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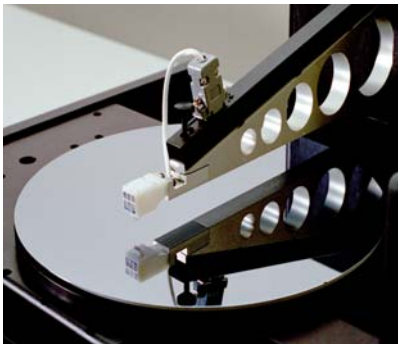
QuadPro Detailed Theory of Operation

The Standard QuadPro:

The QuadPro-A12 is designed to perform resistivity test on 12 inch wafers. It is a stand alone system including three important components – mechanical motion, testing apparatus and software control system. We apply the 4 point probe technique outlined by the ASTM F84-99 standard to read V/I and apply the error corrections outlined by the standard to calculate the sheet resistance of the material.

Mechanical Motion

The QuadPro employs a lead screw driven stepper motor with 25 micron accuracy and for positioning the sample. In the default state, the probe head is up and out of contact with the sample being tested. Users choose between 5 and 49 points to test and the software automatically selects the pattern for testing and calculates the exact number steps to send to the X-Y stepper control. Once the test sample has moved to position, a pneumatically controlled piston drives the probe arm and probe head down and into contact with the test sample. At the conclusion of the test, the pneumatic piston is released and the probe head rises by spring pressure.



A small manually controlled knob to the right of the probe arm does the initial setup of the probe head contact. It has an adjustable range of about 30mm to accommodate different thicknesses of test samples. In the down or contact position, the probe head should depress the probe pins 50-60%. This contact is set-up visually by the user on the first test sample.

The SP4 probe head is used for probing. We offer a variety of probe heads. The probe head is designed as a low cost disposable 4 point probe. Replacement cost of the heads are almost 50% less expensive than our competitors . The probe head is mounted by 2 6-32 by ½ inch socket cap screws to the quick disconnect bayonet. The bayonet fits easily into the probe arm and is held in place by a thumb screw. The SP4 probe head when used properly is expected to last 100,000 contacts before needing to be replaced.

Testing Apparatus

The QuadPro testing apparatus includes the Keithley 2400 and Keithley 2000 meters, a *Lucas Labs* I/O board, a 12 DC volt source, GP-IB interface board mounted into the computer, GP-IB cables to the meters, and shielded cables to the probe head. The KT 2400 acts as the current source and has a programmable range of 1 pA to 1 Amp. The KT2000 is an accurate digital volt meter. In the QuadPro, the cables between the meters and probe head are about 1.5 meters.

When testing, the computer talks to both meters through the GP-IB interface board. The probe head is lowered into contact by switching the TTL signal on the KT2400. A 12 volt signal is given to the solenoid controlling the pneumatic piston lowering the probe head into contact at the 1st position. Following contact, the current source begins to step through a variety of current settings looking for the voltage to read within the millivolt range. We call this auto ranging. This part of the software is key to attaining the best accuracy. After the 1st point is measured and the test settings recorded on the computer, the probe head is raised and the device under test is moved to the next position. The recorded settings are used for all subsequent measurements on the same sample. The testing continues through out all positions.

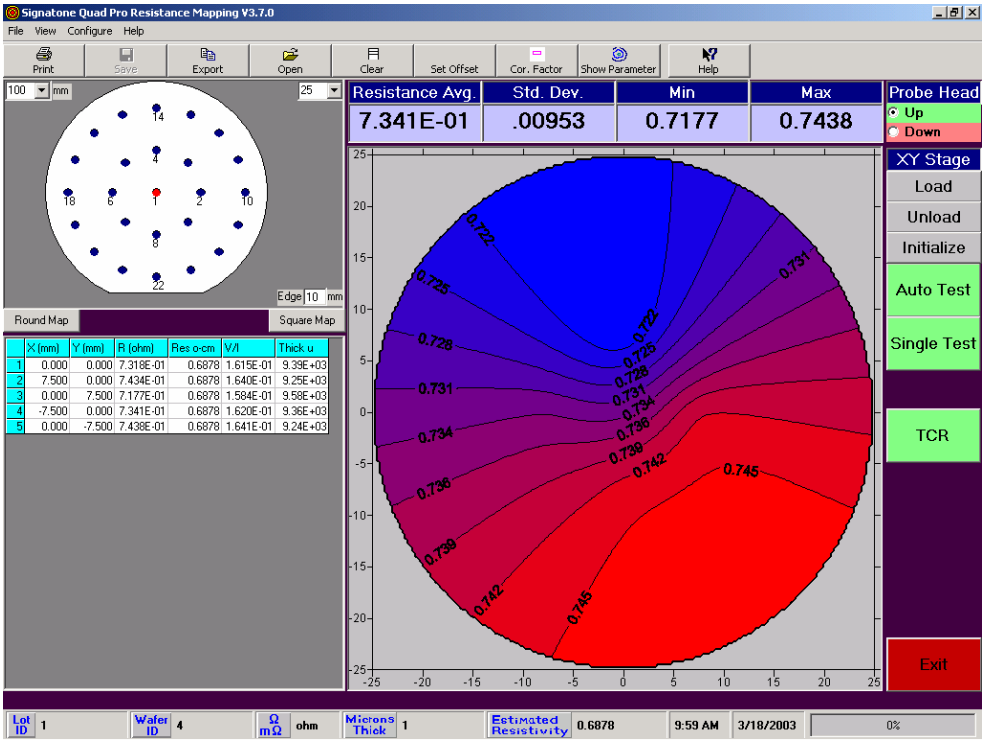
Computer and Software

The control system consists of an industrial computer with a Pentium processor IV, 512 MB RAM, >40 GB hard disk. The operating system is Windows 2000. A General Purpose Interface Board (GP-IB) is mounted in one of the PCI slots. The cable connects from this board to the Keithley meters. The installed software includes QuadPro 3.7 or later version, Surfer 8 graphic software, MS Office 97 and the GP-IB drivers. The QuadPro software is written in visual basic and compiled for distribution.

The QuadPro software has seven key functions and features described below-

1- *Calibration of the system*
   The QuadPro makes measurements accurate to 1%. However, verification is necessary after changing probe heads or if the probe head is suspected to be damaged. This is done by testing a NIST traceable standard, usually a 3 inch wafer. After testing the wafer standard, a correction factor is calculated and applied to all subsequent measurements.
2- *X-Y Positioning Calculations*
   Based on the entering the number of desired probe points, shape of the test sample and edge exclusion, the software calculates the X-Y coordinates for testing the sample automatically.
3- *Initializing, Loading and Centering the X-Y stage*
   The software initialized the stepper drive system through a USB connection to the stepper control box. The test sample is loaded to the center position ready for testing. Minor adjustments to center offsets are also accommodated through the utilities.
4- *Test and Autorange*
   The test is started by clicking the *Auto Test* button on the right of the screen. The user is asked to enter the thickness or the known bulk resistivity for the material being tested. The probe head contacts the center position of the sample and begins the auto range stepping as explained in the test

section. At the conclusion of the test, the data is stored in the table on the left. *'V/I'* is the actual measurement, *R (ohm)* is the sheet resistance calculation taking in to account all of the correction factors.



5- *Auto Stepping and Testing*

After the 1st test, the software and computer commands the stepper motors to move to the next position. The test is started again. The value of the test is stored in the table. This stepping and testing continues until the table is filled and all positions have been tested. There is also an error trapping routine that allows retesting at a location if good contact was not made and the readings were unstable. At the conclusion of the last point, the *Resistance Average, Standard Deviation, Minimum Value and Maximum Value* are displayed.

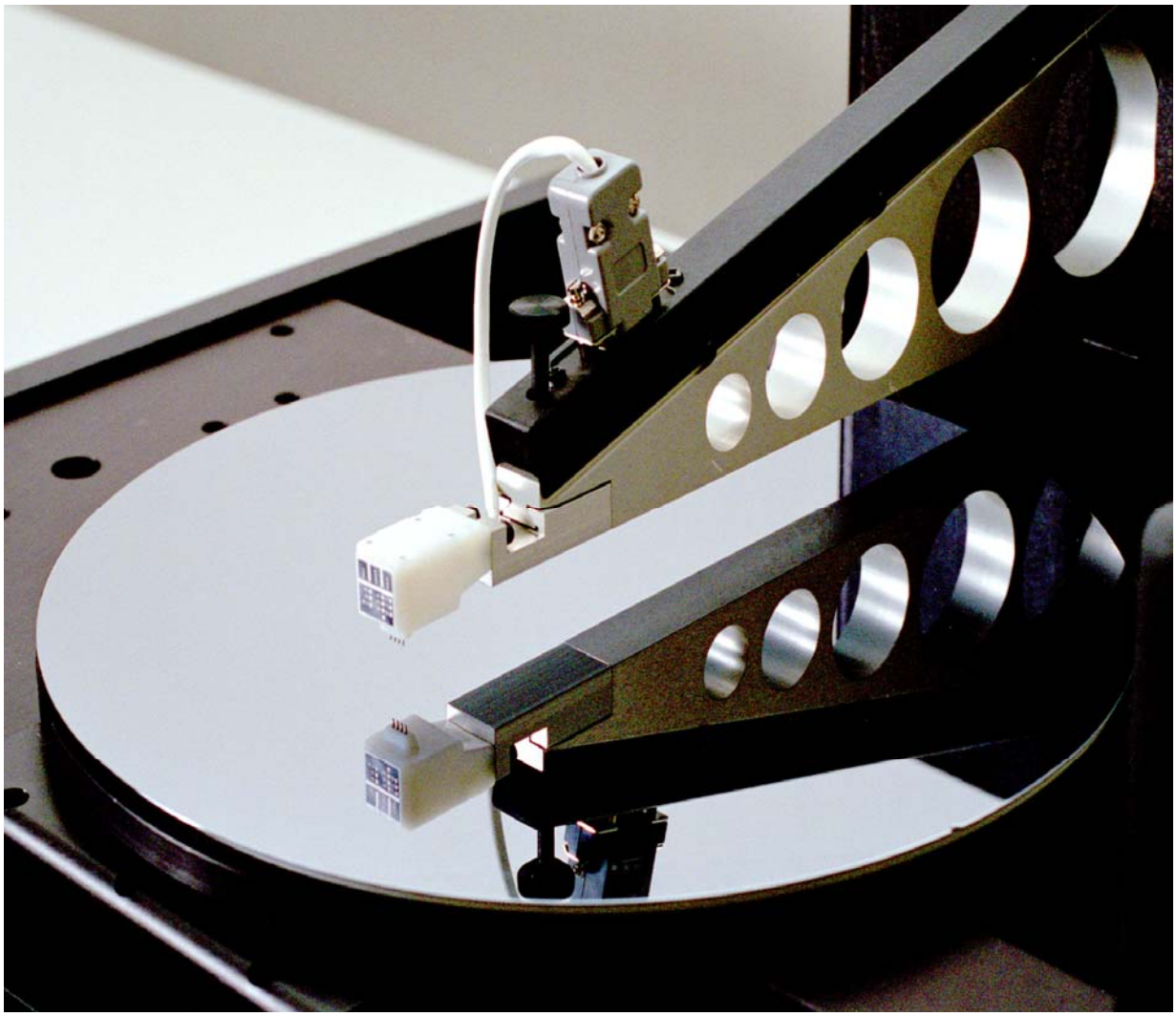
6- *Graphing*

At the conclusion of the test, the user is prompted to enter a file name to store the data. The binary data is then store and also passed to Surfer the graphic software package. The values on the map in the table are used to create a 2D color, 3D or 3D cross section map.

7- *Exporting*

The tabular data may be exported. When export is selected, a .xls worksheet is created with all of the tabular data. This requires Excel 97.

QuadPro Resistivity System



- ✓ Reports Average Resistivity, Resistivity Standard Deviation, Average Sheet Resistance and Sheet Resistance Standard Deviation
- ✓ Temperature Coefficient of Resistance (TCR) measurements integrated with automated temperature chuck and source meter. (Optional)
- ✓ Automated 2D Color Contour mapping, 3D and Crossection mapping
- ✓ Employs the Dual Configuration Testing method for improved accuracy and repeatability
- ✓ For samples 10 to 300mm
- ✓ 1 to 49 NIST traceable automated measurements per sample

QuadPro Automatic System

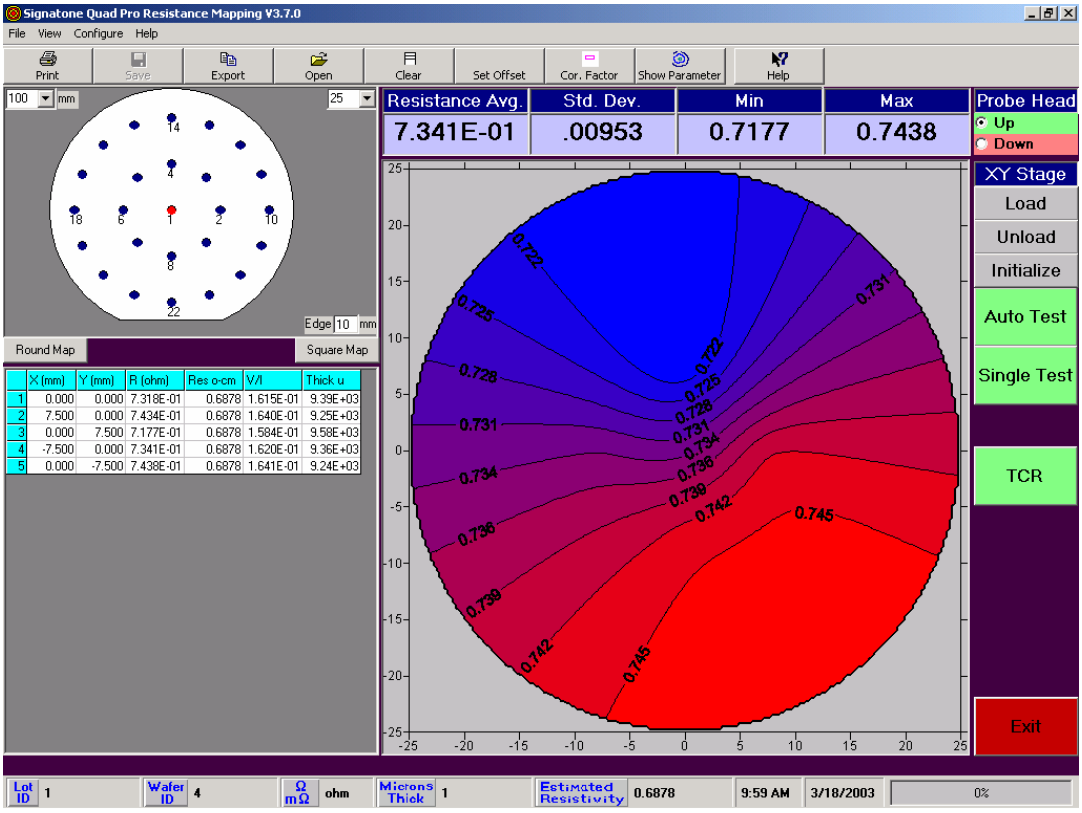
The QuadPro includes a computer, stepper controller, and base station with either a 200 or 300mm diameter isolated chuck. The software allows for selecting 1, 5, 9, 25 or 49 points for automated testing and mapping of the test sample. Positioning patterns may be set to either round or square configuration.

The edge exclusion may also be defined. On the first measurement, the software auto ranges the meter finding the best settings for the sample testing. Dual configuration assures that errors introduced by the probe head manufacturer are eliminated, increasing the repeatability and accuracy of measurements. The Software controller automatically steps to each position and records the X-Y position, Sheet Resistance, Resistivity and V/I measurement in a visible table.

Upon completion of the test points, a wafer contour map is displayed. The contour map may be toggled between 2D and 3D viewing. The average and standard deviation of resistivity and sheet resistance display prominently above the contour map.

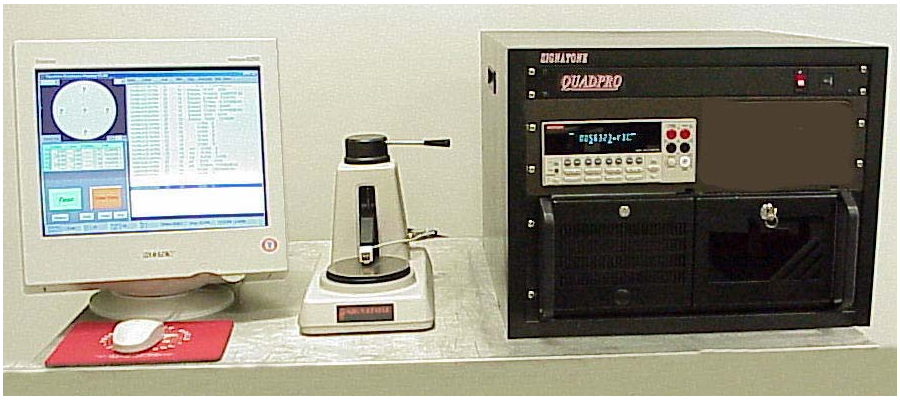
QuadPro Source Meter options *Keithley 2400 Source Meter*

The QuadPro standard configuration includes the Keithley 2400 Source Measurement Meter. This meter allows resistance measurements in the range of 1 milliohm to 2 megaohms. Some of the newer high resistance materials require a greater resistance measurement range. For those applications, Signatone implements the Agilent 4156 Parametric Analyzer along with special triaxial shielding. This configuration increases the range from 100 milliohms to 10 gigaohms, *see below*.



QuadPro and Manual systems

Since 1968, Signatone has offered a simple manual resistivity measurement stand. This simple stand may be incorporated with QuadPro computer and source meter for easy accurate measurements. Of course, the sample is positioned by hand. A lever lowers the probe head into contact with the sample. The auto ranging, dual configuration and data collection features do the calculations accounting for edge error and probe head error assuring repeatable NIST traceable accurate results.



QuadPro-301-6

Four Point Probe heads

Signatone offers two probe heads to choose from; the SP4 and the HT4. The SP4 is an inline probe made of delrin and used in most applications. Several choices are available for configuration to your specific application. The three spacings are .040, .050 and .0625 inches. The three pressures available are 45, 85, and 180 grams. Tips are made of Tungsten Carbide or Osmium and a choice of .0016, .005, .010 inches radius.

The HT4 inline four point probe head is made of ceramic and designed for high temperature and high resistance measurements. The HT4 accurately collects data at temperatures up to 650°C. The coaxial high temperature wiring also allows resistance measurements up to 10 Gigohms. The HT4 features spacing of .050 and .0625 inches and pressure is fixed at 180 grams. Tips are made of Tungsten Carbide or Osmium and a choice of .0016, .005, .010 inches radius.

Lucas Labs

Pro4 Resistivity System

Pro4-440R

The Pro4 provides simple answers to sheet and bulk resistivity measurements. Since 1968, Lucas-Signatone has offered an inline four point probing solution. To make the measurements, the user lowers the four-point probe head onto sample then selects the *Test* button in the software. The computer automatically controls the Keithley 2400 series and steps through a number of current settings to find the ideal current for accurate readings. A V/I measurement is taken and recorded. The system uses the Dual Configuration test method of ASTM Standard F84-99 to compensate for errors in probe spacing and errors caused by proximity to the edge of the conducting layer. NIST traceable calibration standards are available for purchase with the system. Proper use of the standards and the calibration procedure insures the specified system accuracy of better than 1%. The standard range of the system is 1 miliohm to 800K ohm per square.

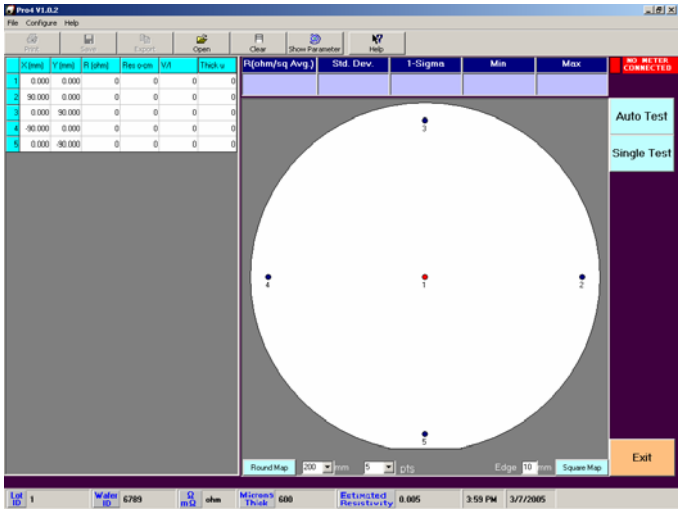
The Pro4 system includes four components; Keithley 2400, four-point probe head, Pro4 software, and Pro4 stand.

Four Point Probe heads

The SP4 is a low cost disposable an inline probe made of Delrin and used in most applications. Several choices are available for configuration to your specific application. The three spacings available are .040, .050 and .0625 inches. The three pressures available are 45, 85, and 180 grams. Tips are made of Tungsten Carbide or Osmium and a choice of .0016, .005, .010 inches radius. The Pro4 includes two bayonet type quick disconnects to make changing the probe head easy.

Pro4 Probe Stand

The new Pro4 stand includes several features to assure accurate resistivity measurements. A swing arm with micro switch assures the probe head is moved straight up and down and current is not applied until the probe head is adequately contacted the sample. A fine 'Z' adjustment knob on the right side raises or lowers the probe head a range of 20mm to set-up testing on the sample. A bayonet style quick mount allows for easy changing of the probe head. The sample to be tested is mounted onto a Teflon chuck and easily pushed to position. The stand is available in 100, 150 and 200mm configurations. The stand is pre-wired and ready to connect to the Keithley 2400 Source meter.

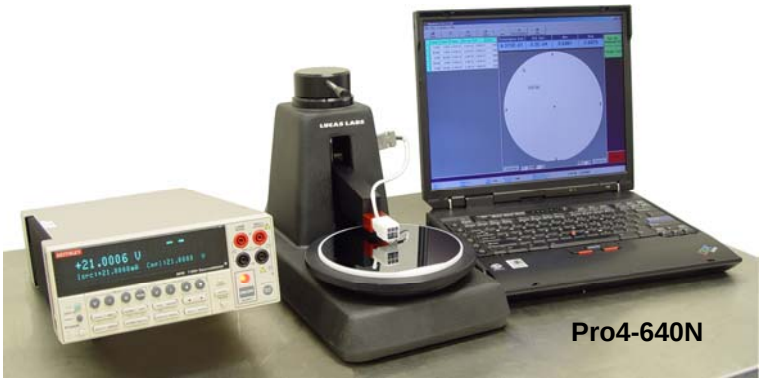


Pro4 Software

The Pro4 software manages the tests, displays results and allows printouts or export of the data. The user inputs the size and shape of the sample, edge exclusion and number of points to be tested. The user may also define pass/fail criteria and which parameter (Sheet Resistance, Resistivity, or V/I) to display. A graphic picture of the target probe points is displayed. Prompts tell user to move to the next position. Upon completion of testing all points, the average, standard deviation, 1-Sigma, minimum and maximum are prominently displayed. Upon completion, a summary report may be printed showing the data and pass/fail status.

Ordering Information

Pro4 software must be run on a computer with Windows 2000 or Windows XP Professional. The computer must have an RS-232 port available. Lucas Labs offers two computers to choose from, a laptop or industrial rack style computer with the Keithley meter mounted in the rack as well. Two SP4 probe heads are included in the system along with bayonet mounts.



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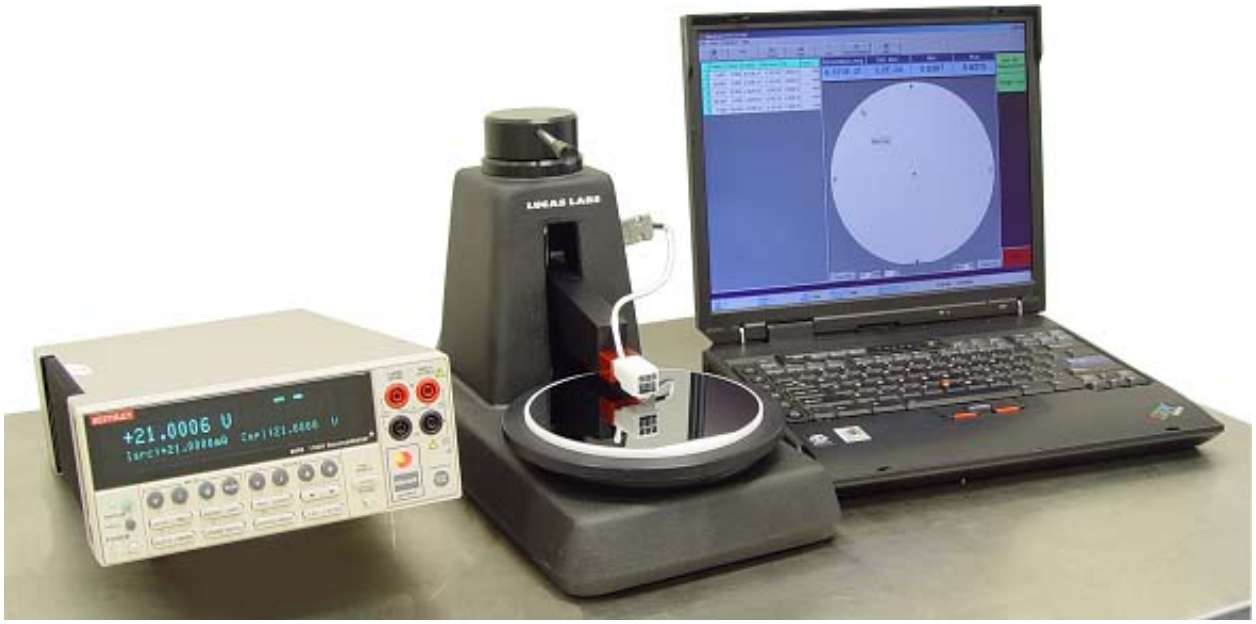
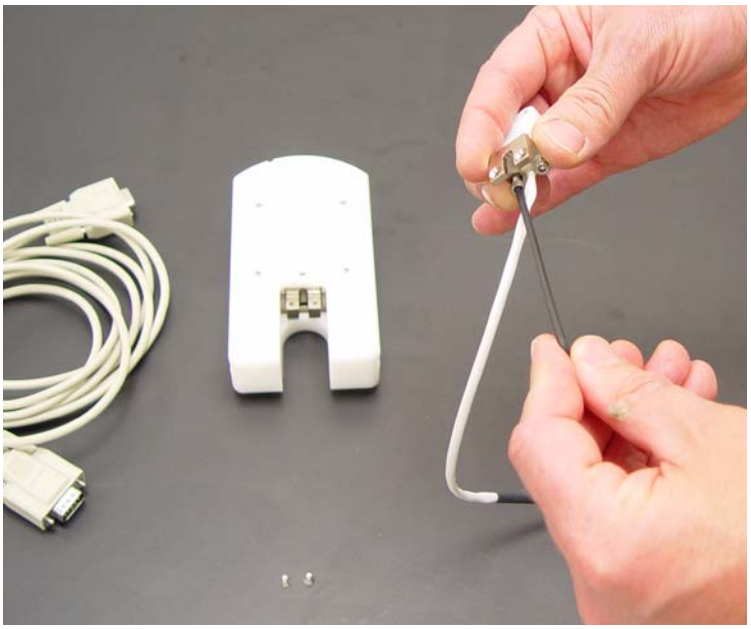
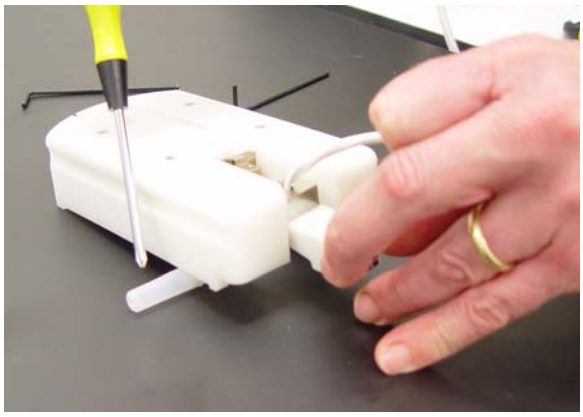


In addition to the Pro4 system, Lucas Signatone Corporation offers a hand-held* four point probe:

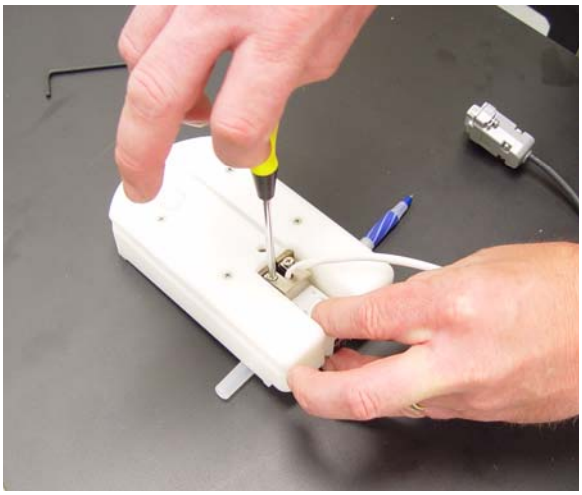
The Hand-Held four point probe kit, in addition to the Pro4 system.
** not a portable device - must use the Pro4 system.*



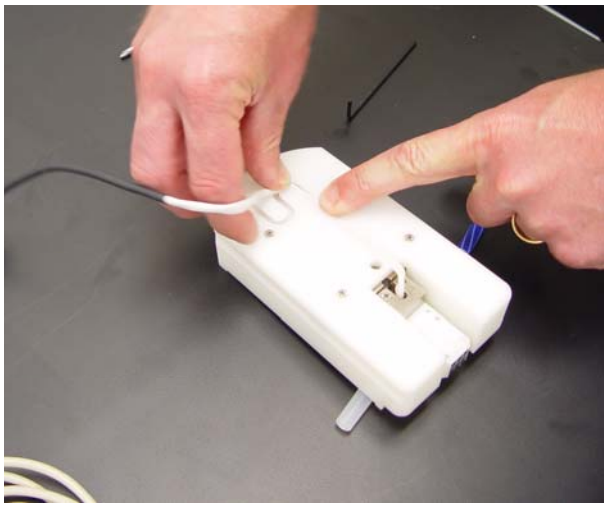
Step 1: mount the four point probe (4PP) to the external mounting block.



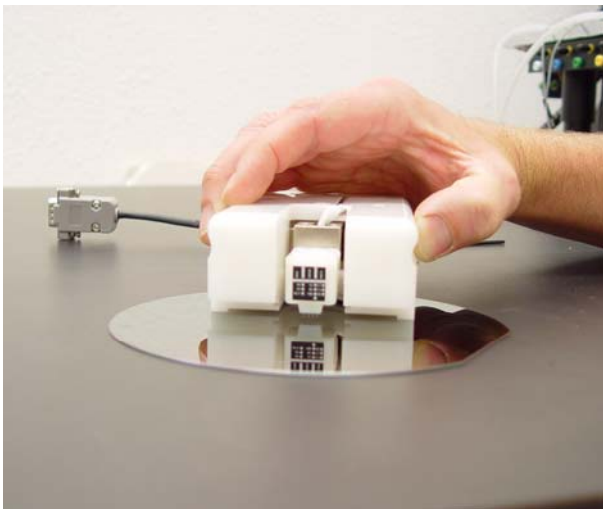
Step 2: prop up the front of the hand-held base before mounting the 4PP to prevent damaging the tips on the 4PP head.



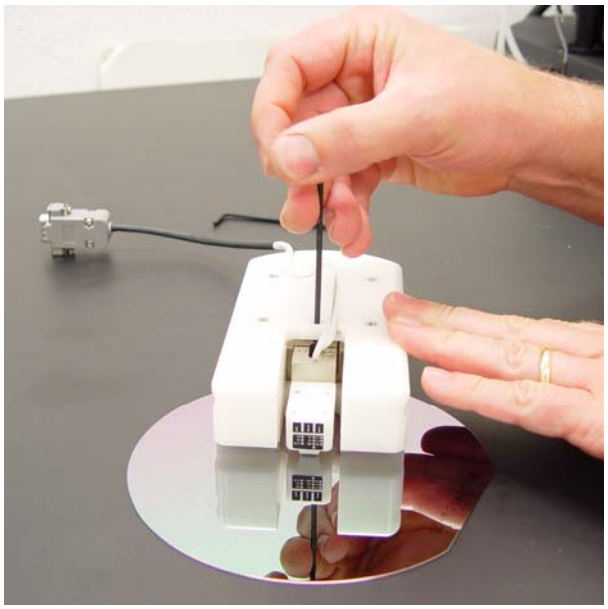
Step 3: mount the 4PP to the internal mounting block



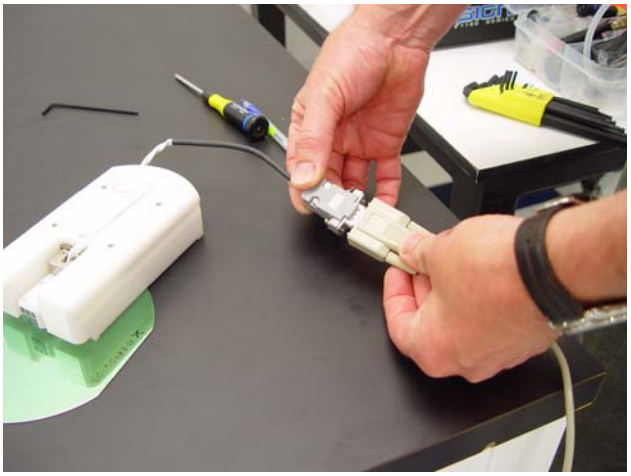
Step 4: feed the 4PP wire through the machined groove in the Delrin block.



Step 5: test the depth of the 4 pins. Don't release the block from your hand.

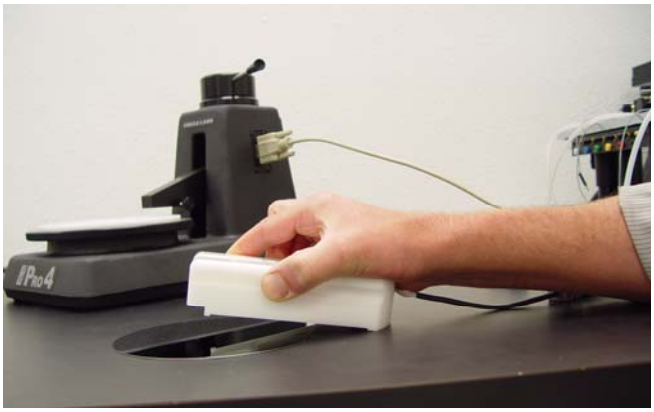


Step 6: adjust the pin depth

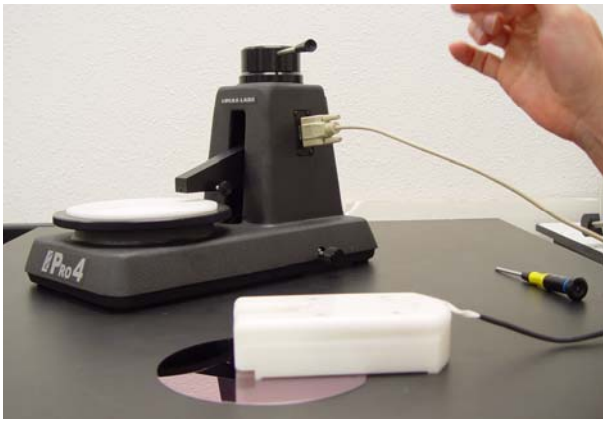


Step 7: attach the 4PP to the provided cable

Step 8: attach the provided cable to the Pro4 base



Tapered end helps with lifting the probes out of contact.



A weight inserted in the base of the hand-held device helps keep the probes in contact.