Four-Point Probe System

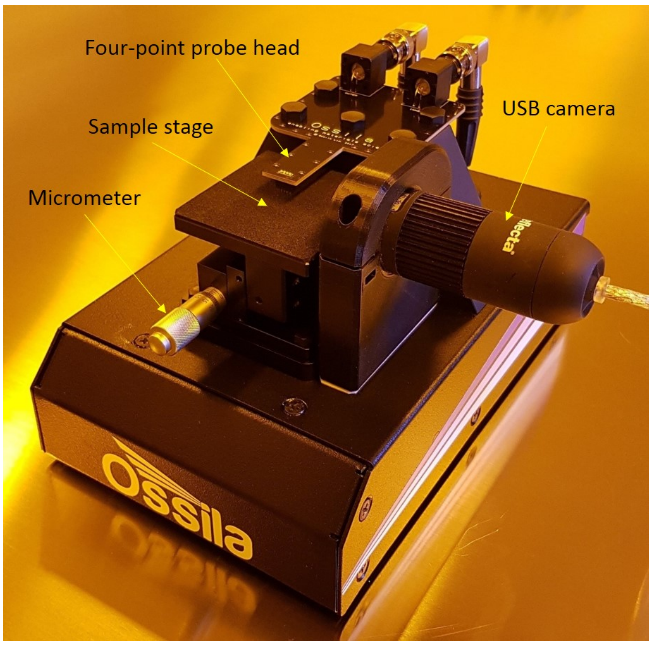
Version: May 10, 2023

Accurate resistivity measurements are critical when characterizing materials, but they are not always easy to make such a measurement on different material types, while they require different instrumentation and techniques.

Electrical resistivity is a basic property that defines how well a material conducts current. It's determined by measuring the resistance of a material sample, then factoring in its geometry. The three basic types of bulk materials: metal, insulator and semiconductors can be defined by their resistivity.

- **Metals** are good conductors of current with typical resistivities of about $\mathbf{10^{-8}\ \Omega.m}$
- **Insulators** are poor conductors with typical resistivities of about $\mathbf{10^{7}}$ **to** $\mathbf{10^{19}\ \Omega.m}$
- **Semiconductors** conduct current better than insulator but not as well as metals; they may fall anywhere from about $\mathbf{10^{-5}}$ **to** $\mathbf{10^{5}\ \Omega.m}$

Ossila Four-Point Probe System ia a device to measure resistivity of bulk materials and thin layers (nanometre range) at room temperature.



The system can measure sheet resistances in the range of 100 mΩ/□ to 10 MΩ/□, enabling the characterisation of a wide range of materials. If the sample thickness was provided, then the average resistivity in Ω.m and conductivity S/m will also be displayed.

The four-point probe head utilises gold-plated, gentle spring-loaded contacts with rounded tips. This results in a constant contact force of 60 grams, preventing the probes from piercing fragile thin films, whilst still providing good electrical contact.

System Specifications

Probe spacing	1.27 mm
Rectangular sample size	minimum 5 mm
Circular sample size ⌀	minimum 5 mm
Maximum sample thickness	10 mm
Voltage range	±100 μV to ±10 V
Current range	±1 nA to ±150 mA
Sheet resistance range	100 mΩ/□ to 10 MΩ/□ (ohms per square)

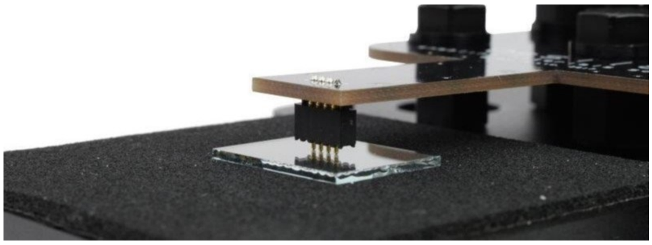
	Current range:	4-	Max 200 μA
1-	Max 150 mA	3-	Max 2000 μA
2-	Max 20 mA	5-	Max 20 μA

Sheet resistance is a special case of resistivity for a uniform sheet thickness. Commonly, resistivity (also known as bulk resistivity, specific electrical resistivity, or volume resistivity) is in units of $\Omega \cdot$ m, which is more completely stated in units of $\Omega \cdot$ m2/m ($\Omega \cdot$ area/length). When divided by the sheet thickness (m), the units are $\Omega \cdot \mathrm{m} \cdot (\mathrm{m/m})/\mathrm{m} = \Omega$. The term "(m/m)" cancels, but represents a special "square" situation yielding an answer in ohms. An alternative, common unit is "ohms per square" (denoted Ω/□), which is dimensionally equal to an ohm, but is exclusively used for sheet resistance. 10 Ω/□ has an actual resistance of 10 Ω, regardless of the size of the square.

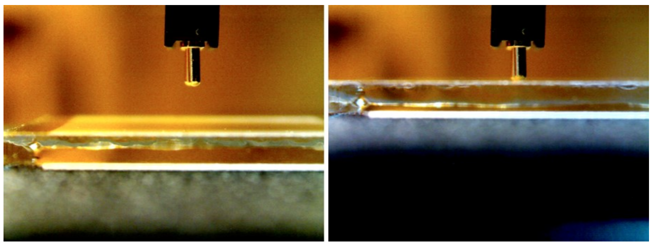
Performing a Measurement

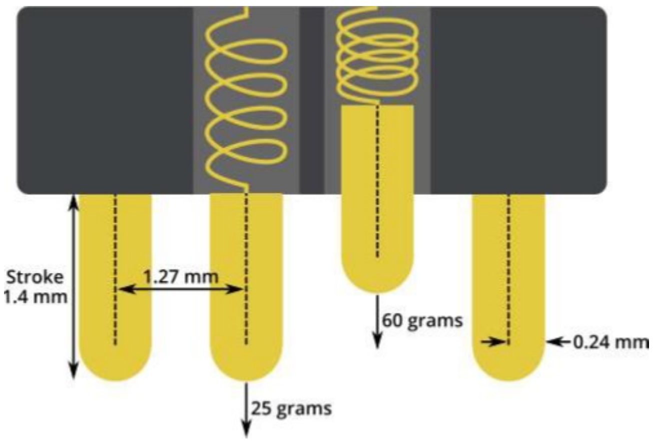
Taking a measurement with the Four-Point Probe System is simple, as it has a built-in source-measure unit included in the system. After plugging the system into the power and PC (USB cable) and connecting the USB camera to the PC, start the USB camera software amcap or Digital Viewer II and the Ossila Sheet Resistance software Ossila Sheet Resistance (both found on the taskbar), and follow these steps:

1. Place the sample on the sample stage centered under the four-point probe head. The tips should be far from the sample edges (as the probe spacing or higher), this is to measure in the center of the sample if possible.



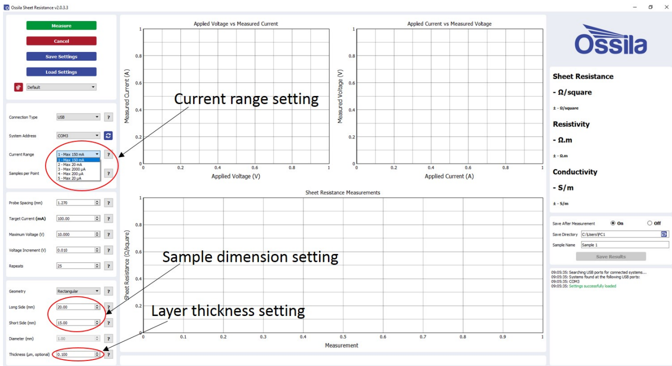
2. Use the micrometer to raise the sample stage until the probes are in good contact with the sample. check this process by the USB microscope.



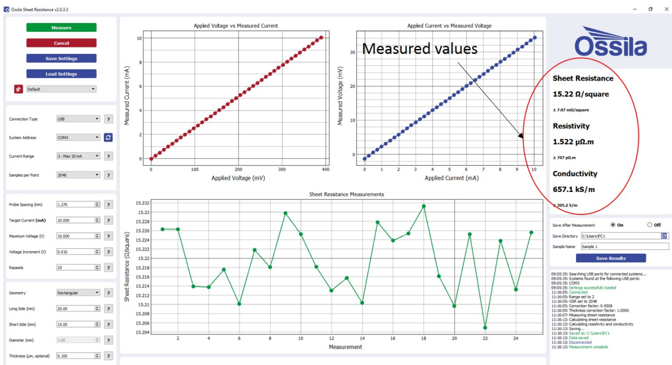


As the probes are spring-loaded, they will compress as the sample is raised into them, creating a constant contact force. If the sample is not centered, lower the sample stage until the probes are not in contact before repositioning it to prevent damaging the probes.

3. Set the appropriate Current range on the source-measure unit (choose from left hand side column). For this you will need to estimate the order of magnitude of the sample. The lower the resistance, the lower the required range number. If you do not know what resistances are likely, start with range 1 (up to 150 mA current) and move down the ranges if the target current cannot be achieved.

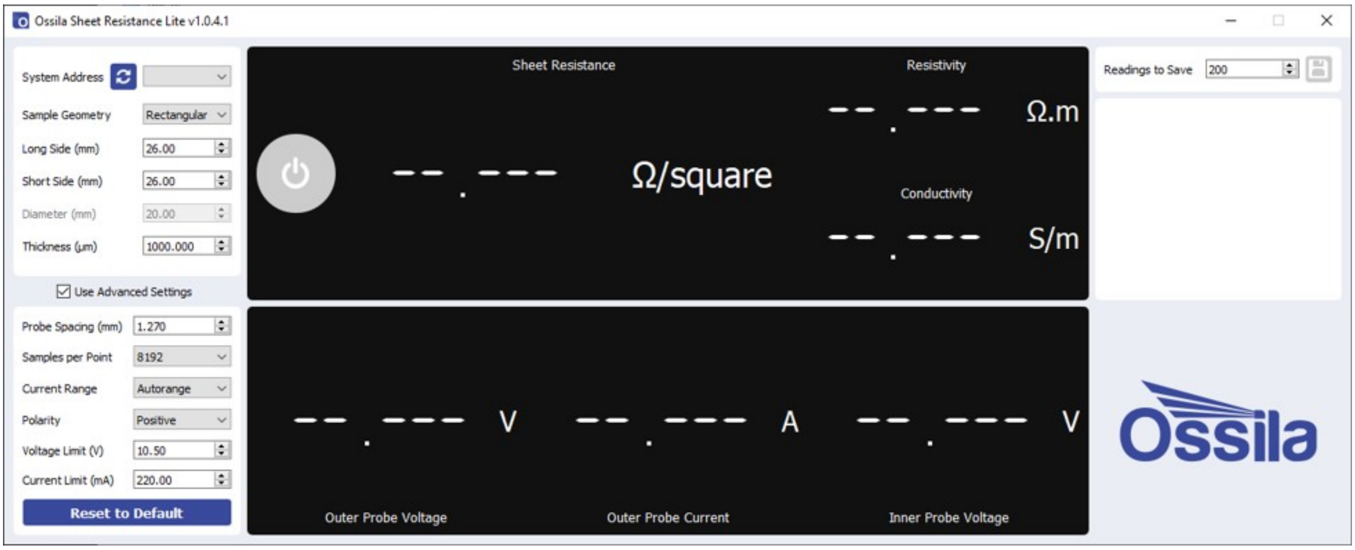


4. Click the Measure **Measure** button. The system will then try to apply the set target current between the outer two probes. Once this has been achieved, the voltage will be measured between the inner two probes and the sheet resistance calculated from these values. Once the measurement has fnished, the average sheet resistance will be displayed in the results box on the right side of the window.



5. The resistivity and conductivity will also be displayed if the sample thickness was provided.

Steps 3 and 4 can be reduced to a very short and effective measurement step by using a second measuring software Ossila Sheet Resistance Lite Ossila Sheet Resistance Lite, this would be a better alternative if the current ranges are difficult to estimate. Here you only press measure and stop. By stopping the measurements you will see the last measurement on the screen.



It is possible to make an average over 200 measuring points when this function is activated.

6. Measure at different points on the sample for better accuracy. The precision of the measurement with this system can vary between 0.05% uppto 5% depending on the sample and system setting parameters. Precision is the maximum deviation between identical measurements (useful for comparative measurements).

Full measurement procedure can be seen in the movie given in the link below:
https://www.ossila.com/products/four-point-probe-system?variant=31916570945

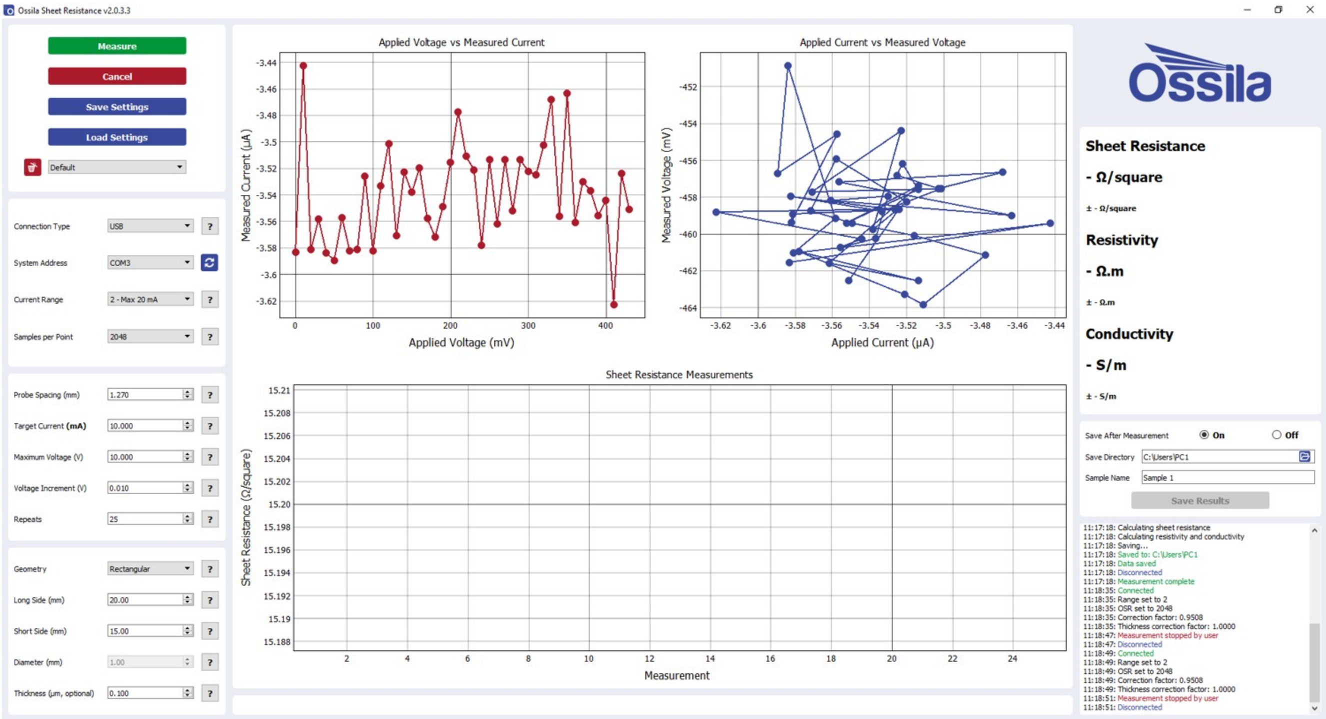
Material **(conductor)**	Resistivity ρ_o (Ω.m)	Conductivity σ (S/m)	C (nm)
Silver	1.6×10^{-8}	6.2×10^{7}	—
Copper	1.7×10^{-8}	5.9×10^{7}	—
Gold	2.2×10^{-8}	4.5×10^{7}	—
Aluminum	2.6×10^{-8}	3.8×10^{7}	—
Tungsten	5.0×10^{-8}	2.0×10^{7}	—
Zinc	5.9×10^{-8}	1.7×10^{7}	—
Cobalt	6.0×10^{-8}	1.7×10^{7}	—
Nickel	7.0×10^{-8}	1.4×10^{7}	—
Indium	8.0×10^{-8}	1.2×10^{7}	—
Iron	9.7×10^{-8}	1.0×10^{7}	—
Platinum	11×10^{-8}	9.4×10^{6}	—
Tin	11×10^{-8}	9.1×10^{6}	—
Chromium	13×10^{-8}	7.9×10^{6}	—
Titanium	40×10^{-8}	2.5×10^{6}	—
Nichrome	110×10^{-8}	9.1×10^{6}	—
ITO	1×10^{-5}	1.0×10^{5}	—

Trouble-shooting

1. The Applies Voltage vs Measured Current and Applied current vs Measured Voltage are not liner and looks chaotic.

Cancel measurement 

. Check on camera pictures if the probes are in good contact with sample surface. Check if you are measuring on the correct sample side (not the back side, uncoated side). Change the current range to lower range.**The lower sample resistance, the lower the required current range number**. If none solved the problem? Meanings you sample is totally insulator (sheet resistance cannot be measured by this device).



2. The Applies Voltage vs Measured Current and Applied current vs Measured Voltage are not liner. Check if the probes are in good contact with sample surface and/or change the current range to lower range.