Cascade CPS-06 Four-Point Probe

You may use this set-up after receiving training from the facility staff. Consult the facility staff if you have any questions or would like to make measurement types not described below. Reservations in FOM are not necessary as of now, but be sure to log on and off when you start and finish.

The four-point probe system is connected to a Keithley 2400 Source-Meter which is configured for single resistance measurements by sourcing current (50 nA to 1.05 A) and measuring voltage (1 µV to 211 V); consequently, the upper limit of measurable resistance is ~4 GΩ. The Agilent B1500A analyzer can be used to measure higher resistance. The Keithley can also be run using LabView, which is particularly useful for automatic calculations. From left to right, the probe head tips are connected to the following jacks: black (I+), red (V+), white (V-), and green (I-). The head is configured to touch down on the surface and then move down an additional 0.04" (~1 mm) with the resistance of the spring force. (See reverse side for information on calculating resistivity and sheet resistance.)

Probe heads (Have a manager show you how to change properly)

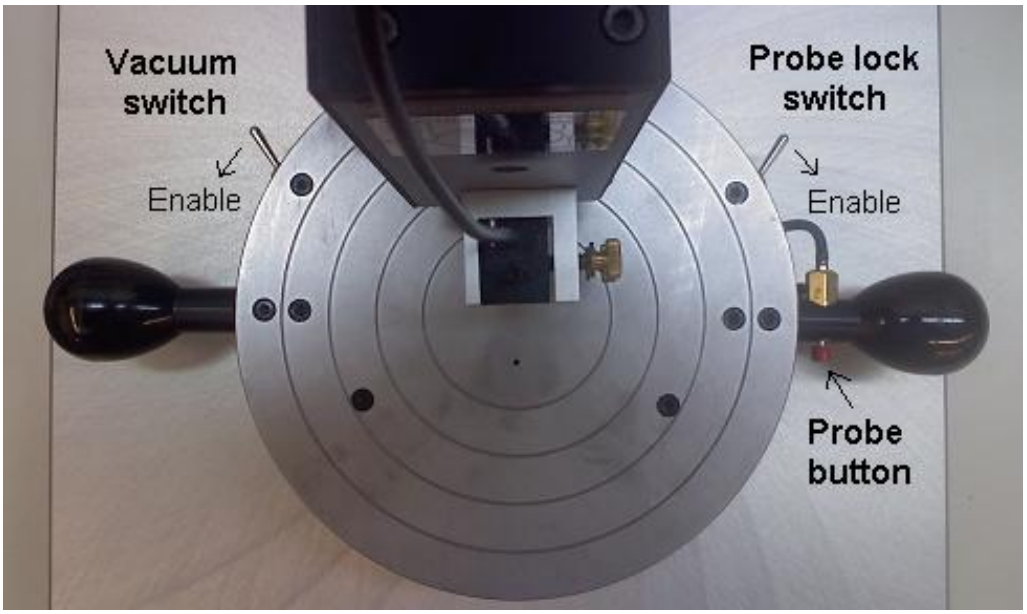
The probe heads are interchangeable, and specifications for each one are listed on the chart on the desk. In general, tungsten carbide tips (harder, sharper, higher spring force) are better for testing materials such as silicon where a native oxide needs to be penetrated; for thin films through which it is not desirable to pierce (thus measuring the underlying substrate resistance), osmium tips (softer, rounder, lower spring force) are better. Probe heads are kept in a box in the blue cabinet. If you need to change heads, unplug the head from the top of the probe body, then hold the head and loosen the two brass screws on the right side of the probe. Remove the head and place it securely in its case, and put the case in the box. Place the new head in so that its top surface touches the horizontal pin and its back and left sides are flush against the holder. Then tighten the screws and plug the cable in.

Keithley configuration notes

- If the Keithley has been controlled by LabView, pressing the Local button may be necessary to re-enable manual control.
- Press **Edit** once to edit the sourced current. Press **Edit** a second time to edit the compliance (power) limit.
- The probe operates within specifications when measured voltage is ~5 mV or greater, so an appropriate current should be sourced in order to reach this level. (See reverse side for details.)

Performing a measurement

1) Log on to the probe in FOM, which should automatically turn on the pump.
2) Flip the vacuum switch (left side) forward to enable vacuum. This will lock the chuck down onto the probe base.
3) Place the substrate on the chuck.
   Note – To verify proper head motion, steps 3 – 4 and 7 – 8 can be performed with the chuck set off to the side of the head rather than under it.
4) Flip the probe lock switch (right side) forward to bring the probe head down onto the substrate.
5) Press the **OUTPUT ON/OFF** button on the Keithley to enable measurement. The meter will beep, the button will light up, and the measured voltage will be displayed.
6) Press the **OUTPUT ON/OFF** button on the Keithley to disable measurement.
7) Flip the probe lock switch back (or release the probe button) to bring the probe head up.
8) If necessary, repeat steps 3-7 for additional samples.
9) Flip the left toggle switch to disable vacuum to the chuck.
10) Log off of the probe in FOM and verify that the pump turns off.



Calculating resistivity and sheet resistance

The general expression for **resistivity** as measured by linear 4-point probe geometry is

$$\rho = sa2\pi\frac{V}{I}$$

where *s* is the probe spacing and *a* is a thickness correction factor. For a general plot of *a* as a function of layer thickness divided by probe spacing, see http://www.fourpointprobes.com/gt2.pdf. For our probe spacing (.0625" = 1.59 mm), two specific equations can be derived. For **semi-infinite samples** with all boundaries at least 8 mm from the probes, *a* = 1, so

$$\rho[\Omega m] = .01[m] * \frac{V}{I}[\Omega]$$

Resistivity for **thin films or layers** of thickness (*t*) less than ~800 µm, *a* = .72**t/s*, so

$$\rho[\Omega m] = 4.52 * t[m] * \frac{V}{I}[\Omega]$$

Sheet resistance is defined as resistivity divided by thickness for these thin layers, so

$$R_S[\Omega] = 4.52 * \frac{V}{I}[\Omega]$$

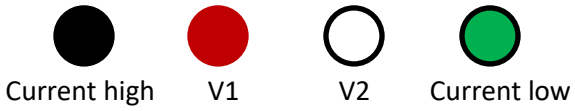
Probe precision specifications

The probe is specified to operate properly when resistance values as measured in the forward and reverse directions are within 2% of each other. Multiple materials have been tested on this probe by maintaining the current direction and measuring the resulting voltage in each direction. In general, this forward/reverse (absolute value) difference is observed to be inversely proportional to voltage, with the 2% requirement satisfied when the voltage is greater than 4.6 mV. If the initial measured voltage is lower than this, simply increase the sourced current proportionally as needed. Note that this makes it difficult to accurately measure highly conductive materials with the Keithley. For example, the maximum 1 A current applied to one gold film resulted in a voltage of only ~2 mV and a forward/reverse difference of 4.8%. For further details, consult facility staff.

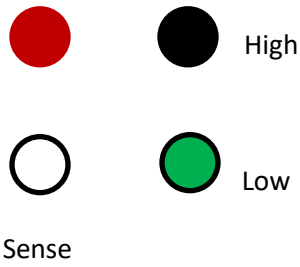
Additional guidelines and notes

- Do not measure any sample that may leave residue on the probe tips, such as wet hydrogels or loose nanoparticles.
- Detailed instructions for running the LabView VI "4-WIRE.vi" are provided in the VI.
- Please note that ohmic heating of the sample may occur during measurement. Consequently, it may be desirable to minimize the current used. It may also be advantageous to use the LabView VI given that it only applies current for a very short time. Be especially careful with thermally sensitive samples.
- Measuring a sample in multiple locations and orientations can help determine whether the sample is homogeneous and isotropic.

Cascade connections



Keithley 2400



B1500, use 4 SMUs, e.g. for high resistance film (low current sourcing)

SMU2, perform low-current sweep, set voltage compliance high. Measure current (and voltage)

SMU3, source 0 current, measure voltage

SMU4, source 0 current, measure voltage

SMU5, set mode to common.

Plot I2 vs. Voltage difference (i.e. V3-v4).

Refer to Agilent parametric measurement handbook