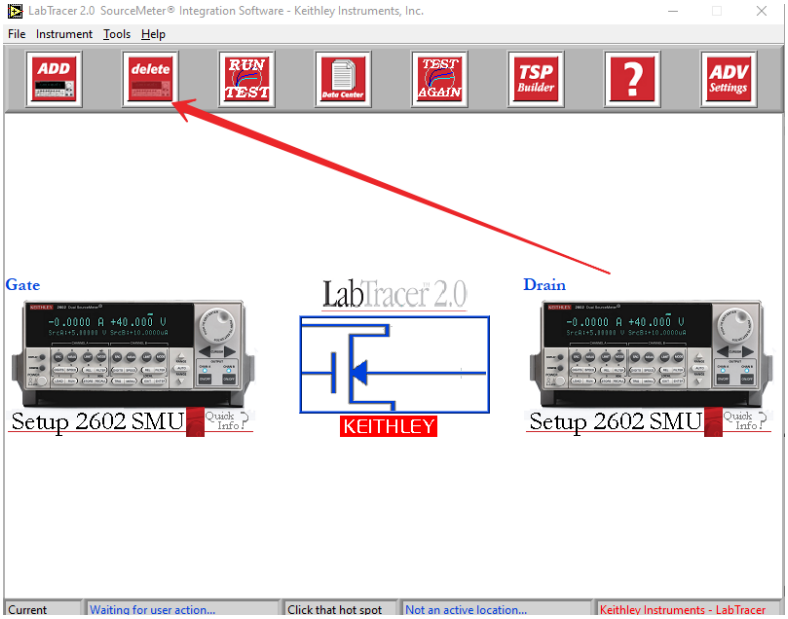
LabTracer Software

Download and install, all steps are explained. The software runs on a PC/Laptop and communicates with SourceMeter (2440) using a GPIB interface.

Four Probe Measurement Worksheet.xlsx

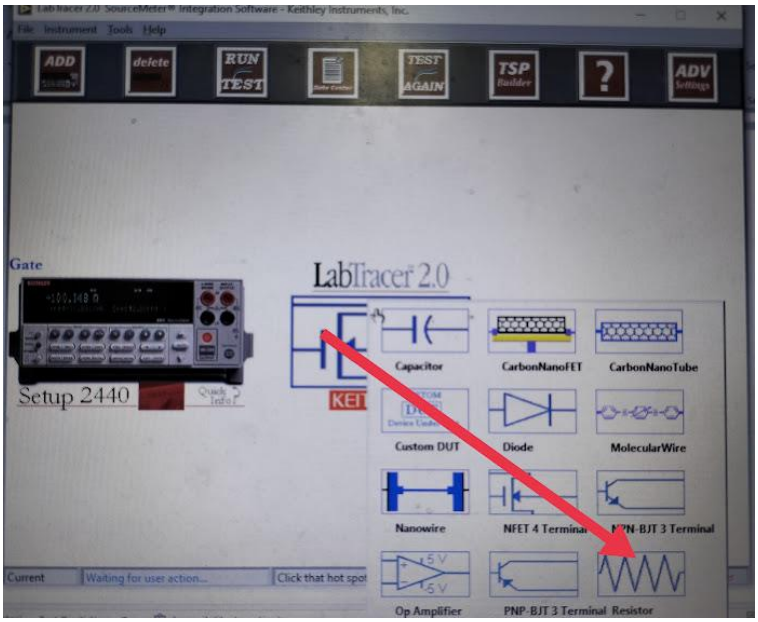
Setting up LabTracer

1. Run LabTracer
2. Delete Drain

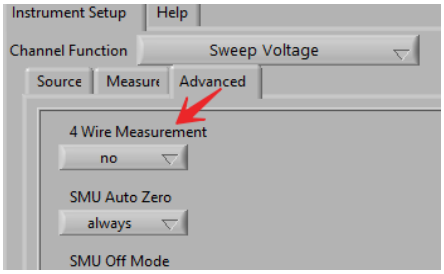


3. Click on Meter and select 2440 from the dropdown list

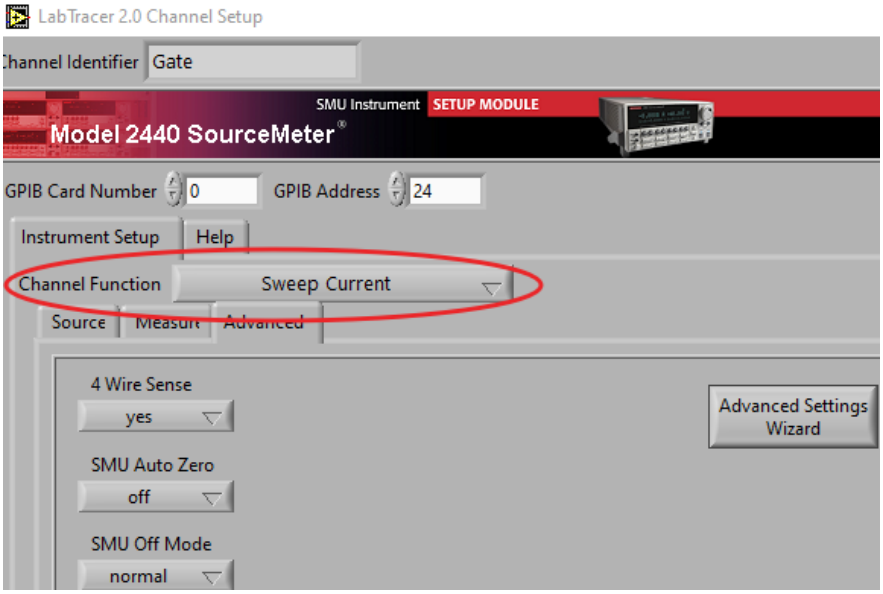
4. Click LabTracer 2.0 and select resistor from dropdown list



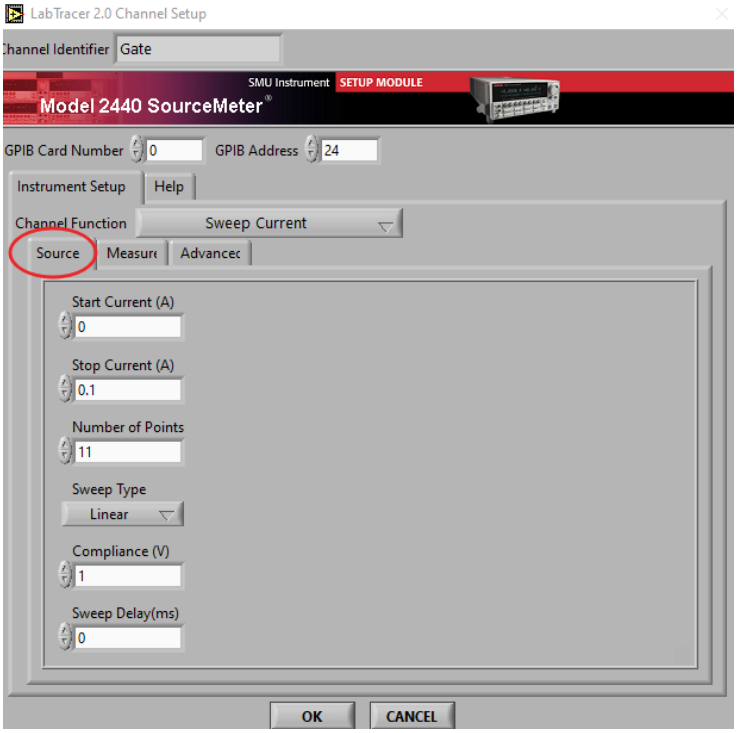
5. Press the “Setup 2440” (below the 2440 meter), press advance, and select YES below the 4-Wire Measurement.
6.



7. From the channel Function select “sweep current”



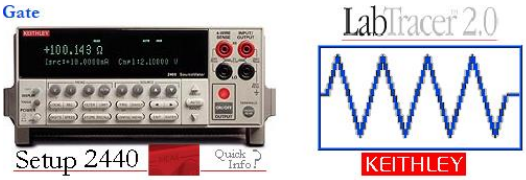
8. Press source and select parameters according to the requirements (impedance) of the sample.



9. Press OK

Taking Measurements with LabTracer

1. Press “RUN TEST”

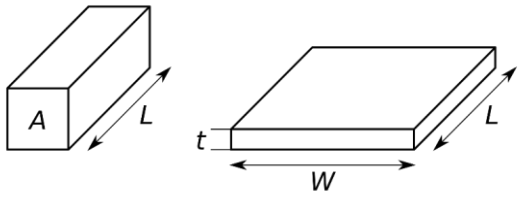


2. Press graph button to see the graph
3. Press “DATA SHEET” to save data
4. Press “FORMULA” to set any formula for the analysis

Sheet resistance

Sheet resistance or the surface resistance is a measure of the lateral resistance through a thin square of material i.e. the current is along the plane of the sheet and not perpendicular to it. It gives an easy comparison between different samples because. It is independent of the size of the square. Sheet resistance can be measured using a four-point probe method. The sheet resistance can be expressed as

$$R = \rho\frac{L}{Wt} \; and \; if \; L = W \; then \; \; Rs = \frac{\rho}{t}$$

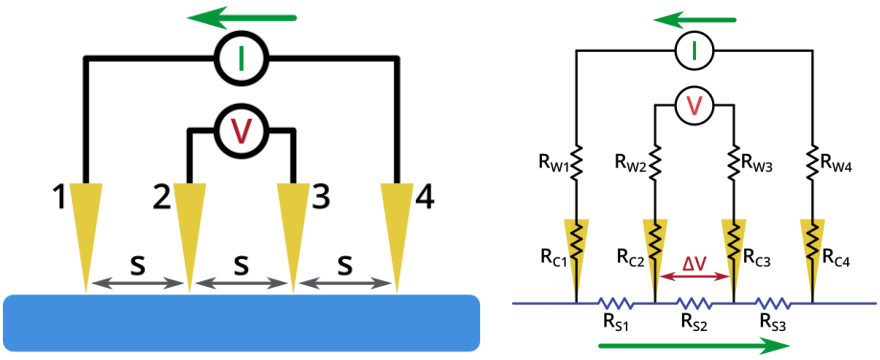


Probe Tip Specification

Probe Tip Size	0.5mm
Probe Tip Spacing (s)	1.5mm

Four Terminal Sensing (Kelvin Sensing)

It uses separate pairs of current carrying and voltage sensing terminals for more accurate measurements than the two probe method. Four probes are equally spaced and collinear, where the outer two probes (force pair) carry current and inner two probes (sense pair) measure voltage. Separation of current and voltage electrodes eliminates the lead and contact resistance from the measurement. This is an advantage for precise measurement of low resistance values. A separate pair of sense connections (voltage leads) does not include the voltage drop in the force leads or contacts. Since almost no current flows to the measuring instrument, the voltage drop in the sense leads is negligible.



Schematic and circuit diagram of four point probe method. Reference

Four-point probes are also used to measure sheet resistance of thin films. It can measure resistivity of either bulk or thin film specimen, however the geometric correction factors are needed to account for the size, shape, and thickness of the sample.

Resistivity Measurements by 4-Probe Method

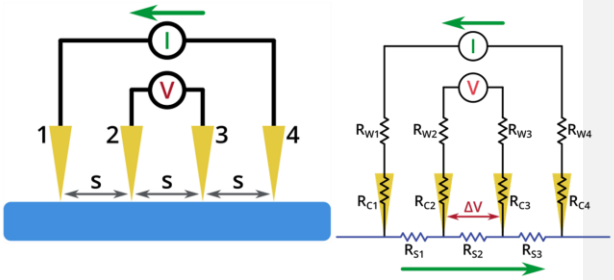
Four probes methods is used for the low resistive samples.

Thin Film (t << s) For a very thin layer t << s, (formula valid if S≤1/40 times the size of sample and t≤ 1/40 times S)

$$\rho = \frac{\pi t}{ln2} \times \frac{V}{I}$$

Bulk Sample (t >> s) For bulk samples t >> s. The expression for bulk resistivity:

$$\rho = 2\pi s \frac{V}{I}$$



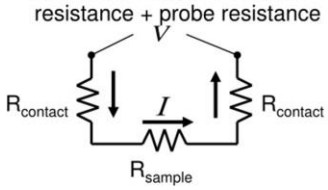
Correction Factor k

Resistivity Measurements by 4-Probe Method

A separate pair of sense connections (voltage leads) does not include the voltage drop in the force leads or contacts. Since almost no current flows to the measuring instrument, the voltage drop in the sense leads is negligible

Two-point probe

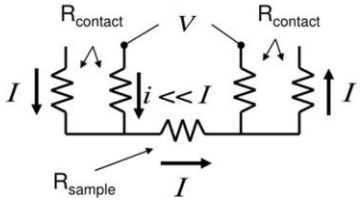
Measures sample + contact resistance + probe resistance



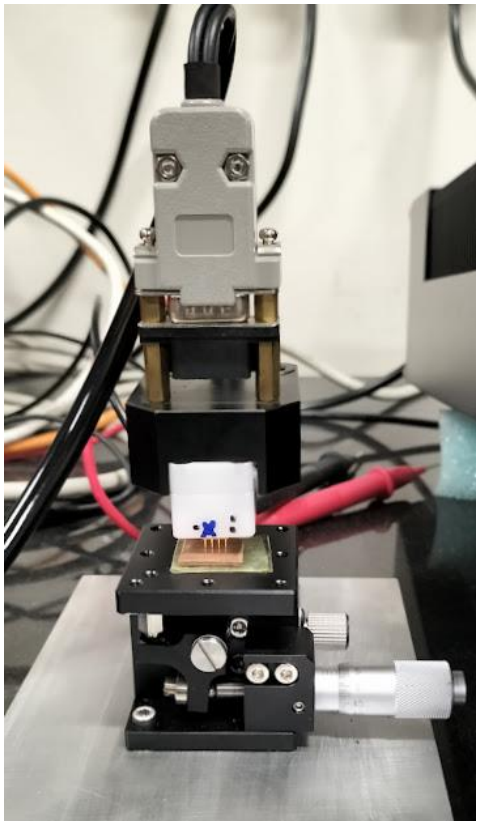
$$V_{meas} = I\left(R_{contact} + R_{sample} + R_{lead}\right)$$
$$= \underbrace{IR_{sample}}_{desired} + \underbrace{I\left(R_{contact} + + R_{lead}\right)}_{significant}$$

Four-point probe

Measures sample only



$$V_{meas} = (I+i)R_{sample} + i\left(R_{contact} + R_{lead}\right)$$
$$= \underbrace{IR_{sample}}_{desired} + \underbrace{i\left(R_{sample} + R_{contact} + + R_{lead}\right)}_{negligible}$$



Thin Film (t << s)

For a very thin layer t << s, the expression for is as follows:

$$\rho = \frac{\pi t}{ln2} \times \frac{V}{I}$$

This expression is valid when the sample dimensions are significantly larger than the probe tip spacing (s), typically having dimensions 40 times larger than tip spacing and the sample is 40 times thinner than the tip spacing (s), otherwise, a correction factor needs to be applied.

Correction Factors

Circular Samples

For a circular sample of diameter **d** and distance **s** between probes, measured resistance at the center of the sample, use the following table for the correction factor.

d/s	Correction
3	0.5
3.448	0.5734
4	0.6462
5	0.7419
6.061	0.8089
7.5	0.8665
8.696	0.8972
10	0.9204
12.5	0.9475
15	0.9628
20	0.9788
28.57	0.9895
40	0.9945
100	0.9991
infinite	1

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Rectangular Samples

For a rectangular sample of width w and length l and distance **s** between probes, measured resistance at the center of the sample, use the following table for the correction factor.

w / s	**l / w = 1**	**l / w = 2**	**l / w = 3**	**l / w = 4**
1			0.2204	0.2205
1.25			0.2751	0.2751
1.5		0.3263	0.3286	0.3286
1.75		0.3794	0.3803	0.3803
2		0.4292	0.4297	0.4297
2.5		0.5192	0.5194	0.5194
3	0.5422	0.5957	0.5958	0.5958
4	0.6870	0.7115	0.7115	0.7115
5	0.7744	0.7887	0.7887	0.7887

7.5	0.8846	0.8905	0.8905	0.8905
10	0.9313	0.9345	0.9345	0.9345
15	0.9682	0.9696	0.9696	0.9696
20	0.9822	0.9830	0.9830	0.9830
40	0.9955	0.9957	0.9957	0.9957
∞	1	1	1	1

Thick Samples

If the sample is 40% thicker than the probe tip spacing, an additional correction factor is required, which depends upon the t/s ratio, listed in the table below:

t / s	Correction Factor
0.4	0.9995
0.5	0.9974
0.5555	0.9948
0.6250	0.9898
0.7143	0.9798
0.8333	0.9600
1.0	0.9214
1.1111	0.8907
1.25	0.8490
1.4286	0.7938
1.6666	0.7225
2.0	0.6336

Bulk Sample (t >> s)

For bulk samples we assume that the probe tip spacing is infinitesimal and samples are semi-infinite in lateral such that t >> s. The expression for bulk resistivity:

$$\rho = 2\pi s \frac{V}{I}$$

Resistivity of Materials

https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity

http://hyperphysics.phy-astr.gsu.edu/hbase/Tables/rstiv.html

References

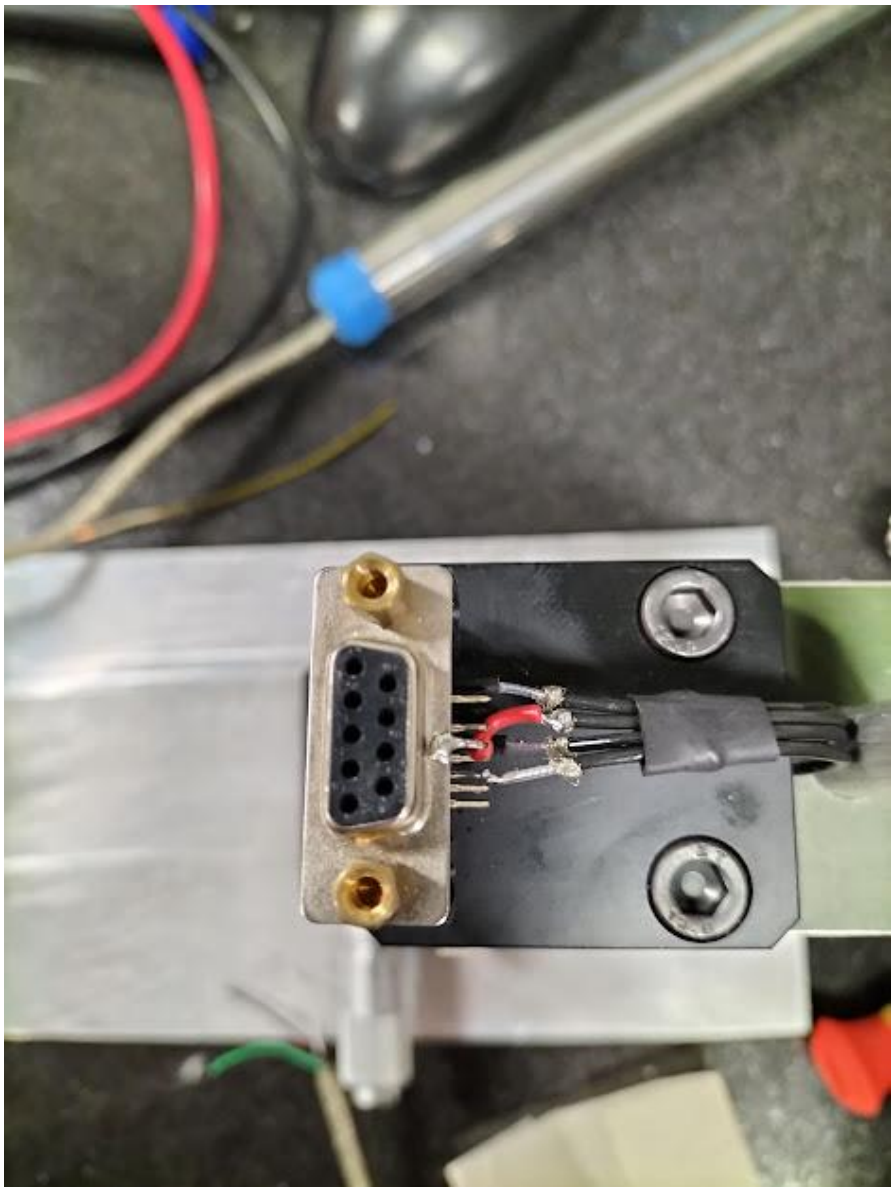
http://four-point-probes.com/four-point-probe-manual/

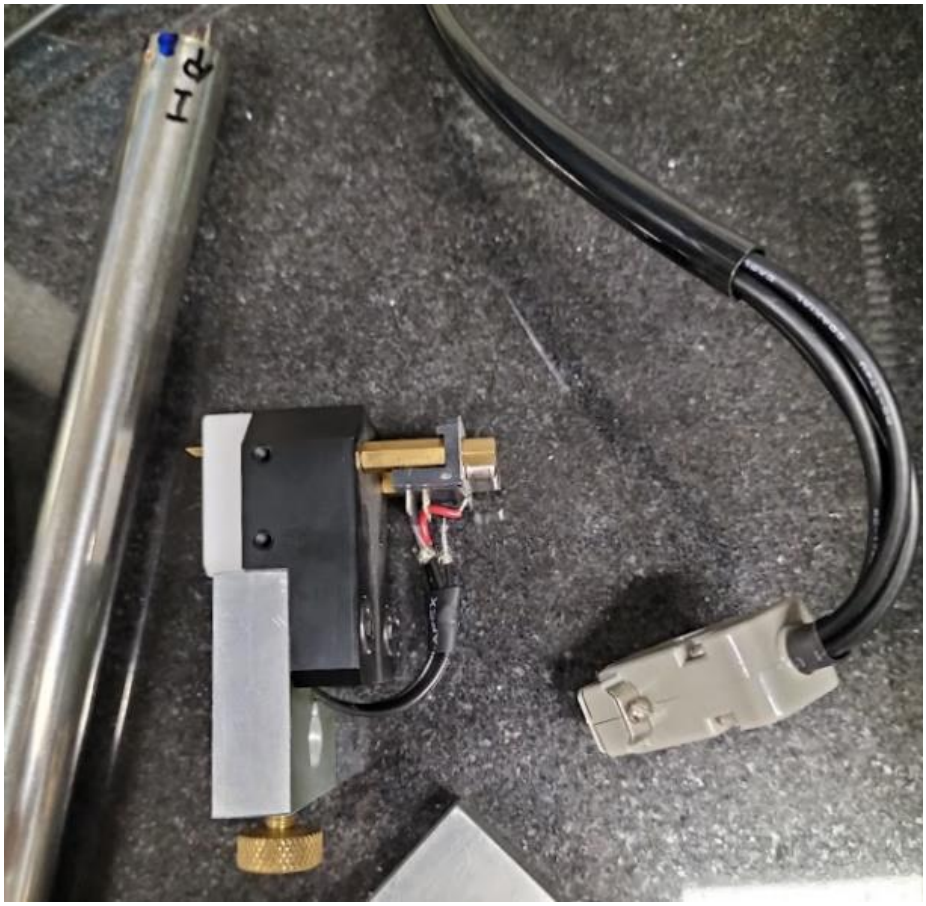
http://four-point-probes.com/questions-answers-regarding-sample-size-and-correction-factors/

https://www.ossila.com/pages/sheet-resistance-theory

Structural, electrical and magnetic properties of evaporated permalloy thin films: effect of substrate and thickness

Troubleshooting

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