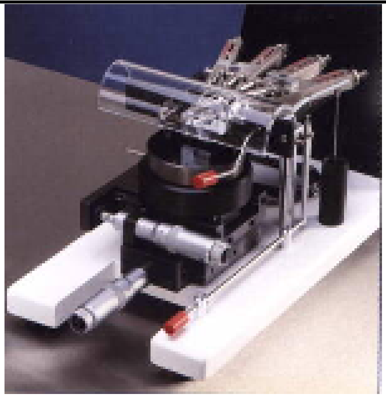
Maintenance and Use of the
Jandel Engineering Ltd.
UNIVERSAL PROBE



Description

Referring to the attached drawing, Fig. 6, the needles are located by two sets of accurately spaced ruby balls. Each needle is constrained by a spring-loaded ruby ball at each guidance level.

The arrangement is kinematic and thus free of all lateral play. The needles slide through their guides with minimum friction. Exchanging needles does not affect the characteristics of the unit: provided that the needles are of the same diameter, spacing and colinearity will be retained - a small difference in nominal size is unimportant.

Method of Operation

A camshaft 48 (Figs. 8 and 9) operated by a small lever 49 projecting through the perspex cover sets the machine for either four-probe (Fig. 9) operation (lever up) or three-probe (Fig.8) operation (lever down).

During the four-probe operation all four needles rise and fall normally. The velocity control should be set as desired. *The lead marked 4PL should be used to connect the probe to the Resistivity Test Unit.*

During three-probe operation the tension on the first probe should be reduced to zero and the lever pulled down. This lifts the first probe tension gauge finger so that it is inoperative. The central probe finger is raised slightly so that this probe contacts the specimen last. The velocity control knob should be set to give a probe descent rate of approximately 1mm per second. *The lead marked SLR should be used to connect the probe to the Resistivity Test Unit.*

The Probe Release Mechanism

The needles are lifted from their lowest position by lifting the lever with the red knob at the front of the instrument. This lever engages the release latch which then maintains the needles in the raised position. Slight pressure on the red knob on the instrument base releases the mechanism, allowing the needles to descend at a velocity dependent on the dashpot setting. It is advisable to press the red knob for two to three seconds before releasing otherwise the latch may re-engage when the dashpot is set for minimum velocity.

To Change Needles

Any or all of the needles can be changed as necessary. Spares are supplied with long ligaments so that they can take any position. To change all needles proceed as follows;

1. reduce all tension gauge loads to zero.

2. take off the acrylic dustcover via two screws.

3. unsolder the needle ligament connections where they are attached to the screened wire extremities.

4. lift each tension finger in turn, as far as it will, and take hold of the needle and lift it up and sideways to pass the end of the tension gauge finger and remove it.

5. insert replacement needles with the opposite procedure. Take care that the needles emerge straight at the lower end, because of the spring loaded arrangement it is possible for needle 1 to emerge out of needle 2 guidance at the lower end. Careful observation will eliminate this.

6. arrange the ligaments in order, clear of each other, in a smooth curve. Solder each ligament in turn. When satisfactory, cut off the excess ligament with care. For the best alignment place a 2mm thick sample under the needles before soldering.

To Clean the Guidance Block

Proceed as 1 to 4 above, then

1. remove two M3 screws from the rear and release the guidance block.

2. ultrasonically clean the block while assembled.

3. rinse with isopropyl alcohol and allow to dry - **DO NOT USE A HOT PLATE**

4. reassemble to the vertical plate, take care that the block is properly positioned in its recess.

5. tighten two M3 screws and refit needles as described previously.

Adjustments

1. Needle travel - referring to the attached drawing, screw No. 46 limits the downward descent of the needle lowering mechanism. Screw No. 47 limits the vertical lift: both screws have been set before despatching the apparatus and should not require adjustment.

2. Velocity of descent - this is adjusted by screw No. 41 beneath the base. Screwing clockwise closes the dashpot vent, retarding needle descent, screwing anticlockwise speeds descent. **Note** - do not force this screw excessively.

Changing Tension Gauge Fingers

Undo the clamp screw and remove the tension gauge whose finger is to be changed. The tension gauge is secured by the clamping force and by double sided sticky tape at the rear.

The finger is a push fit in the “bell crank” and may also be secured with “loctite”. This can be released by heating with a soldering iron. Remove the old finger and clean the hole so that the new one can be fitted using “loctite” or similar adhesive.

Check that the tension gauge is repositioned correctly so that the 1.00mm ruby ball is located precisely on the top of the needle when it is lowered. Move the tension gauge forward or back to align in one direction, and flex the finger itself to align in the other direction (L-R).

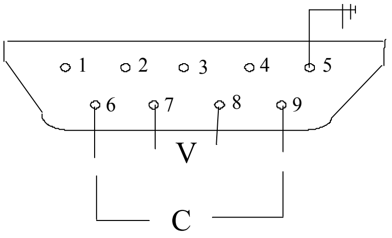
Finally reclamp the tension gauge tightly.

The design of this guidance system only permits the measurement of smooth flat specimens such as parallel slices.

We will be pleased to answer any problem which may arise in the use of the **JANDEL UNIVERSAL AND FOUR-POINT PROBE.**

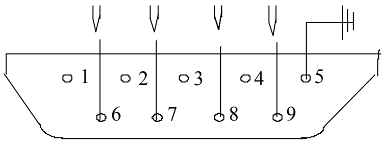
Wiring of Four Point Lead (4PL)

SOCKET (on lead)



PLUG (on Probe Station)

Probes L-R



Using A Jandel Universal Probe

In general it should be safe to use a load of 50-60g, adjusted by the nut on the tension gauges, set all to the same figure on the scale. Adjust the dashpot so that the needles descend in approximately 1 ½ seconds. The Resistivity Test Unit should be connected to the probe with its lead and plugs. (Marked 4PL) The flying lead on the probe should be connected to the vacuum wafer adapter with the screw on the adapter (take off the adapter to do this safely). This connects the wafer adapter to earth. Check electrically if the whole probe is earthed also. Although this is not essential, it is desirable. We provide a hinged metal cover and this too should be connected to earth. If necessary add a link wire with crocodile clips to ensure earth. We assume that mains supplies are provided with an earth, connected to the third wire in our mains lead, usually coded yellow/green. Semiconductor wafers can be affected by light, particularly that emitted from fluorescent lights. Measurements should be made with the probe screened from both light and electrical interference, or electric fields produced e.g. by induction heaters and furnaces. Metallic films on non-conducting substrates are not affected by light.

Three Point Mode (Spreading Resistance)

Explanation

The method of measuring spreading resistance demands an equipment capable of reproducing the same point contact conditions measurement after measurement. The Universal Probe incorporates a kinematic probe guidance system, a controlled velocity of descent, an adjustable and controlled load.

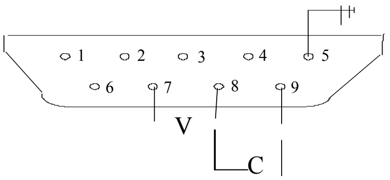
The measured resistance R_{SR} is given by $R_{SR} = V_{SR} / I_{SR}$ where I_{SR} is the measuring current which flows through the sample, and V_{SR} is the associated voltage drop measured between the centre probe and non-current carrying probe.
In the three probe system for a uniform material the spreading resistance of a contact is related to the resistivity (□) of the material by R_{SR} = □□/4a where a is the EFFECTIVE radius of contact.

Practical Facilities on The Universal Probe

The tension gauge on the left should be set at zero load, and the lever (49 in fig. 2) pulled down to operate the camshaft (48 in fig. 8). The signal lead should be the one marked SRL which ensures that the current source and digital voltmeter are appropriately connected - viz measuring current through probes 27 and 28, voltage drop measured across probes 28 and 29. Thus, the spreading resistance probe is 28, which lags behind 27 and 29 so that its contact is mechanically undisturbed by the other two. The load on these should be set to 45g.

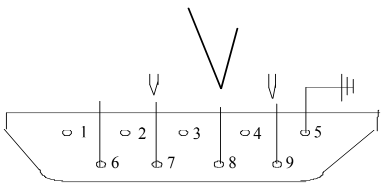
Wiring of Spreading Resistance Lead (SRL)

SOCKET (on lead)



PLUG (on Probe Station)

Probes L-R



General

The principal application of Spreading Resistance Measurements is depth profiling. A sample of the wafer is bevelled at an angle of 1 degrees or less, and the probe stepped along the bevel. If X is the movement of the stage carrying the specimen, d is the depth into the structure, and □□the bevel angle then X= d sin □.

The actual resistivity of the sample can only be deduced by using the spreading resistance probe to measure a standard wafer of known resistivity and deriving the sample resistivity by proportion.

NOTE: The spreading resistance measurement technique - including the preparation of samples and probes has been the subject of many papers and symposiums under the auspices of the National Bureau of Standards, Gaithersburg, Maryland, USA.

Notes on Four Point Resistivity Measuring With Jandel Equipment

General

Before attempting measurement one needs to know something of the sample or the wafer - is it silicon? (Germanium is easier to contact and measure). Metallic and other layers are also deposited on semiconductor, sapphire or ceramic wafers.

First, is the sample clean and fresh?
If the sample is old it may be etched, washed and dried which will remove oxide which can impede ohmic contact.

Secondly, is the sample homogenous i.e. is it uniformly doped or does it have a layer on its surface e.g. by epitaxy, diffusion, ion-implantation, or sputtering etc?

If the sample has a layer it must be of the opposite conductivity type to the substrate i.e. electrically insulated from the substrate. A layer of the same conductivity type cannot be measured by the four point method because the substrate offers an easier path for the current, and the measured resistivity is effectively that of the substrate.

If the layer is thin, meaning sub-micron, one must avoid puncturing the layer by excessive needle loading, by sharp or rough needle tips, or too rapid descent velocity of the probes, excessive current can also inject minority carriers.
All these effects cause some leakage into the substrate, so that the measuring current in the layer is reduced, and the resistivity measured is too low.

Limits of Measurement Capability

1. The material must be capable of being probed, i.e. the probes must be able to make ohmic contact with the material e.g. Germanium, Silicon and metals. Materials such as Gallium Arsenide cannot normally be probed unless it is doped and measured with special measuring techniques such as that in the Four Dimensions Inc. GaAs probe.

2. Very low resistivity material e.g. aluminium, gold, platinum requires the maximum current from the current source to achieve a readng on the digital voltage display.

Calculation of Resistivity

A selection of correction factors are published by various authorities, covering the modifications to be made according to the specimen size and shape being measured, we show two examples for measurement of circular samples in the centre with a linear probe of spacing 's'.

Basically, bulk resistivity (for a semi-infinite volume) = 2 x pi x s x (V/I) ohm.cm where s is the spacing of the probe in cm, I the test current, and V the measured voltage.

Sheet resistance for wafers and films R_S = 4.532 x V / I ohms per square.

Bulk resistivity for wafers and films q = R_S x t = 4.532 x V x t / I where t is the thickness in cm.

General Comments

1. Most wafers and films approximate to 'infinite sheets' at the present time, but if the thickness is greater than 5 □□the probe spacing (normally 1.00mm) i.e. 5mm then the semi-infinite solid formula is within less than 1%.

2. From the other point of view a reasonable sized wafer may be measured with a four point probe using the above sheet resistance formula. Provided the wafer thickness does not exceed 0.625 of the probe spacing the calculation is within 1%.

Please see table below.

FPP Correction Factors for Sample Thickness t		**FPP Correction Factors for sample diameter d**	
t/s	**C_1 (t/s)**	**d/s**	**C_2 (d/s)**
0.3	1.0000	10	4.1712
0.4	0.9995	20	4.4364
0.5	0.9974	30	4.4892
0.6	0.9919	40	4.5080
0.7	0.9816	50	4.5167
0.8	0.9662	60	4.5215
0.9	0.9459	70	4.5244
1.0	0.9215	80	4.5262
1.2	0.8643	90	4.5275
1.4	0.8026	100	4.5284
1.6	0.7419	200	4.5314
1.8	0.6852	□	4.5320
2.0	0.6337		

3. Remember that other geometrical effects affect the result if the wafer is not measured at the centre because the number of possible current paths is limited.

We recommend study of the following original papers:

a) Linear Array Probes

Circular wafers at centre:
1. D. E. Vaughan, Br.J. Appl. Phys., 12, 414 (1961)
2. M. A. Logan, Bell Sys. Tech. J., 40, 885 (1961)

Off centre but on radius:
3. L. J. Swartzendruber, National Bureau of Standards Technical Note 199 (1964)

Perpendicular to radius:
4. M. P. Albert and J. F. Combs, IEEE Trans. Electron Devices, ED-11, 148 (1964)
5. L. J. Swartzendruber, Solid State Electronics, 7, 413 (1964)

Rectangular sample at centre and off centre:
6. M. A. Logan, Bell Sys. Tech. J., 46, 2277 (1967)

Half cylinder:
7. E. B. Hansen, Appl. Sci. Res., 8B, 93 (1960)

Circular rod:
8. H. H. Gegenwarth, Solid State Electronics, 11, 787 (1968)

Rectangular bar:
9. A. Marcus and J. J. Oberly, IEEE Trans. Electron. Devices, ED-3, 161 (1956)

Note: All the foregoing is based on measurement using a four point linear probe, the current being passed between the outer probes and the voltage measured across the inner two probes.

b) Square Array Probes

Small slice at centre:
as 9 above
Small slice along a radius:
as 3 above
Square sample:
10. M. G. Buehler, Solid State Electronics, 10, 801 (1967)

Thick sample near boundary:
11. S. B. Catalano, IEEE Trans. Electron. Devices, ED-10, 185 (1963)

thin infinite sheet:
as 10 above

Note: Square array probes have the current passed between two adjacent probes and the voltage measured across the two opposite when used for resistivity measurement.