**Guide to Four-Probe Measurements**

**Part A: Installation**

1. Install anaconda (free download) as a single user
2. Once installed click on the environment panel and click on the play icon and select Open Terminal

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1. In terminal you can now install library packages needed
2. Enter:

pip install pymeasure

1. Enter:

pip install pyvisa-py

1. Install the **Spyder** App from Anaconda

A screenshot of a computer

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You can use other python IDEs if you prefer but this one is suitable.

1. Next download the code for four probe measurements from:

<https://github.com/kevcritc/Keithley2400_Control>

1. Save the code to a directory in OneDrive (your data will appear in the same directory)

**Part B: Making measurements**

1. Drag and drop the Keithley\_2400\_GUI.py code into the Spyder (alternatively open if through Spyder)
2. Switch the Keithley Source Meter on and wait for the start sequence to end
3. Run the code by click on the play icon:

A screen shot of a computer

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1. Once the connection with the Keithley is made a GUI will appear.

There are two made modes of operation. A single sweep through current (measuring voltage) or a full sweep say starting at 0A going to Imax and then returning to Imin.

Data is saved as a CSV file in the folder containing the [Keithley\_2400\_GUI.py](https://github.com/kevcritc/Keithley2400_Control/blob/main/Keithley_2400_GUI.py) code on your Onedrive.

**1. Introduction**

A **four-probe measurement** is a standard technique for accurately determining the **resistivity** of a material while eliminating the effects of **contact resistance**. This is particularly useful for semiconductors, thin films, and bulk materials in electronics and materials science.

**Advantages of the Four-Probe Method:**

* Eliminates the influence of **contact resistance**.
* Provides **highly accurate** resistivity values.
* Suitable for **thin films, bulk materials, and semiconductor devices**.
* Applicable for measuring **sheet resistance** of materials used in **solar cells, OLEDs, and nanotechnology** applications.

**2. Required Equipment**

* **Keithley 2400 Source Meter** (or equivalent current source)
* **4-point probe station** with **spring-loaded probes**
* **Voltmeter or nanovoltmeter** for precise measurements
* **Probe station with temperature control** (if required)
* **Computer with Spyder or Python environment** for automated data collection

**3. Setting Up the Measurement**

**3.1 Sample Preparation**

* **Clean the sample** to remove oxides and contaminants.
* For thin films, **ensure uniform thickness** and place on an **insulating substrate**.
* **Verify probe alignment**: probes should be **evenly spaced (s)**.
* Ensure **gentle but firm** probe contact to avoid damaging the sample.

**3.2 Connecting the Probes**

* **Outer probes (1 & 4)**: Apply **current (I)**.
* **Inner probes (2 & 3)**: Measure **voltage (V)**.
* Use **shielded cables** to minimize electrical noise.

**3.3 Configuring the Keithley Source Meter**

1. **Set Current Range** (starting with low current and increasing gradually):
   * **High Conductivity Materials (e.g., metals, graphene)**: **100 µA - 10 mA**
   * **Semiconductors (e.g., Si, GaAs, thin films)**: **10 nA - 100 µA**
   * **High Resistance Materials (e.g., insulators, lightly doped semiconductors)**: **10 nA - 10 µA**
2. **Set Compliance Voltage**:
   * Typically **0.1V – 10 V**, based on material resistivity.
3. **Ensure Proper Grounding** to avoid electrical interference.

**4. Performing a Measurement**

**4.1 Single Measurement**

1. Select **Single Sweep Mode**.
2. Apply a **low current** and measure voltage between inner probes.
3. Increase current **gradually**, checking for linearity in the I-V curve.
4. Check that the noise is sufficiently low for the measurement and that compliance is not being reached.

**4.2 Full Sweep Measurement**

1. Select **Full Sweep Mode** to observe the complete I-V characteristic.
2. Set current range: e.g. **0 A → Imax (10 mA) → Imin (-10 mA)**.
3. Monitor voltage response and record data.
4. If **nonlinear behaviour** is observed, check for:
   * Poor contact resistance
   * Semiconductor junction effects
   * Excessive heating

**4.3 Strategies for Low-Noise Measurements**

* **Start with low currents**: Reduces thermal and contact resistance effects.
* **Use shielded cables and a Faraday cage**: Minimizes electromagnetic interference (EMI).
* **Ensure temperature stability**: Resistivity varies with temperature.
* **Use averaging techniques**: Reduces signal fluctuations.

**5. Data Analysis & Resistivity Calculation**

**5.1 Sheet Resistance Calculation**

For **thin films**, sheet resistance is calculated as:

Where:

* Sheet resistance (Ω/square)
* s Probe spacing (cm)
* R resistance (Ω) (taken from the V/I gradient)

For **bulk resistivity**:

Where t is the thickness of the sample (cm).

Note that if the sample is thicker than 40% of the spacing then Geometric Correction Factors are needed (See references).

**5.2 Common Artifacts & Troubleshooting**

|  |  |  |
| --- | --- | --- |
| **Artifact** | **Possible Cause** | **Solution** |
| **High contact resistance** | Poor probe contact | Clean surface, increase pressure |
| **Noise in measurements** | EMI interference | Use shielded cables, Faraday cage |
| **Nonlinear I-V response** | Semiconductor effects | Reduce applied voltage |
| **Thermal drift** | High currents | Lower current, ensure thermal stability |
| **Unequal probe spacing** | Misalignment | Reposition probes |

**6. Best Practices for Reliable Measurements**

✅ **Always start with low currents** and increase gradually.  
✅ **Use averaging techniques** to reduce fluctuations.  
✅ **Check probe alignment** before measurements.  
✅ **Use known reference materials** for calibration.  
✅ **Record multiple measurements** to ensure repeatability.

By following these guidelines, you can obtain **accurate, repeatable, and high-quality four-probe measurements** for resistivity analysis in various applications.

**7. Safety**

Ensure the measurement is done inside the earthed-box. High currents and voltages can be easy applied particularly if poor contacts are made to the sample. This can damage the instrument and cause electric shock. It is important to switch the Keithley off when changing samples. Do not use without training.

* 1. **References**

<https://www.ossila.com/pages/sheet-resistance-theory#example-applications>