Four Point Probe I-V Electrical Measurements Using the Zyvex Test System Employing a Keithley 4200

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Introduction

It is difficult to electrically characterize very small circuit elements in current-generation semiconductors. Most modern prober systems have unacceptably large metal pad requirements in order to effect such measurements, and unwieldy manual mechanical probe stations with optical microscopes cannot resolve fine features. With standard gate dimensions of less than 90 nm and space budgets shrinking continuously, the smallest probe pad dimensions required for most prober systems remain fixed at about 50 microns. This limitation is largely the result of the inaccuracy of probe movements and the size of the actual probe tips. The Zyvex Test System is designed to overcome these limitations by offering 5 nm movement precision with probe tip diameters less than 20 nm, and current-measuring capability down to 1 pA.

For general purpose resistance measurements and I-V curve generation, 2-point electrical measurements are normally used. However, when the resistance being measured is relatively low, or the resistance of the probes or the contacts is relatively high, a 4-point probe will yield more accurate results. The Zyvex Test System employs a Zyvex S100 Precision Manipulator System and a Keithley Model 4200 Semiconductor Characterization System, with a measurement resolution of 100 fA. With a combined system noise floor below 55 fA_{RMS}, current measurements of 1pA are readily achievable.

Theory of 2-Point Measurements

Ohm's law is used in order to determine a resistance: **R=V/I**. A known current is sourced and flows through the unknown resistance. We measure the voltage that develops across the resistance by dividing the measured voltage by the sourced current. A problem that occurs when using a 2-wire setup is that the voltage is measured not only across the resistance in question, but also includes the resistance of the leads and contacts **(Figure 1)**. When using an ohmmeter to measure resistances above a few ohms, this added resistance is usually

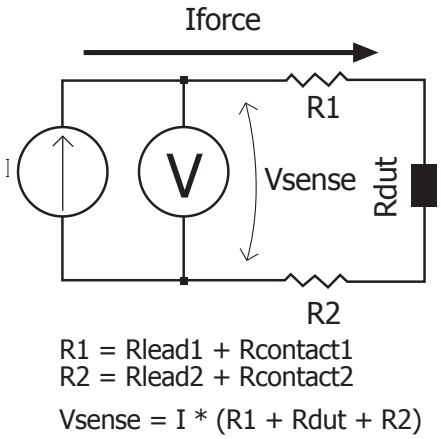

Figure 1 2-point measurement

not a problem. However, when measuring low resistances or when contact resistance may be high, obtaining accurate results with a two wire measurement could be a problem.

Theory of 4-Point Measurements

A solution to the problem of 2-point measurements in which the lead and contact resistance is measured along with that of the device under test (DUT) is the 4-wire or "Kelvin" measurement. Because a second set of probes is used for sensing and since negligible current flows in these probes, only the voltage drop across the device under test is measured **(Figure 2)**. As a result, resistance measurement or I-V curve generation is more accurate.

Background

The Zyvex Test System is a positioning and testing tool for micro- and nanoscale research and development applications. It accommodates up to four positioners (three-dimensional stages) which grasp, move, test, and optimally position micro- and nanoscale samples in Scanning Electron Microscopes (SEMs) and Focused Ion Beam Systems (FIBS).

The Zyvex Test System employs a Keithley Model 4200 Semiconductor Characterization System (SCS) which is an automated instrument designed to provide IV and CV characterization of semiconductor devices and test structures. Its advanced digital sweep parameter analyzer combines speed and accuracy for deep sub-micron characterization. Tests are easily and quickly configured and run from the Keithley Interactive Test Environment (KITE). KITE is an application program designed and developed specifically for characterizing semiconductor devices and materials. Source and measurement functions for a test are provided by up to eight Source-Measure Units (electronic instruments that source and measure DC voltages and currents). Test capabilities are extended by support of a variety of external components. For less precise measurement and testing applications, other Keithley instruments may be employed to configure the system more closely to the requirement.

Preparation and Testing

To implement a 4-point measurement **(Figure 3)**, all 4 positioners of the test system are used. Each positioner controls a single probe. The probes are positioned in a line on the DUT. The outer and inner probes that are closest to each other on the DUT connect to the same Source-Measure Unit (SMU). The outer probe connects to the force terminal on

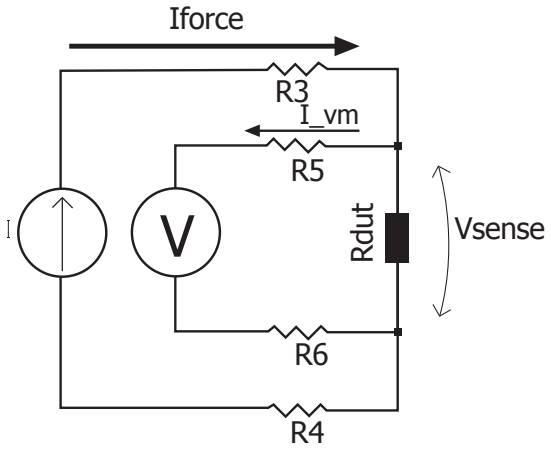

Figure 2 4-point measurement

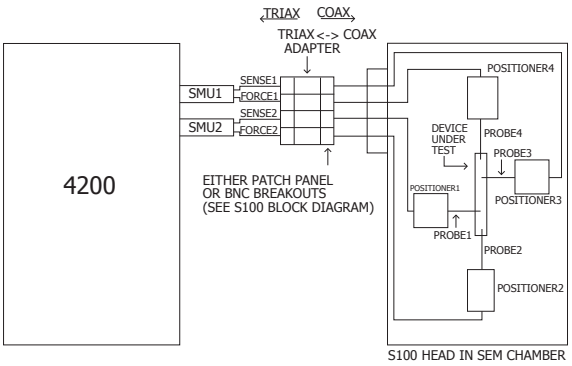

Figure 3 Schematic diagram of Zyvex S100 test head with Keithley 4200

the SMUs; the inner probe connects to the sense terminal on the SMU.

Because the Zyvex test head employs coaxial cables and the 4200 uses triaxial cables, an adapter is required. The signal lines of the coax and triax cables should be tied together and the shields should be tied to each other as well. The guard of the triax is left open. Keithley's #237-BNC-TRX adapters can be used. Caution should be used with other adapters because they may not interface between the coax and triax cables in the same way. Note that the connections between the 4200 and S100 can be made at the patch panel rack or on the BNC breakouts **(Figure 4)**.

The Keithley Interactive Test Environment (KITE) program on the 4200 is used to run the test. The "4-point" interactive test module which is found in the KITE folder titled 2 wire-resistor can be used to generate results for the I-V curve. This is a pre-configured routine that implements 4-point measurements using 4 cables and 2 SMUs as described above.

Conclusion

The Zyvex Test System is an effective measurement tool for IV characterization of nanoscale components. With 4-point probe capability, 1pA accuracy, and 5 nanometer precision movement, the system offers a unique combination of features that are ideal for semiconductor characterizations.

References

1. Cable/Harness Testing Made Easy™: http://www.cirris.com/testing/resistance/fourwire.html
2. Zyvex S100 System Manual
3. Keithley Low Level Measurements 5th Edition
4. Keithley 4200-SCS Semiconductor Characterization System Reference Manual
5. Keithley 4200-SCS Semiconductor Characterization System User's Manual

S100 BLOCK DIAGRAM

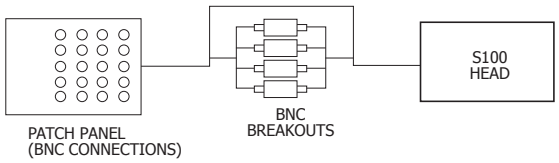

Figure 4 S100 block diagram