MONOLITHIC CIRCUIT TEST

STANDARDS

By George O. Compton and Joseph R. Adame

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SUMMARY

This final report covers the work performed under Contract
NAS 8-21199. This contract with Fairchild Semiconductor, a Division
of Fairchild Camera and Instrument Corporation, was for the
preparation of "Monolithic Circuit Test Standards" for use in Line
Certification of monolithic circuits. Dr. A. M. Holladay, of the
Astrionics Laboratory, George C. Marshall Space Flight Center,
National Aeronautics and Space Administration, Huntsville, Alabama,
was the Technical Contract Monitor.

Mr. George O. Compton was the principal investigator during the
period of this contract. Mr. Joseph R. Adame also worked on the
contract.

No New Technology was developed during the work on this contract.

INTRODUCTION

The following specifications have been prepared after a survey of
Research and Development and Manufacturing Facilities. Methods,
except for certain proposals, are as used in day-to-day operations.
Proposed tests have been presented after consultation with scientists
and engineers most knowledgeable in the areas covered.

Items included in the Contract scope of work, which are not covered
in this series of standards, include.

1. <u>Water</u> - CO_2 and Organic content.

2. <u>Substrate</u> - Inclusions.

3. <u>Mounting</u> - Centrifuge and Radiographic Evaluation.

4. <u>Electrical Tests</u> - Bipolar Transistor parameters, except storage time and alpha cut-off frequency.

Present technology of hyper-pure water evaluation is not sophisticated enough to have evolved meaningful tests for either CO_2 or Organic content.

Inclusions in substrate material will be most readily apparent after epitaxy.

MIL-STD-202, Method 212 and MIL-STD-750, Method 2006 are deemed adequate for evaluation of mounting and packaging by centrifuge.

No improvement upon MIL-STD-202, Method 209, is presently available for radiographic examination.

MIL-STD-750, Methods 3001-4151 are adequate for process control, except that the storage time and alpha cut-off frequency are difficult to measure prior to dicing. Measurement of stored charge, Q_{bx}, is suggested as a substitute for these A-C tests.

During the course of the Contract, it has become apparent that additional research is required in several areas. Evaluation of water for use in semiconductor manufacture would be a fertile area of effort.

Present radiographic techniques leave much to be desired when examining devices manufactured with low mass materials. Aluminum wire, for example, is impossible to detect in X-Ray photographs of integrated circuits.

Current methods for detecting gross leaks utilize the observation of bubbles from defective devices. This is both a slow and subjective technique. An improved procedure should be developed which is more definitive and quantitative. One approach would be the introduction of liquid into the package which could later be detected in radiflow-type equipment.

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Method 101

Substrate Bulk Resistivity
(Four Point Probe)

1. Purpose   This method may be used to determine the
                    resistivity of the substrate. A four-point probe
                    is used to obtain sheet resistance for a material
                    of known thickness, which yields resistivity:

$$\rho = A \frac{V}{I} \qquad A = F(W, S)$$

if $W << S$

$$\rho = 4.53\ W \frac{V}{I}$$

Where: W = Substrate Thickness

         S = Probe Spacing

         $\frac{V}{I}$ = Sheet Resistance of the Layer

2. Apparatus

   2.1   Four-Point Probe
         A. M. Fell Co.
         (or equivalent)

   2.2   Power Supply, Constant Current
         0.1, 1.0, 10mA Ranges
         (any source)

   2.3   Voltmeter, Digital
         Fairchild 7100
         (or equivalent)

1

3.   Materials

.3.1   Glass Microscope Slides, 1" x 3"

4.   Procedure

4.1   Place the wafer to be measured on the glass slide under the four point probe head. Center the wafer so that no probe point is closer than 1/8" from the edge of the wafer. See Figure 1.

4.2   Set the constant current selector to 0.01 ma.

4.3   Turn the constant current generator switch on.

4.4   Screw the four point probe down on the wafer using the end ratchet until the proper contact causes the ratchet to slip.

4.5   Check to see if the constant current meter is indicating full scale. If not, raise the probe and repeat step 4.4.

4.6   Switch the polarity of the current generator from plus to minus and observe the current reading for any variation.

4.7   If full scale current readings are obtained in both positions, (i.e., plus and minus), read the indicated V/I on the voltmeter.

4.8   The V/I readings should be within 10% of each other when the polarity of the current generator is reversed. If this is not so, release the pressure on the probe head 1/4 turn of the ratchet at a time until the readings do agree within 10%.

4.9   Take three V/I readings on each check wafer, average and record. See Figure 2 for example.

5.   Calibration

5.1   Probe Spacing

5.1.1   Cover a 1" x 3" glass microscope slide with aluminum foil.

2

5. 1. 2   Obtain an impression of the four point probe points.

5. 1. 3   Measure spacing with any optical comparator.

5. 1. 4   Adjust spacing per probe manufacturer's instructions.

6.   <u>Accuracy</u>

Obtainable accuracy is ± 10%.

7.   <u>Test Frequency</u>

This test should be performed on every substrate.

FOUR POINT PROBE – SET-UP
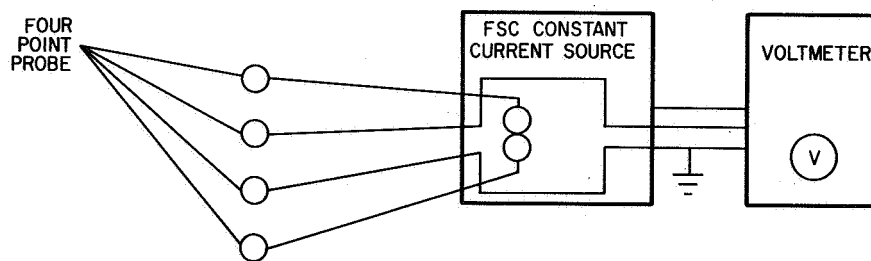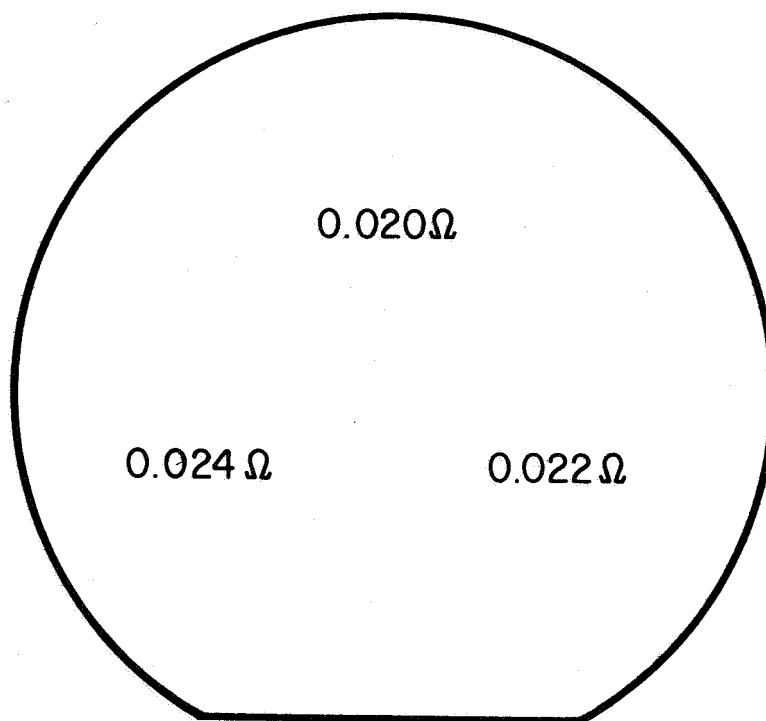
Figure 1.

Figure 2. Resistivity Measurement

$$\frac{V}{I} = \frac{0.024 + 0.022 + 0.020}{3} = 0.022$$

$$W = 10^{-3} \text{ cm} = 250\mu = 2.5 \times 10^{-1} \text{ cm}$$

$$\rho = 4.53 \text{ W} \frac{V}{I}$$

$$= 4.53 \times 2.5 \times 10^{-1} \times 2.2 \times 10^{-2}$$

$$= 4.53 \times 2.5 \times 2.2 \times 10^{-3}$$

$$= 0.25 \ \Omega - \text{cm}$$

5

Method 102

Substrate Orientation
(ASTM)

1.   Purpose   The purpose of this method is to determine the deviation of a slice from the <111>, <100> or <110> planes. It utilizes the reflection of light from a point source which is reflected by etch pits in the wafer to a cross-lined screen. The sample is mounted on a Goniometer calibrated in degrees and minutes to measure angular displacement in two planes.

2.   Apparatus

    2.1   Optical Orientation System
           Sylvania Crystal Orientation Instrument
           (or equivalent)

    2.2   Sandblast Unit
           S.S. White Industrial Air-Brasive Unit
           (or equivalent)

3.   Materials

    3.1   Sodium Hydroxide, Reagent grade

    3.2   Deionized water

    3.3   Abrasive, S.S. White No. 1

4.   Procedure

4. 1   Sample Preparation

4. 1. 1   Cut a slice according to standard production process.

4. 1. 2   Sandblast slice.

4. 1. 3   Etch slice in 10% sodium hydroxide solution at 90° C for about 5 minutes.

4. 1. 4   Rinse thoroughly in deionized water.

4. 1. 5   Blow dry with a nitrogen gun.

4. 2   Measurement

4. 2. 1   Mount slice in sample holder on Goniometer.

4. 2. 2   Turn on zirconium arc lamp.

4. 2. 3   Adjust Goniometer position to bring the center of the light pattern to a zero reference point on the screen.   See Figure 1.

4. 2. 4   The angular reading of the Goniometer adjustment is the degree of misorientation.

4. 2. 5   Check measurement by rotating the slice 180° and noting that deviation is of equal value to 4. 2. 4, but of opposite sign.

5.   Calibration

5. 1   Set Goniometer to zero position.

5. 2   Substitute first surface mirror for slice in sample holder.

5. 3   Adjust sample holder to place center of light pattern at zero reference point on the cross-lined screen.

6.   <u>Accuracy</u>

Accuracy obtainable is $\pm$ 15 minutes of arc.

7.   <u>Test Frequency</u>

Each crystal sliced should be sampled for deviation.

FIGURE I OPTICAL CRYSTAL
ORIENTATION INSTRUMENT

Method 103

Substrate Thickness

1.   Purpose   The purpose of this test method is to determine the thickness of the substrate by direct measurement.

2.   Apparatus

   2.1   Thickness Gauge
   Federal Electronic Gauge
   Model 100B-48
   (or equivalent)

   2.2   Calibration Gauges
   "Jo Blocks"
   (or equivalent)

3.   Materials

   None.

4.   Procedure

   4.1   Place the substrate, best side up, on the gauge anvil.

   4.2   Depress the foot pedal to lower the probe to the wafer surface.

   4.3   Measure the wafer thickness in the five locations shown in Figure 1.

   4.4   Compare the thickness readings and determine average thickness and range of variation.

5.   Calibration

   Measure a thickness standard of known size and, using the zero control, adjust the meter until there is direct correlation.

6.   <u>Accuracy</u>

Accuracy obtainable is ± 1 micron.

7.   <u>Test Frequency</u>

This should be a periodic test.
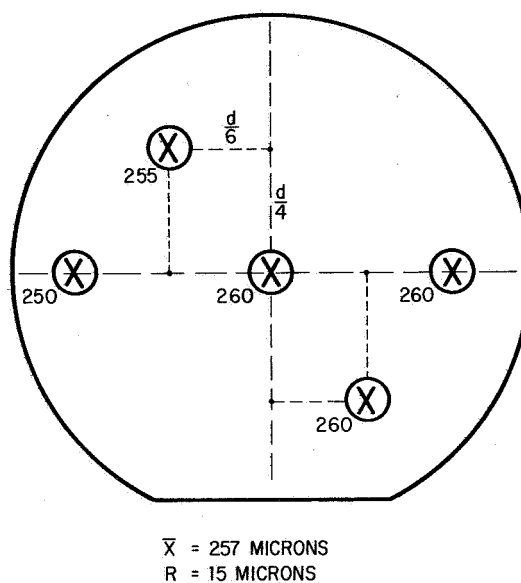
Figure 1. Thickness Measurement

Method 104

Substrate Parallelism

1.   Purpose   The purpose of this test is to measure the degree of
parallelism of the substrate sides. Thickness
measurement across the substrate is compared to
determine any taper.

2.   Apparatus

   2.1   Thickness Gauge
Federal Electronic Gauge
Model 100B-48
(or equivalent)

   2.2   Calibration Gauges
"Jo Blocks"
(or equivalent)

3.   Materials

None.

4.   Procedure

   4.1   Place the substrate, best side up, on the anvil. Figure 1.

   4.2   Depress the foot pedal to lower the probe to the wafer
surface.

   4.3   Note the thickness of the substrate as indicated on the
meter dial.

   4.4   Repeat 4.2 and 4.3 several times and obtain an average
across the substrate if classification is necessary.

5.   Calibration

Measure a thickness standard of known size and, using the zero
control, adjust the meter until there is direct correlation.

1

6. <u>Accuracy</u>

Accuracy obtainable is $\pm$ 1 micron.

7. <u>Test Frequency</u>

Each substrate should be measured.

$\overline{X}$ = 257 MICRONS
R = 15 MICRONS
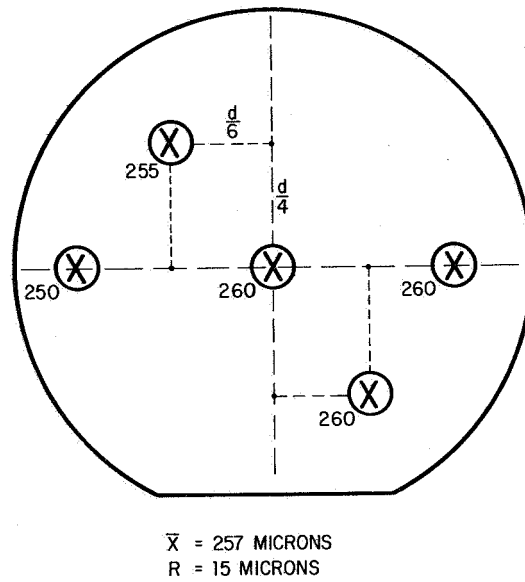
Figure 1. Thickness Measurement

Method 105

Substrate Flatness

1. __Purpose__   This test may be used to determine bowing of the substrate. It utilizes the flexing of a bowed substrate during thickness measurement.

2. __Apparatus__

   2.1   Thickness Gauge (contact type)
   Federal Electronic Gauge
   (or equivalent)

   2.2   Microscope Lamp
   American Optical Co.
   Model A0653
   (or equivalent)

3. __Materials__

   None.

4. __Procedure__

   4.1   Adjust lamp to provide low angle (less than 45°) illumination of the wafer upon the gauge anvil.

   4.2   Lower the gauge probe to the wafer.

   4.3   Observe wafer surface for deformation (convex bow) or raising of opposite side (concave bow).   Figure 1.

   4.4   Repeat 4.3 to include center and three perimeter locations.

5. __Calibration__

   None.

6. __Accuracy__

   Accuracy is dependent upon the thickness of the substrate and its surface finish.

1

7. Test Frequency

This test should be performed on all thin (less than 100 micron) substrates and periodically on others.

NOTE: This test may be performed concurrently with thickness or parallelism measurements.
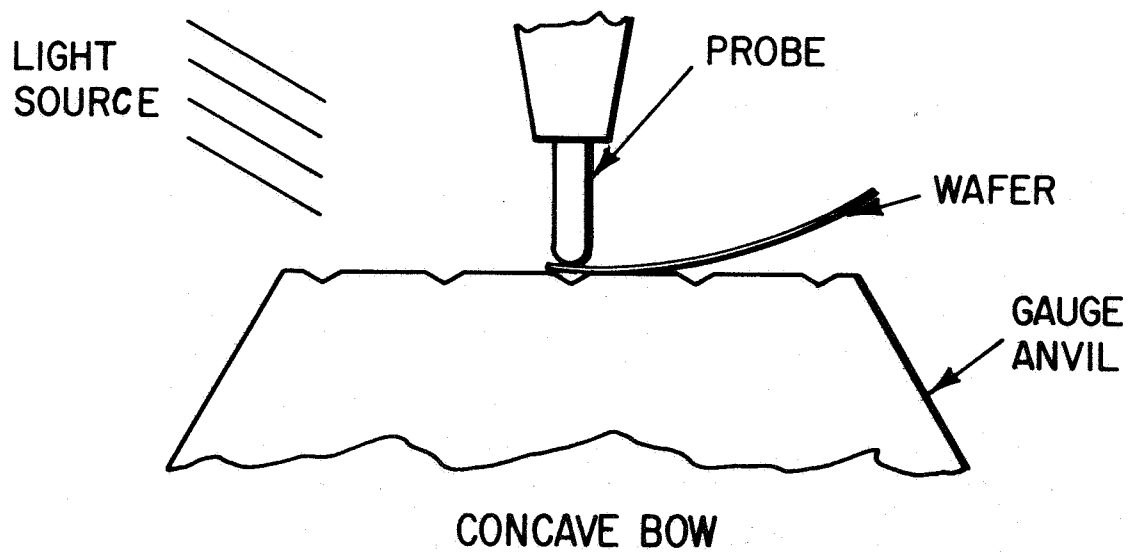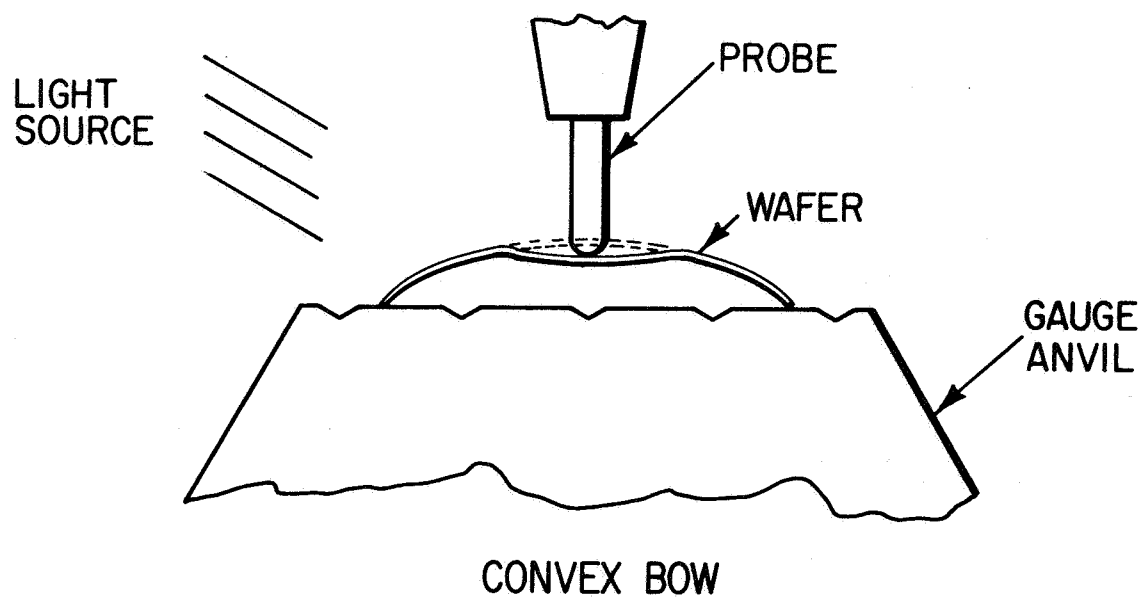
Figure 1. Substrate Bowing

3

Method 106

Substrate Crystal Perfection
(Dow Corning, ASTM)

1. Purpose   The purpose of this method is to determine
               crystalline perfection of substrates. It utilizes a
               peferential etch to reveal dislocations, lineage,
               slip, etc.

2. Apparatus

    2.1 Metallurgical Microscope
         Bausch and Lomb, Model 31-20-68-38 (DMETR)
         (or equivalent)

3. Materials

    3.1 Chromium Trioxide, Reagent grade.

    3.2 Hydrofluoric Acid, Electronic grade.

    3.3 Deionized Water.

4. Procedure

    4.1 Preparation

         4.1.1 Obtain a polished substrate.

         4.1.2 Mix two stock solutions:

                A - 100ml Deionized Water
                     50 grams Chromium Trioxide

                B - 50ml Hydrofluoric Acid

    NOTE: Solution may be stored after mixing.

1

4. 1. 3   Etch wafers for 10 - 12 minutes (25°C).

4. 1. 4   Rinse thoroughly with deionized water.

4. 1. 5   Dry with nitrogen gun.

4. 2   Inspection

4. 2. 1   Using a microscope with a grid eyepiece, count the number dislocations in one or more squares of the grid at each of nine locations on the sample. See Figures 1 and 2.

4. 2. 2   Calculate the dislocation density as pits per square centimeter using the following equation:

$$\text{Density} = \frac{\text{Total No. Pits}}{\text{No. Squares x Area of One Square}}$$

4. 2. 3   Note the number found of each of the following defects:

4. 2. 3. 1   Lineage   A plane imperfection appearing as a linear array of etch pits with density greater than 25 per millimeter. See Figure 3. Pits are aligned point to base.

4. 2. 3. 2   Gross Lineage   Parallel lineages within 200 microns of one another.

4. 2. 3. 3   Slip Line   A plane imperfection in a crystal appearing as a very straight line of pits with density greater than 25 per millimeter. Pits will be aligned with bases on a straight line.   See Figure 4.

4. 2. 3. 4   Grain Boundary   The boundary between two areas of different crystal orientation. Etch pits cannot be resolved at boundary. See Figure 5.

4. 2. 3. 5   Twin Lamella   A boundary with no obvious change in orientation across the boundary (found only on <111> planes). See Figure 6.

2

5.   <u>Calibration</u>

None.

6.   <u>Accuracy</u>

Not applicable.

7.   <u>Test Frequency</u>

This test should be performed periodically.
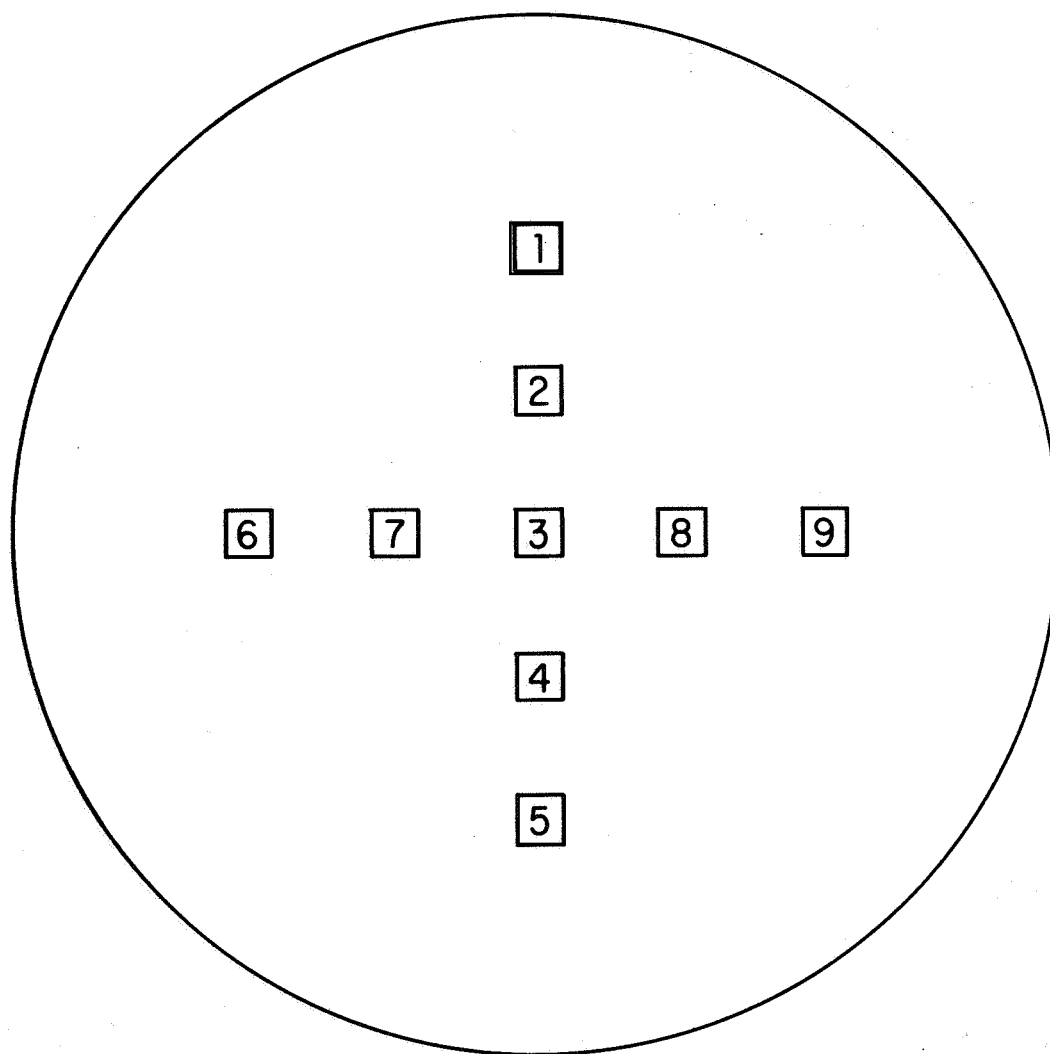
Figure 1.   Sampling Pattern
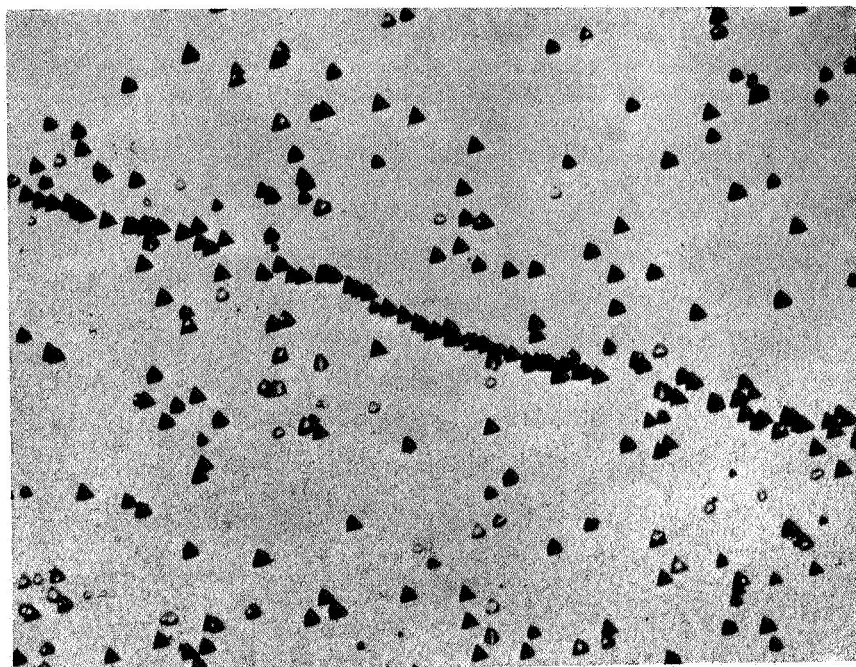
Figure 3. Lineage
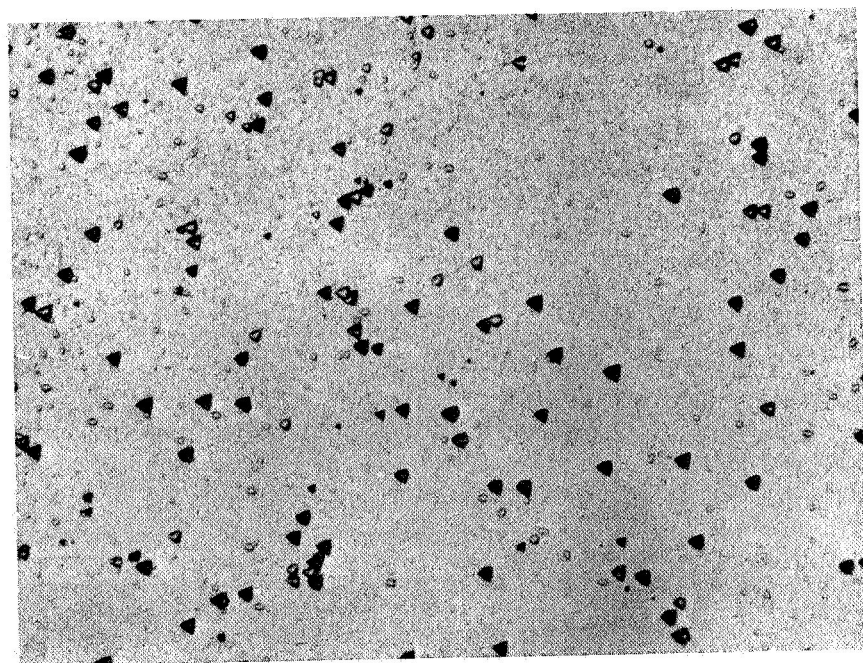
Figure 2. Dislocations

5
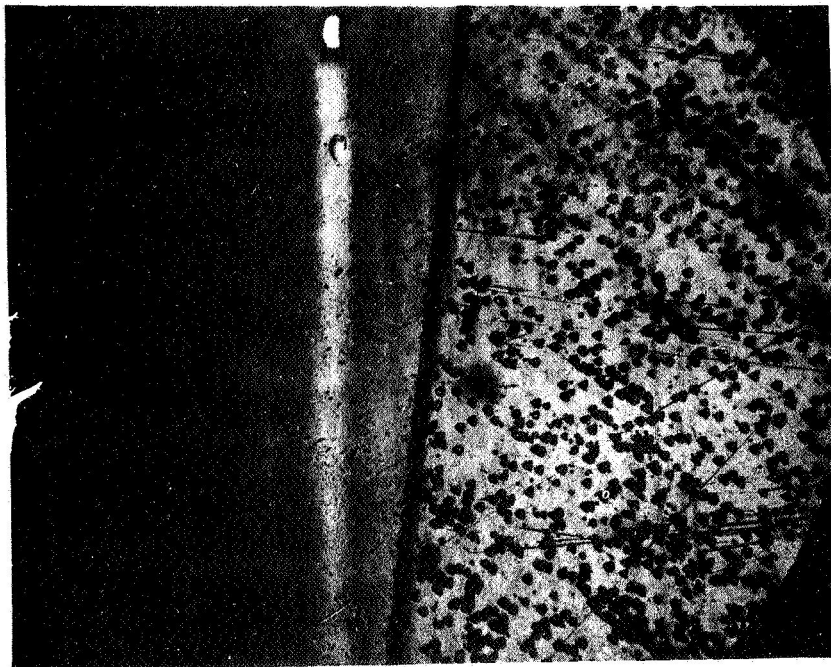
Figure 5.   Grain Boundary
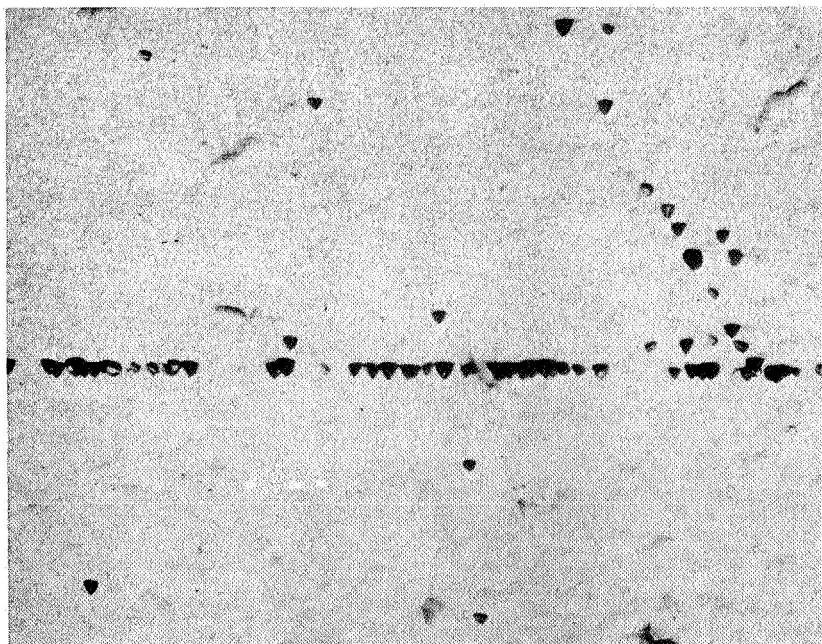
Figure 4.   Slip Line
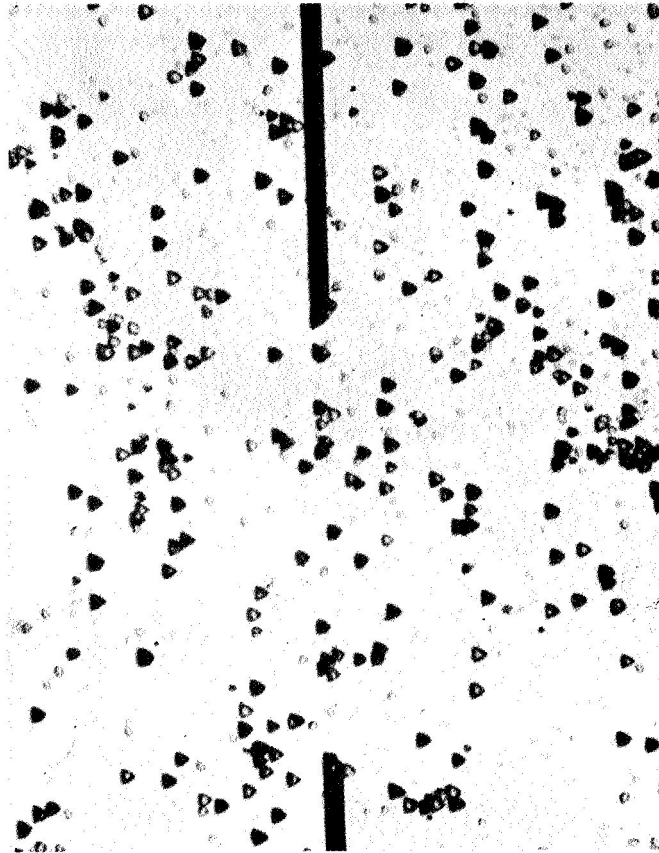
Figure 6.   Twin Lamella

Method 107

Substrate Conductivity Type
(Hot-Probe)

1. <u>Purpose</u> This test may be used to determine the conductivity type of the device substrate. It utilizes the thermoelectric effect where the majority carriers tend to migrate to the hot probe, causing deflection of a galvanometer.

2. <u>Apparatus</u>

   2.1 Galvanometer
   (any source)

   2.2 Soldering Iron, small
   (any source)

3. <u>Materials</u>

   None.

4. <u>Procedure</u>

   4.1 Connect the equipment as shown in Figure 1.

   4.2 Turn on the soldering iron and allow 5 minutes to reach temperature.

   4.3 Place the substrate to be tested upon the aluminum.

   4.4 Touch the sample surface with the probe tip.

   4.5 Observe the Galvanometer deflection to determine conductivity type.

5. <u>Calibration</u>

   At the start of testing a small battery may be placed on the aluminum strip and probed to verify correct connections.

1

6.   Accuracy

This test is 100% accurate below 5 Ω-cm resistivity material.

7.   Test Frequency

This test should be performed on a sample basis on each lot of wafers.
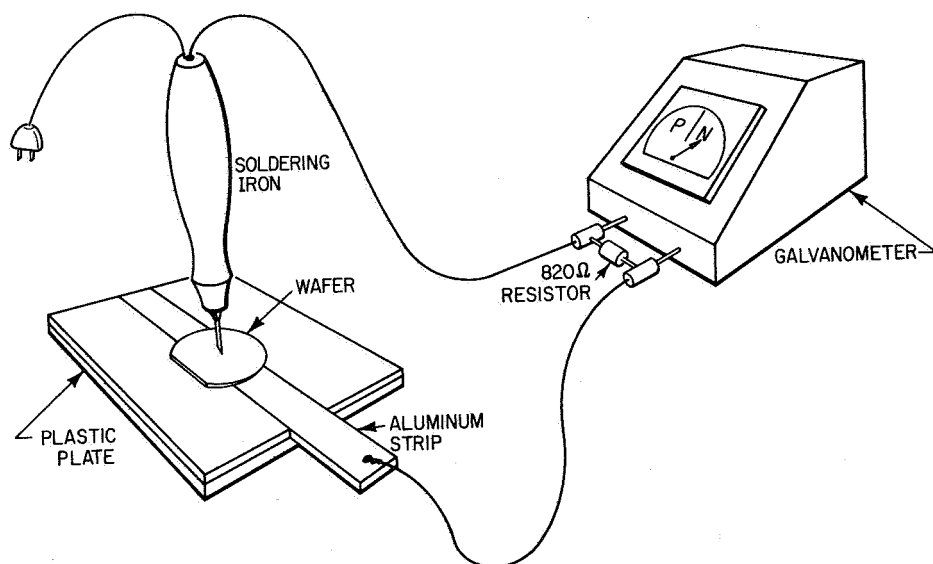
Figure 1.   Hot Probe Setup

Method 108

Substrate Surface Finish

1. <u>Purpose</u>   The purpose of this test is to determine the surface finish of the polished substrate.

2. <u>Apparatus</u>

    2.1   Microscope Illuminator
          American Optical   AO No. 653
          (or equivalent)

3. <u>Materials</u>

    None.

4. <u>Procedure</u>

    4.1   Pick up wafer with clean tweezers.

    4.2   With the light source collimated, rotate the polished surface so that it is illuminated through a wide range of angles.

    4.3   Note any roughness, ripple or "orange-peel".

5. <u>Calibration</u>

    Not applicable.

6. <u>Accuracy</u>

Surface irregularities with a peak-to-valley distance of about $2900\,\overset{\circ}{A}$ ($\frac{\lambda}{2}$ for sodium) may be observed.

7. <u>Test Frequency</u>

All wafers should be inspected.

Method 109

Substrate Width or Diameter

1. Purpose   This method may be used to measure the width or diameter of a substrate to determine process compatibility.

2. Apparatus

2.1 Steel Rule, six inch
     (any source)

2.2 Go-No-Go Gauge
     (any source)

3. Materials

3.1 Bibulous Paper

4. Procedure

4.1 Direct Measurement

    4.1.1 Place steel rule on a clean sheet of paper.

    4.1.2 Place wafer upon rule with maximum dimension along ruled edge.

    4.1.3 Note width or diameter as required.

4.2 Go-No-Go

    4.2.1 Place two sheets of bibulous paper upon the working surface.

4.2.2   Upon one place a 4" x 4" thin metal plate containing a hole of maximum allowable diameter.

4.2.3   Upon the other, place a plate with a minimum diameter hole.

4.2.4   Gauge wafers to be smaller than maximum and greater than minimum diameters.

5.   Calibration

None.

6.   Accuracy

6.1   Accuracy obtainable is $\pm$ 1/32 inch.

6.2   Accuracy required is $\pm$ 1/16 inch.

7.   Test Frequency

7.1   Direct measurement should be done periodically.

7.2   Go-No-Go testing should be performed on all wafers to be heat treated at high temperatures.

Method 110

Water Resistivity

1. Purpose   This method may be used to determine the resistivity of high purity water. It utilizes a resistance bridge with temperature compensation.

2. Apparatus

    2.1 Resistance Bridge
    Beckman Solu Bridge, Model RD-146-Y1
    (or equivalent)

3. Materials

    None.

4. Procedure

    4.1 Plug instrument power cord to 110 volt source.

    4.2 Place instrument on table or other solid footing.

    4.3 Connect cell to binding posts 1 and 2 (no polarity).

    4.4 Attach cell to water outlet.

    4.5 Turn water to about one-fourth full flow.

    4.6 After one to two minutes, measure water temperature at discharge.

    4.7 Adjust temperature compensation dial to agree with water conditions.

4.8   Using sensitivity dial, adjust tuning-eye (iris) to best close distune (two faint shadows will form one matched dark one).

4.9   Allow one minute to stabilize, and note resistivity indicated on sensitivity dial.

5.   <u>Calibration</u>

Calibrate per manufacturer's instructions.

6.   <u>Accuracy</u>

Accuracy obtainable is $\pm 10\%$.

7.   <u>Test Frequency</u>

This test should be performed periodically.

Method 111

Water Solids
(Particle Count)

1. Purpose   This method may be used to determine the number
                  of undissolved particles present in high purity
                  water.

2. Apparatus

    2.1 Microscope
         Bausch and Lomb, Model 31-20-68-38 (DMETR)
         (or equivalent)

3. Material

    3.1 Small Knife
         Exacto
         (or equivalent)

    3.2 Tweezers
         EREM No. 2A
         (or equivalent)

    3.3 Filter Paper, 0.45 micron membrane
         Gelman, GA-46
         (or equivalent)

4. Procedure

    4.1 Obtain a 0.45μ membrane filter from any area utilizing
         these filters within the plant. Record time, date, area,
         department and amount of water flushed through filter.
         Label direction in which water flowed through filter.

1

4.2   With an exacto knife, cut about a quarter (1/4) inch area from the center of membrane filter.

4.3   With tweezers, pick the center piece and place face up (upstream) under the prescribed microscope and count particles under a 40X magnification. In order to bring lens into focal adjustment, focus on edge of filter paper with coarse adjustment knob of microscope then bring particles into focus with fine adjustment knob. All distinguishable particles shall be counted as one.

4.4   Divide the number of particles counted by the number of liters flushed through filter and multiply by 8×10^5. If no particles are seen in the first field of view, scan a total of fifteen (15) fields of view, divide number by fifteen (15) and proceed with calculations.

Example:

Quantity of Water = 1000 liters

Number of Particles = 10

Fields Scanned = 15

$$\text{Particles/Liter} = \frac{10 \times 8 \times 10^5}{1000 \times 15} = \frac{8}{15} \times 10^3 = 534$$

5.   Calibration

None.

6.   Accuracy

Accuracy obtainable is $\pm 10\%$ for 0.5 micron particles.

7.   Test Frequency

This test should be performed periodically.

Method 112

Water Bacteria Count

1. <u>Purpose</u>   This test may be used to obtain a bacteria count
    for high purity water.

2. <u>Apparatus</u>

    2.1 Bacteria Counter
         Quebec Colony Counter
         (or equivalent)

3. <u>Materials</u>

    3.1 Pipette, 1 ml

    3.2 Petri Dish, 100 x 15mm

    3.3 Broth Solution, Agar

4. <u>Procedure</u>

    4.1 <u>Preparation of Broth</u>

        4.1.1   Weigh out 4.8 grams of Agar and mix in a clean
                400 ml beaker with 200 ml of cold distilled
                D.I. Water (25°C).

        4.1.2   Place mixture on a hot plate and heat to boiling
                to dissolve the medium completely. Keep well
                stirred.

        4.1.3   Cover container with aluminum foil and place in
                autoclave.

1

4.2   Sterilization

4.2.1   Petri dishes, 1 ml pipette, water sample bottles and glass stoppers and Agar. Nutrient medium shall be sterilized at 15 pounds pressure for 15 minutes. Wrap Petri dishes individually in aluminum foil.

4.3   Actual Procedure

4.3.1   Allow water to run for at least five minutes prior to drawing samples. Draw water sample in sterile container, fill to top, stopper, wrap top of bottle in tin foil and identify.

4.3.2   The sample bottle should be shaken vigorously 25 times, and 1 ml. should be drawn with a standard sterile pipette. If a second sample is desired, shake the sample bottle vigorously another 25 times before the second is withdrawn.

4.3.3   The withdrawn 1 ml water sample should be transferred to a sterilized 100 x 15 mm petri dish. Add 10 ml of liquefied Agar (which is maintained at a 44°C $\pm$ 1°) directly to the petri dish. The cover of the petri dish is lifted just enough for the introduction of either the pipette or culture medium. The lips of all test tubes or flasks used for pouring, the medium should be flamed. The medium and sample in the petri dish should be thoroughly mixed and uniformly spread over the bottom of the petri dish by tilting and rotating the dish.

4.3.4   Allow the Agar medium and water sample to solidify. The medium in all plates should be solidified as rapidly as possible after pouring and the plates placed immediately in the appropriate incubator. Not more than 20 minutes should elapse between pouring and plating.

4.3.5   Invert the petri dish and store in incubator at 20°-25°C for 72 hours $\pm$ 3 hours.

4.3.6   Counting should be done with a Quebec Colony Counter. If such equipment is not available, counting may be done with a lens giving magnification of 1.5 diameters. In order to insure uniformity of counting conditions, illumination equivalent to that provided by the Quebec Colony Counter should be employed.

4.3.7   Counting Colonies: At a 0 - 1.5X magnification, count total number of colonies in 9 squares, and calculate number of colonies per ml of water. See Figure 1.

5.   Calibration

None.

6.   Accuracy

Accuracy obtainable is $\pm$ 5%.

7.   Test Frequency

Test should be performed periodically.

3
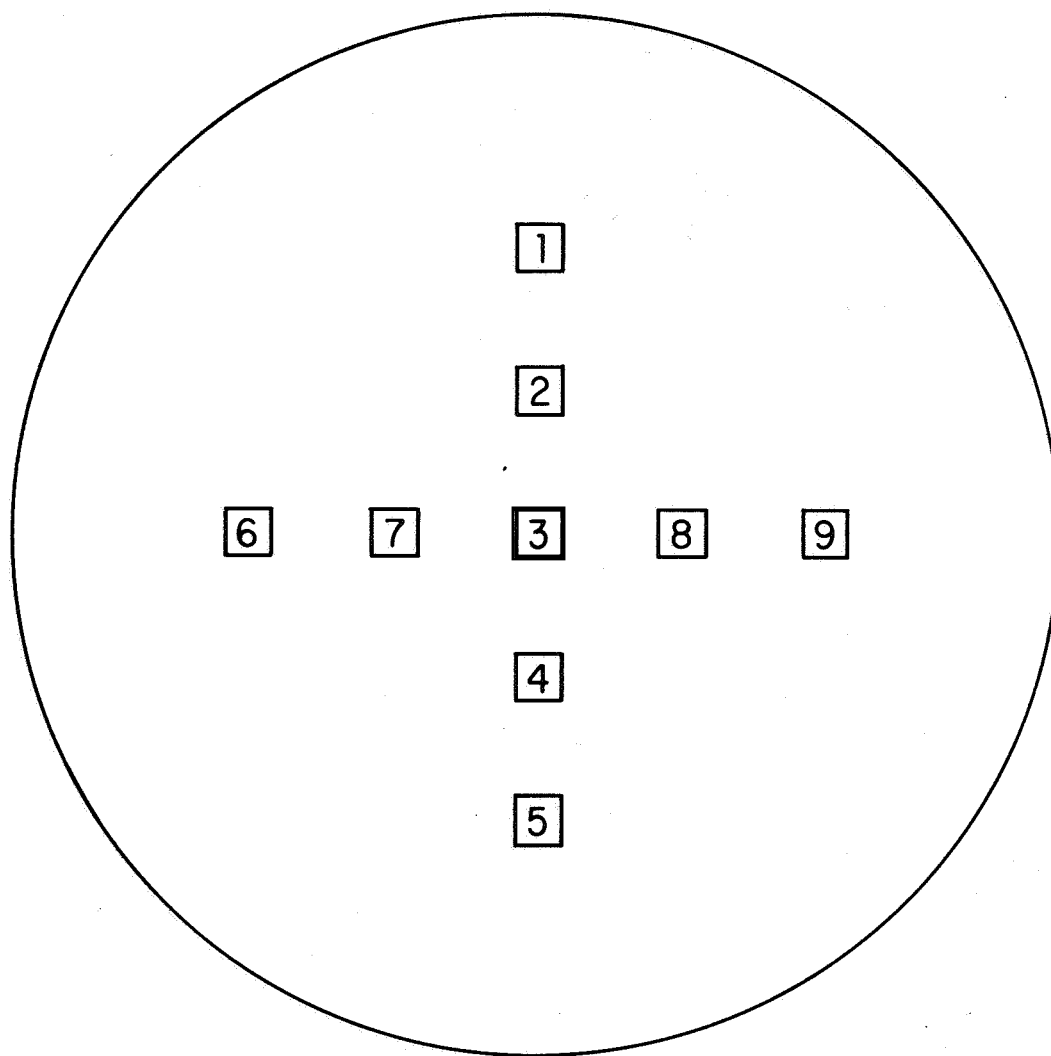
Figure 1.   Sampling Pattern

Method 113

Photoresist Viscosity
(ASTM No. D445-65)

1.   Purpose   This method may be used to determine the viscosity
             of any photoresist. It utilizes a Cannon-Fenske
             Viscometer   where a fixed volume of the liquid is
             allowed to flow by gravity through a capillary.

2.   Apparatus

   2.1   Viscometer
         Cannon-Fenske Viscometer
         Series 200, 300 and 500
         (any source)

   2.2   Viscometer Holder
         (any source)

   2.3   Viscometer Thermostat
         (any source)

   2.4   Thermometer
         Kinematic Viscosity Test Thermometer
         (any source)

   2.5   Timer 0.2 second or less/Division
         (any source)

3.   Materials

   3.1   Photoresist

   3.2   Photoresist Stripper

   3.3   Viscosity Oil Standard

1

4. <u>Procedure</u>

    4.1 Select a clean viscometer which will give the minimum specified time with the given photoresist or 200 seconds, whichever is greater. See Table I.

    4.2 Charge the viscometer with the photoresist to be evaluated.

    4.3 Allow the charged viscometer to remain in the bath long enough to reach $24 \pm 1°C$.

    4.4 Use pressure to adjust the head level of the photoresist sample to a position about 5mm ahead of the first timing mark.

    4.5 Measure to the nearest 0.2 second, the time required for the meniscus to pass from the first timing mark to the second.

    4.6 Calculate the kinematic viscosity as follows:

Kinematic Viscosity = Ct

where: C = Calibration constant of the viscometer
t = Flow Time

5. <u>Calibration</u>

Calibrate the viscometer with any standard oil, by measuring its flow time and applying the following equation:

$$C = \frac{V}{t}$$

where: V = Viscosity for the standard oil.

6. <u>Accuracy</u>

Accuracy obtainable is $\pm 1\%$.

7. <u>Test Frequency</u>

This test should be performed for every lot of photoresist.

Viscometer Applicable for Various Photoresists

Resist	Series
KPR	200
KPR-2	200
KOR	300
KMER	500
KTFR	500

Table I

3

Method 114

Photoresist Viscosity

(Torque)

1. Purpose   This test may be used as a rapid method for determining the viscosity of raw KMER. It utilizes the resistance the fluid has to the motion of a rotating spindle. It may be adapted for other types of photoresist, if a correlation study is made with a Cannon-Fenske Viscometer per ASTM No. D445-65.

2. Apparatus

    2.1   Synchro-Lectric Viscometer,
           Brookfield RVT model.
           Scientific Products
           (or equivalent) See Figure 1.

    2.2   Beakers, pyrex, 100, 600 and 1000 milliliter.
           (any source)

    2.3   Stirrer, Utility
           single speed No. 58000.
           Scientific Products Company,
           (or equivalent)

3. Materials

    3.1   KMER

    3.2   KMER thinner

    3.3   Trichloroethylene

    3.4   Acetone

4. Procedure

    4.1   Preparation

           4.1.1   Using a sink with a vented hood, pour 50-100 ml of trichloroethylene into a 600 ml beaker and rotate to ensure walls of beaker are cleaned. Pour TCE down the drain.

1

4.1.2   Pour 50-100 ml of acetone into beaker and rotate to ensure all TCE is absorbed and pour down the drain. Blow dry with N_2 gun.

4.1.3   Into DRY beaker, pour 350-400 ml of raw KMER (shake bottle vigorously for 30 seconds immediately before use). Set timer for 10 minutes and stir KMER with electric stirrer. Into a 100-ml beaker pour 60-70 ml of KMER thinner. When ten minutes are up, stop electric stirrer, dismantle blade and place into beaker full of thinner.

4.2   Measurement

Note: Room temperature shall be $24 \pm 1°C$.

4.2.1   Bring the sample directly under the spindle holder, install spindle No. 2 (number is on neck of shaft) and make sure that the spindle is suitable centered. The spindle should be correctly immersed to the groove found on the shaft. Do this by lowering or raising entire spindle assembly on stand. NOTE: Handle spindle with forefinger and thumb. Grasp shaft between groove and spindle only.

4.2.2   Turn speed selector knob to 50. With right hand turn the on-off toggle switch to on and allow spindle to rotate at least a dozen times to equilibrate itself with the viscosity of the material. With left hand press down on clutch lever in back of spindle assembly. This will automatically "lock" dial. Turn toggle switch off and record dial reading. Important: If dial reading does not come into scale view, do not release clutch lever. Simply turn toggle switch on and off until dial comes into view. Release clutch lever and record reading.

4.2.3   Record dial reading on to proper log sheet and from Brookfield Factor Finder obtain proper multiplication factor. This is done in the following manner:

4.2.3.1   The top two letters on the "slide" designate the viscometer model number. Slide the rule until letters RV appear.

4.2.3.2   The number in large bond type directly below the model letters designates the spindle number. Slide the rule to No. 2.

4.2.3.3   The numbers on the left side of the column designates the speed of the spindle. Go down to 50.

4.2.3.4   The numbers on the right side of the column designates multiplication factor. The number directly across the applied speed is the proper multiplication factor. Multiply dial reading by multiplication factor and enter results in proper log sheet. Viscosity has been measured in centipoise.

Example:

Spindle No.	Speed	Dial Reading	Multiplication Factor	Viscosity
2	50	61	8	488 cp

4.2.4   Raise entire spindle unit out of the sample and remove spindle. Place dirty spindle into beaker full of KMER thinner. Cover sample in beaker with tin foil and do not remove until sample is ready to be checked for surface tension.

5.   Calibration

5.1   Make sure that the Brookfield Viscometer is perfectly level; if not, adjust by turning the knobs on the stand until the bubble level indicates instrument is level.

5.2   Spindle size and speed calibration may be checked by correlation with a Cannon-Fenske Viscometer, series 500, per Method 113, "Photoresist Viscosity" (Cannon-Fenske).

6.   Accuracy

Obtainable accuracy with this procedure is ± 1 percent.

7.   Test Frequency

This test should be performed on a sample of each photoresist lot.
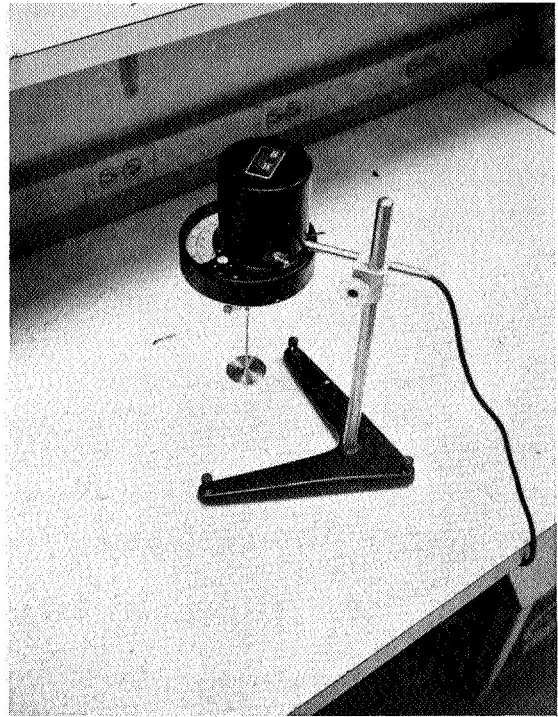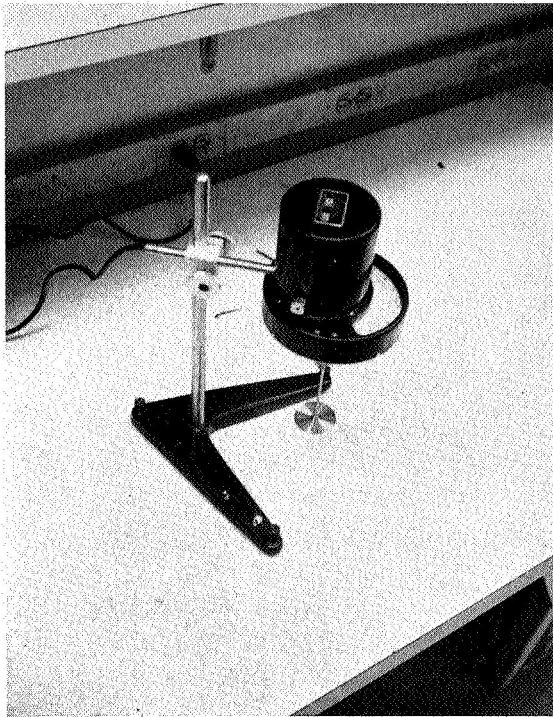
Figure 1. Synchro-Lectric Viscometer

Method 115

Photoresist Solids Residue

1. Purpose   The purpose of this test is to determine the solids
              content of a given photoresist. It utilizes the
              evaporation of solvents and differential weighing.

2. Apparatus

    2.1 Analytic Balance with Magnetic Damper
         Chainomatic
         (Christian Beaker AB-4) Model No. B 1550
         Scientific Products Company
         (or equivalent)

    2.2 Balance, Triple Beam, Metric Ohaus 760 Order No. B1770
         Scientific Products Company
         (or equivalent)

    2.3 Bunsen Burner, Heavy Duty
         Scientific Products Company
         (or equivalent)

    2.4 Desiccator, Scheibler
         Model No. 01450-5
         (or equivalent)

    2.5 Hot Plate, Electric 6" x 6",
         Tempco, Type 1900
         (or equivalent)

    2.6 Oven, Precision
         Delco, N-8012, F. O. 31540 No. 25
         (or equivalent)

3. Materials

    3.1 Photoresist

    3.2 Photoresist Thinner

3.3   Aluminum Weighing Dishes

3.4   Sand, 30 Mesh White

3.5   Applicators, Cotton -Tipped

4.   Procedure

    4.1   For each sample (two samples shall be run on each lot) to be analyzed obtain an aluminum weighing dish and identify by lettering weighing dish flap with lot number.

    4.2   Pour about 10 grams of white sand into weighing dish and get an accurate weight (0.1 gr) of weighing dish, Q-tip and sand. Record lot number and this weight in proper log sheet.

    4.3   Pour 8-10 grams of photoresist into weighing dish and weigh immediately. Record weight in log sheet. Thoroughly mix photoresist into sand with Q-tip and place on 300°C hot plate for 10 minutes.

    4.4   After hot plate place photoresist weighing dish with Q-tip into 105°C oven for 16 hours. Record time weighing dish went into oven and time it came out. Take photoresist dish and place in desiccator for 1 hour. Weigh accurately and record weight in log sheet. Calculate percentage of total solids in following manner:

      a.   Wt. of dish, sand and stirrer   =   15.7 grs.

      b.   Wt. of photoresist, dish, sand and stirrer   =   23.7 grs.

      c.   Wt. of baked photoresist, dish, sand and stirrer   =   17.7 grs.

Substract (a) from (b) to obtain weight of sample.
Substract (a) from (c) to obtain weight of residue.

$$\text{Solids \% by Wt.} \quad = \quad \frac{\text{Wt. of residue x 100}}{\text{Wt. of sample}}$$

$$\frac{2.0 \times 100}{8.0} = 25.0\%$$

5.   Calibration

Zero balances prior to use.

6.   Accuracy

Accuracy obtainable is $\pm 1.0\%$.

7.   Test Frequency

This test should be performed on a sample from each photoresist lot.

Method 116

Photoresist Surface Tension

1. __Purpose__   The purpose of this test is to measure the apparent surface tension of the photoresist. This is accomplished by wetting a platinum wire to the resist surface and measuring the force required to break contact.

2. __Apparatus__

   2. 1   Tensiometer,
   Catalog No. 70535.
   Central Scientific Products, Santa Clara, California,
   (or equivalent)

   2. 2   Beakers,
   100, 600 and 1000 milliliter.
   (any source)

3. __Materials__

   3. 1   Photoresist

   3. 2   Photoresist thinner

   3. 3   Trichloroethylene

   3. 4   Acetone

   3. 5   2-Butanone

   3. 6   Filter paper

4. __Procedure__

   4. 1   Attach pre-cleaned platinum ring to the lever arm of the tensiometer. (See Figures 1 and 2).

   4. 2   Out of the 600-ml beaker containing the raw photoresist, pour about 40-50 ml of photoresist into pre-cleaned 100-ml beaker. Be sure to cover photoresist in 600-ml beaker with tin foil. Place 100-mil beaker on sample table.

1

4.3 With screw (B) in its uppermost position, raise the entire sample table assembly until the ring is immersed about five mm in the liquid.

4.4 Lower the entire assembly until the ring is just below the surface of the liquid and approximately centered with respect to the container. Further lower the liquid by means of screw (B) until the ring is on the surface of the liquid and the index is approximately on zero.

4.5 Increase the torsion of the wire by rotating knob (A) and at the same time lower the sample table by means of screw (B) so as to keep the index on zero. The index is to be kept on zero even though the surface of the liquid is distended. Continue this double movement until the film breaks.

4.6 The scale reading at the breaking point of the film is the apparent surface tension P. Record this in the proper log sheet.

5. <u>Calibration</u>

5.1 Calibration of Tensiometer

5.1.1 Make sure that the instrument is perfectly level before calibrating; if not, adjust knobs on bottom of stand until level (L) indicates instrument is level.

5.1.2 Clamp the torsion arm with the adjustable stops (D). Hang the dry platinum ring on the hook (H) and cut and fit a small strip of paper on the ring as a platform. Release the torsion arm. Turn the knob (A) until the index (1) and its mirror image are exactly in line with the reference line in the mirror. Loosen the dial clamp (C) and rotate the dial (S) until the vernier (V) indicates approximately zero. Tighten the dial clamp and rotate the dial by means of the fine adjustment (F), until the reading of the vernier is exactly zero.

5.1.3 Place on the paper platform some accurately known weight of from 500 to 800 milligrams and turn knob (A) until the index (1) is again opposite the reference line on the mirror. Record the dial reading to 0.10 division. Calculate surface tension by use of following formula:

2

M = 0.600 gram

L = 6.01 cm (use value given in box)

G = 980.3 cm/sec^2

therefore:

$$P = \frac{MG}{2L} = \frac{.6 \times 980.3}{2 \times 6} = 49.01 \text{ dynes/cm}$$

5.1.4   If the recorded dial reading is greater than this calculated value, adjust (G) to lengthen the arm. Repeat this calibration procedure, readjusting the zero position with paper in place after each change of (G) until the dial reading agrees with the calculated value. Each unit on the dial represents a surface tension of exactly one dyne per centimeter.

5.1.5   When calibration is completed, remove paper from ring and readjust zero position. To readjust zero position turn knob (A) until the index (1) and its mirror image are exactly in line with the reference line on the mirror; loosen the dial clamp (C), and rotate the dial until the vernier is exactly on zero. The tensiometer is now ready for use.

5.2   Cleaning of Equipment

Note: In making surface tension measurements one of the most important points is the cleanliness of the ring and the vessels. For accurate work, all glassware and ring must be chemically cleaned.

5.2.1   Clean a 100-ml pyrex beaker by pouring 50 ml of TCE to remove any organic residual. Pour contents down the drain.

5.2.2   Pour 50 ml of acetone into beaker to wash off TCE. Pour contents down the drain.

5.2.3   Immerse beaker into hot (95 ± 5° C) cleaning solution of chromic acid. Grasping beaker with a set of beaker clamps, rinse thoroughly with tap water then with D.I. Water. Rinse with acetone and blow dry with nitrogen. Beaker is now ready for use.

3

5. 2. 4   Clean the platinum ring by rinsing it in 2-Butanone followed by rinsing in D. I. water.   Place the bunsen burner in a ventilated hood where no solvents are present in open containers and light.   Heat the wire   ring in the oxidizing portion of the gas flame until ring turns white hot.   Repeat entire step (No. 4) three times.   Flame only that portion of the ring which will be immersed in liquid under test.   In order to obtain repeat values, ring must be cleaned between each determination.

6.   <u>Accuracy</u>

Accuracy obtainable is approximately $\pm$ 1%.

7.   <u>Test Frequency</u>

This test should be performed on a sample from each photoresist lot.
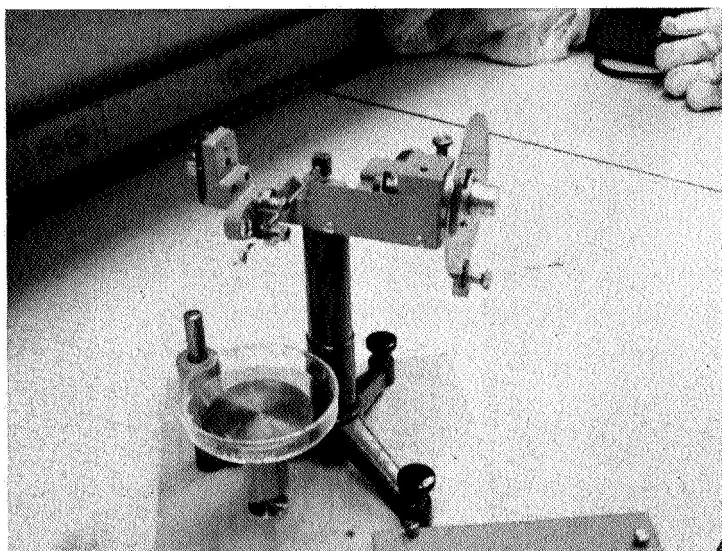
Figure 1. Tensiometer
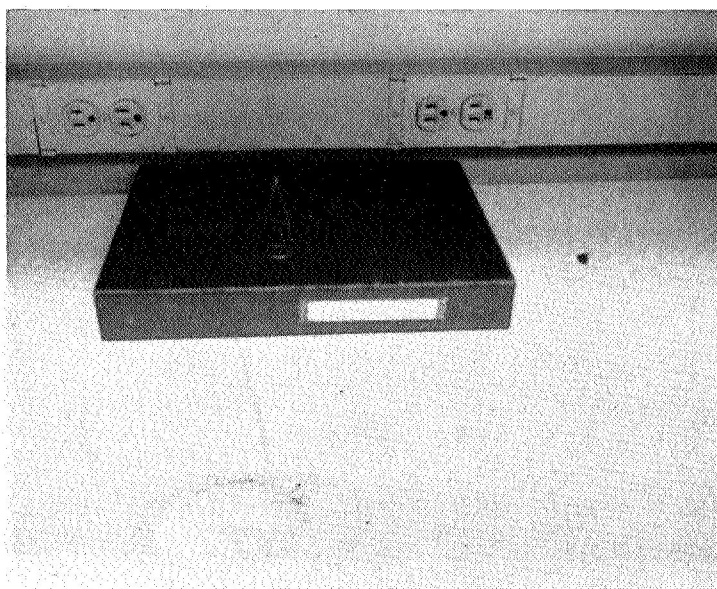
Figure 2. Platinum Wire Ring

Method 117

Thickness of Epitaxial Layer
(Stacking Fault Measurement)

1.   Purpose   The purpose of this procedure is to determine
                    the thickness of the epitaxial layer by means of
                    stacking faults generated at the substrate-layer
                    interface. This method defines the metallurgical
                    interface very accurately for $[\bar{1}11]$ material. The
                    stacking fault forms an equilateral tetrahedron
                    and the measurement of any side of the triangle
                    when revealed by a light, selective etch is
                    readily translated into the layer thickness:

$$T = \sqrt{\frac{2}{3}} \quad A$$

Where T = altitude of the tetrahedron, in this
            case, the epitaxial layer thickness
      A = a side of the equilateral triangle in the
          $[1\,1\bar{1}]$ plane.   See Figure 1.

2.   Apparatus

      2.1   Metallurgical Microscope
             Bausch and Lomb, Dynoptic No. 31-20-66-38
             (or equivalent)

      2.2   Watson lens (Filar) 2x
             Model 1014, London
             (or equivalent)

      2.3   Polyethylene beaker
             (any source)

1

3.   **Materials**

3. 1   Hydrofluoric acid, 49%, Reagent grade.

3. 2   Chromium trioxide (CrO_3), Reagent grade.

3. 3   Applicators, wood, cotton-tipped

4.   **Procedure**

4. 1   Preparation

4. 1. 1   Prepare a Sirtl etch solution of the following composition: 50 grams chromium trioxide (CrO_3), 100 ml deionized water, 100 ml hydrofluoric acid. (NOTE: Mixed solution may be stored)

4. 1. 2   Twist a cotton-tipped applicator to a fine point.

4. 1. 3   Dip the applicator tip into the Sirtl etch.

4. 1. 4   Touch the applicator to the epitaxial layer surface and deposit a small amount of etchant in the areas to be sampled. (Usually three equally spaced 0. 050 mil dots will be adequate for economical production sampling) .

4. 1. 5   Allow 15 - 30 seconds for the etchant to reach depletion and rinse the wafer under flowing DI water.

4. 1. 6   Dry the wafer with a nitrogen gun.

4. 2   Measurement

4. 2. 1   Place the wafer on the microscope stage and locate one of the etched areas in the field of view.

NOTE: "Dark field" illumination should be used for maximum contrast.

4. 2. 2   Set the counter and the vernier at "zero", to obtain only one image of each stacking fault.

NOTE: Most faults will be of a uniform size, but smaller ones of random size may be visible. The smaller stacking faults are caused by inclusions or contaminants which initiate an imperfection after epitaxial deposition has started. See Figure 2.

4.2.3   Turn the counter to the nearest whole number where an apex of the second image touches or slightly overlaps an apex of the original image. See Figure 3. If the second image moves in any direction other than parallel to one of the three sides of the triangle, rotate the Watson lens until parallelism is achieved.

4.2.4   Adjust the vernier until the two apexes just touch.

4.2.5   Read the length of the side in whole units and tenths, then compare with calibration to obtain microns.

NOTE: Most Watson Lens, used with a 40x objective, will show approximately 20 units = 25 microns

5.   <u>Calibration</u>

The Watson lens should be calibrated by placing a B and L precision stage micrometer No. 31-16-99 in the apparatus and comparing the number of units per micron.

6.   <u>Accuracy</u>

6.1   Required accuracy is $\pm$ 0.5 micron.

6.2   With correct angular orientation, equipment capability can be $\pm$ 0.2 micron.

7.   <u>Test Frequency</u>

This test may be performed on a periodic basis to compare with other methods.
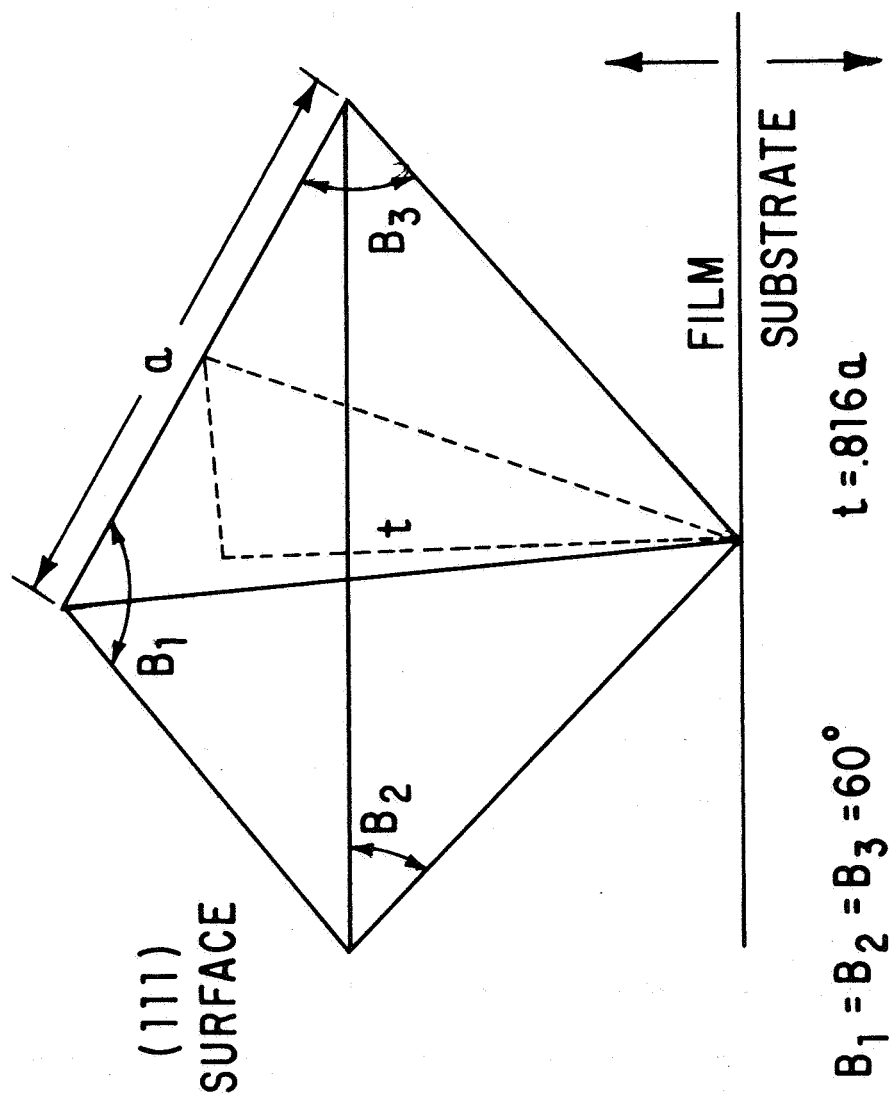
FIG. 1 SCHEMATIC OF A STACKING FAULT IN AN EPITAXIAL FILM ON A <111> SUBSTRATE.

$B_1 = B_2 = B_3 = 60°$

$t = .816 a$

Figure 3.   Stacking Faults (Images Split)

Figure 2.   Stacking Faults (Plane View)

5

Method 118

Thickness of Epitaxial Layer
(Infrared Spectrophotometer)

1. Purpose

This method may be used to determine the thickness of epitaxial films. It utilizes the reflection of infrared radiation from the wafer substrate.

Output trace from the equipment consists of a series of wavelengths corresponding to intensity maxima and minima. The film thickness is determined by the equation.

$$d = \left(\frac{X}{6.77}\right) \left(\frac{\lambda a\, \lambda b}{\lambda a - \lambda b}\right)$$

Where d = Film Thickness

λa, λb = Any two wavelengths

X = An integer specifying the number of fringes between the two wavelengths used in the equation, i. e., b-a

2. Apparatus

2.1 Infrared Spectrophotometer
Beckman IR-5A
(or equivalent)

3. Materials

Not applicable.

4.   <u>Procedure</u>

    4.1   <u>Infrared Scan</u>

        4.1.1   Place a sheet of clean paper in the container under the pen.

        4.1.2   Using tweezers, carefully place the wafer in the holder with the face of the wafer towards the infrared beam. The wafer should be positioned in the slot in such a way that it completely blocks the path of the infrared beam.

        4.1.3   Make sure that there is sufficient ink in the well attached to the pen.

        4.1.4   Check that the pen is in the raised position. The pen may be raised from the paper by using the pen lift lever, which is situated at the lower end of the pen carriage.

        4.1.5   Move the pen carriage to the left end of its traverse.

        4.1.6   Turn the function switch to PEN.

        4.1.7   Adjust the slope of the shutter in the reference space until the pen moves to a position of approximately 75 on the vertical (ordinate) scale of the graph paper.

        4.1.8   Move the pen lift lever to lower the pen on to the graph paper.

        4.1.9   Turn the function switch to the START position, from which it will return automatically to SCAN by spring action. The scan will then occur throughout the instrument range from 11μ to 35μ.

        4.1.10   Allow the scan to occur until the pen carriage reaches the end at 35μ when it will stop automatically. The automatic scan stop also lifts the pen from the chartpaper.

4. 1. 11   Remove the wafer from the holder.

4. 1. 12   Place another wafer in the holder and repeat steps 4. 1. 2 to 4. 1. 11. However, in step 4. 1. 7, position the pen at approximately 50 on the ordinate axis for the second wafer and at about 25 for the third wafer.

4. 1. 13   Replace the paper on which the trace is made after three wafers.

4. 1. 14   Do not touch any of the dials on the instrument except the function switch. The other dials will be set by the Beckman Service representative on his monthly visits.

4. 1. 15   Turn the function switch to the OFF position upon completion.

4. 2   Thickness Calculation

4. 2. 1   Find the first clear peak which is traced at the left of the chart. Determine its wavelength from the scale at the bottom of the chart.

4. 2. 2   Find the last clear peak on the right and obtain its wavelength.

4. 2. 3   Count the number of fringes (cycles) between the peaks chosen.

4. 2. 4   Using the formula from paragraph one, calculate the epitaxial layer. See Figure 1 for example.

4. 2. 5   For very thin epitaxial layers (about six microns or less) only one peak and one valley may be obtained. If this is the case, use the chart as if the reading was across one whole fringe. Then divide the thickness calculated by two in order to give the correct epitaxial thickness value.

5.   Calibration

See individual equipment manufacturer's instructions.

3

6. <u>Accuracy</u>

    6.1   Required accuracy is $\pm$ 0.5 microns.

    6.2   Satisfactory accuracy is obtainable if substrate resistivity is less than 0.025Ω-cm and layer is greater than 5 microns.

7. <u>Test Frequency</u>

This test, or an equivalent, should be performed on every epitaxial film.
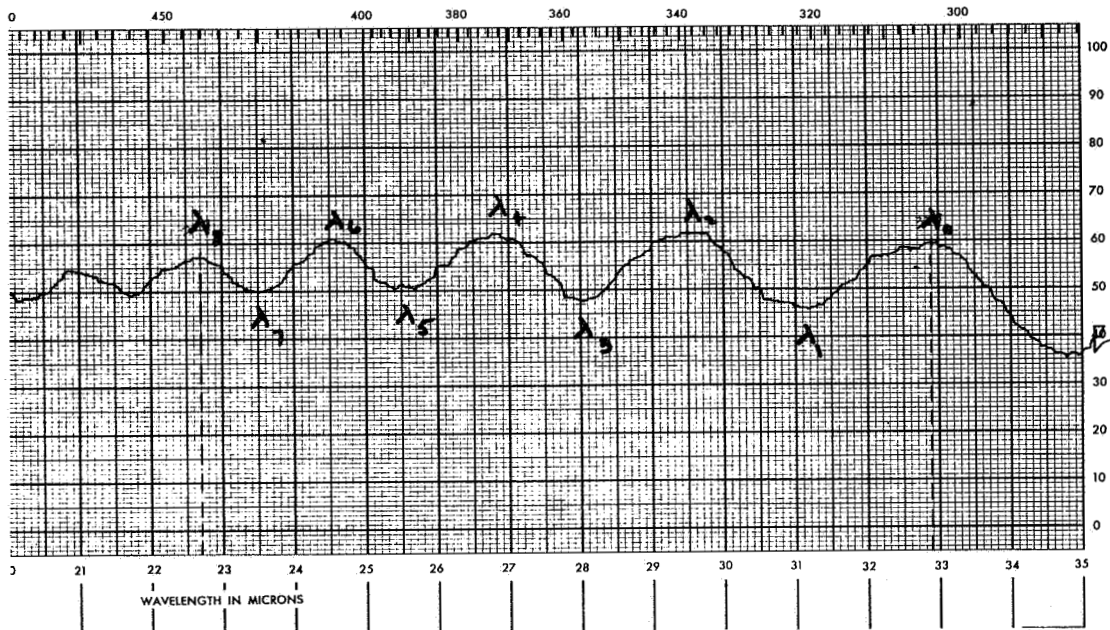
Figure 1.   Infrared Spectrophotometer Trace

$$\lambda_0 = 32.9\mu$$

$$\lambda_8 = 22.7\,\mu$$

$$X = 4$$

$$d = \left(\frac{X}{6.77}\right)\left(\frac{\lambda_0\,\lambda_8}{\lambda_0-\lambda_8}\right)$$

$$= \left(\frac{4}{6.77}\right)\left(\frac{32.9\times22.7}{32.9-22.7}\right)$$

$$= 43.7\mu$$

5

Method 119

Thickness of Epitaxial Layer
(Nomarsky Polarization Interferometry)

1. Purpose   This test may be used to measure extremely thin
                     (0.6 to 2.6 microns) epitaxial films. It utilizes
                     interference fringes from two images of the
                     junction formed by monochromatic light passing
                     through a double quartz prism. The layer thick-
                     ness may be obtained from:

$$d = \left(n + \frac{\Delta S}{S} \right) \frac{\lambda}{2}$$

where   d =   Layer thickness

        n =   Number of fringes

       ΔS =   Fringe displacement

        S =   Fringe spacing

        λ =   Wavelength of incident light

2. Apparatus

   2.1   Metallurgical Microscope
         Reichert No. 304-758
         (or equivalent)

   2.2   Nomarsky polarization interferometer
         Reichert No. 34-973
         (or equivalent)

   2.3   Filter, orange sodium, 5890 Å
         Reichert
         (or equivalent)

1

2.4 Ball-grooving equipment
Figure 1.
(or equivalent)

2.5 Microscope Camera
Polaroid Land
(or equivalent)

3. <u>Materials</u>

3.1 Hydroflouric acid, concentrated, Reagent grade.

3.2 Nitric acid, concentrated, Reagent grade.

3.3 Cupric Chloride, Reagent grade ($CuCl_2 \cdot 2 H_2O$).

3.4 Trichloroethylene, Electronic grade.

3.5 Polishing compound, 1 micron, Linde "A".

3.6 Polishing compound, 0.3 micron, Linde "B".

3.7 Thinner, Dymo.

4. <u>Procedure</u>

4.1 <u>Preparation</u>

4.1.1 Tape test wafer (N/P or P/N to glass slide and identify).

4.1.2 Mix a small quantity of grooving solution in the following proportions:

12 parts   0.3 micron   polishing compound

1 part   1   micron   polishing compound

20 parts   -   Dymo thinner

4.1.3 Place a small drop of a grit mixture on wafer near its center.

4.1.4 Turn the ballmotor on.

2

4.1.5   Clean the ball with TCE using a cotton bud.

4.1.6   Center ball over grit drop. Lower ball gently on to the wafer while holding slide steady. (A 1μ layer requires 3 - 4 seconds of grooving without additional pressure to the ball).

4.1.7   Using TCE and cotton buds, clean off grit from wafer surface. Using clean buds dipped in TCE, clean out groove.

4.1.8   Mix a small quantity of staining solution in the following proportions:

$$55 \text{ ml} \quad HF$$
$$13 \text{ mg} \quad CuCl_2 \cdot 2 H_2O$$
$$1 \text{ drop} \quad HNO_3$$

4.1.9   Place one drop of stain solution in groove.

4.1.10   Place wafer under collimated light. When groove turns black, dip slide into beaker of water. Dry slide and wafer carefully with paper towel.

4.1.11   Groove is ready to be examined under microscope (20x to 50x). If groove or staining are not satisfactory, repeat 4.1.3 to 4.1.10.

4.2   Measurement

4.2.1   Place the wafer on microscope stage (Reichert). Make sure that Nomarski interferometer and orange sodium filter are in place as well as 2 np lens.

4.2.2   Switch the transformer on and set the current to maximum.

4.2.3   Focus the binocular on wafer edge and then slide the wafer until the groove is visible.

4.2.4   Select the best polished part of the groove and turn it till the dark interference fringes outside the groove are almost perpendicular to the groove edge.

4.2.5   Turn the binocular off and observe the groove in the horizontal eye piece near the camera.

4.2.6   Adjust the position of the wafer to focus the interference pattern in order to get the best definition of the junction. The junction is the dark area between the fringes in the fringe field.

4.2.7   Make a photomicrograph of the epitaxial layer.

4.2.8   On a picture showing interference fringes, count the number of whole fringes between the groove edge and the junction. This gives the thickness fringe count to the nearest whole number of fringes.

4.2.9   In order to determine the final fringe fraction, extend two adjacent straight edges into the groove and measure the distance "S" between them. Figure 2.

4.2.10   The junction line described above has regions of light and dark coloring. In the dark regions, the junction line narrows and in the light regions, it widens. Along the junction, measure the distance between the reference line drawn above and the start and the end of a nearest light section of the junction (x and y).

4.2.11   Distance measurement would have a + sign if it has the same direction as fringe entering the groove or a - sign if it is to the opposite side of reference line.

4.2.12   Respecting their signs the ratio $\dfrac{+x+y}{2S}$ gives the fraction of the fringe to add or substract from the whole number of fringes.

4.2.13   Thickness is determined from Table 1: (sodium light) ($\lambda = 5890 \, \text{Å}$). See Figure 3 for example.

4

5.   Calibration

Not applicable.

6.   Accuracy

6.1   Required accuracy is 0.1 micron.

6.2   Accuracy obtainable is 0.05 micron.

7.   Test Frequency

This test should be performed on a sample of every reactor run of thin epitaxial layers.

Number of fringes	Thickness in microns	Number of fringes	Thickness in microns	Number of fringes	Thickness in microns
2.0	0.589	4.9	1.44305	7.8	2.29710
2.1	0.61845	5.0	1.47250	7.9	2.32655
2.2	0.6479	5.1	1.50195	8.0	2.356
2.3	0.67735	5.2	1.53140	8.1	2.38545
2.4	0.7068	5.3	1.56085	8.2	2.41490
2.5	0.73625	5.4	1.59030	8.3	2.44435
2.6	0.7657	5.5	1.61975	8.4	2.47380
2.7	0.79515	5.6	1.64920	8.5	2.50325
2.8	0.8246	5.7	1.67865	8.6	2.53270
2.9	0.85495	5.8	1.70810	8.7	2.56215
3.0	0.8835	5.9	1.73755	8.8	2.59160
3.1	0.91295	6.0	1.767	8.9	2.62105
3.2	0.9424	6.1	1.79645	9.0	2.65050
3.3	0.97185	6.2	1.82590		
3.4	1.0013	6.3	1.85535		
3.5	1.03075	6.4	1.88480		
3.6	1.0602	6.5	1.91425		
3.7	1.0965	6.6	1.94370		
3.8	1.1191	6.7	1.97315		
3.9	1.14855	6.8	2.00260		
4.0	1.178	6.9	2.03205		
4.1	1.20745	7.0	2.06150		
4.2	1.2369	7.1	2.09095		
4.3	1.26635	7.2	2.12040		
4.4	1.29580	7.3	2.14985		
4.5	1.32525	7.4	2.17930		
4.6	1.35470	7.5	2.20875		
4.7	1.38415	7.6	2.23820		
4.8	1.41360	7.7	2.26765		

Table I

Figure 1. Grooving Setup

FRINGES

GROOVE EDGE

JUNCTION

d

REFERENCE LINE

x
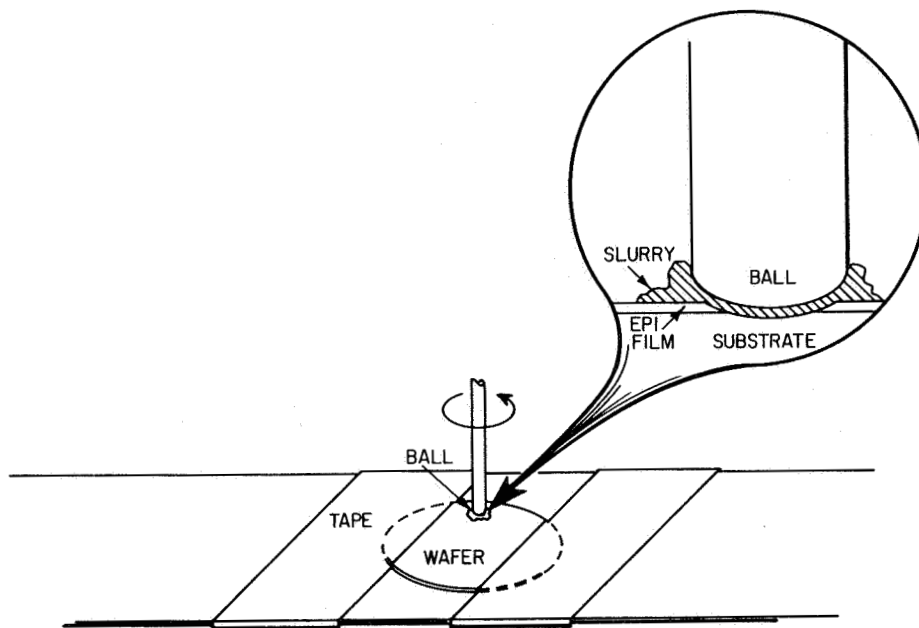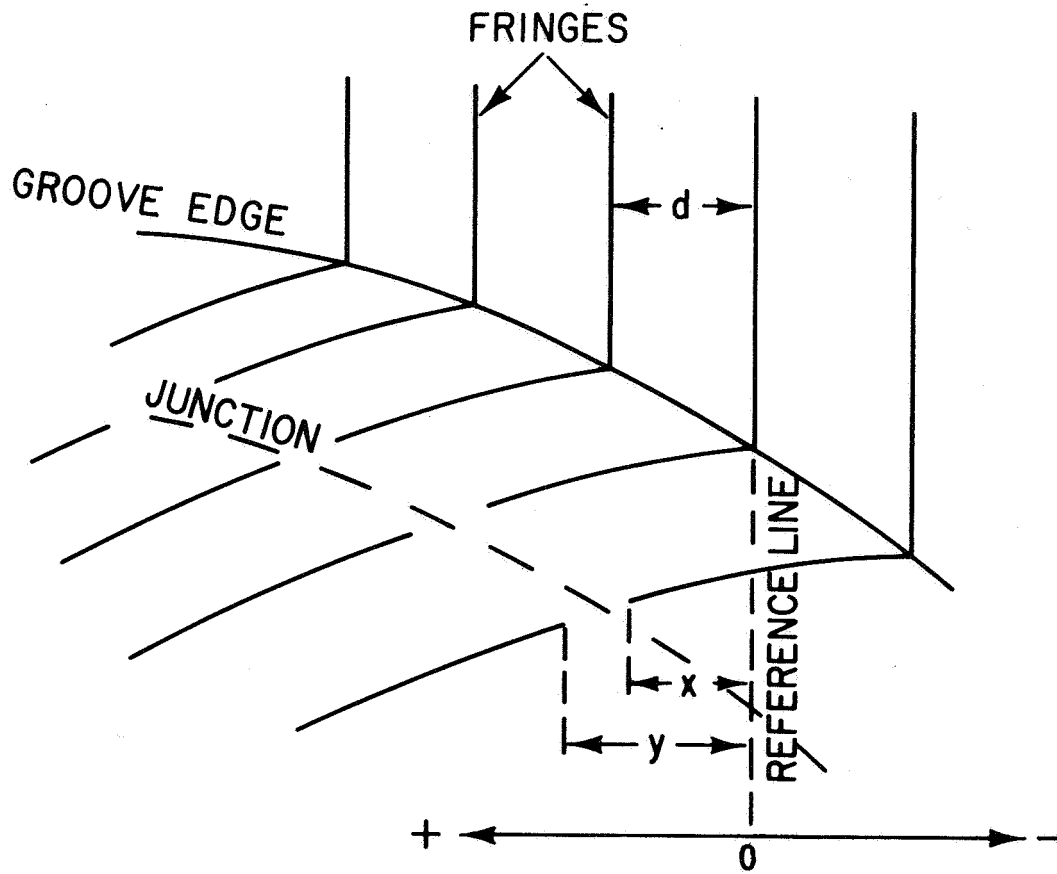
y

+ 0 −

Figure 2.   Nomarsky Fringes Graphic Representation
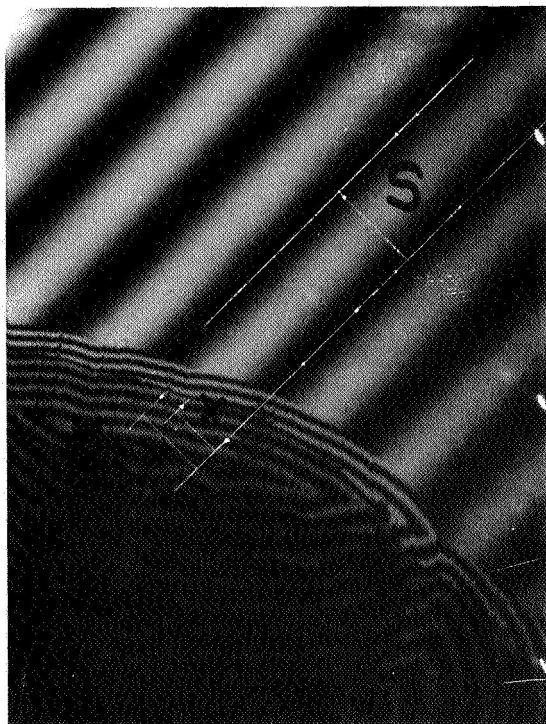
Figure 3. Nomarsky Fringes (Actual)

$\lambda = 5890\text{Å}$, Sodium

$S = 0.50$ inches

$x = 0.28$ inches

$y = 0.40$ inches

$n = 2$ Fringes

$$\Delta S = \frac{x + y}{2} \qquad\qquad \frac{+x + y}{2S} = \frac{0.28 + 0.40}{2 \times 0.50}$$

$$= \frac{0.28 + 0.40}{2} \qquad\qquad = 0.68$$

$$= 0.34 \qquad\qquad \sim 0.70$$

$$d = \left(2 + \frac{0.34}{0.50}\right)\left(\frac{5890}{2}\right) \qquad \text{From Table I:}$$

$$= (2.68)(2945) \qquad\qquad d = 0.795 \text{ micron}$$

$$= 7890\text{Å}$$

$$= 0.789 \text{ micron}$$

9

Method 120

Resistivity of Epitaxial Layer
(Four-Point Probe)

1.   Purpose   This method may be used to determine the resistivity of any epitaxial film. If the film is of opposite conductivity from the substrate, the measurement is direct; if not, the resistivity is indirectly measured through use of a substrate of opposite type. A four-point probe is used to obtain sheet resistance for a film of known thickness, which yields resistivity:

$$\rho = A \frac{V}{I} \qquad A = F(W, S)$$

If $W \ll S$

$$\rho = 4.53 W \frac{V}{I}$$

Where: W = Film thickness

S = Probe spacing

$\dfrac{V}{I}$ = Sheet resistance of the layer

2.   Apparatus

2.1   Four-point probe, 0.040 inch spacing
Dumas
(or equivalent)

2.2   Power supply, constant current 0.1, 1.0, 10 mA ranges
(any source)

2.3 Voltmeter, Digital
Fairchild 7100
(or equivalent)

3. Materials

3.1 Glass microscope slides, 1" x 3"

4. Procedure

4.1 Process a check wafer through the epitaxial reactor to be evaluated.

4.2 Place the wafer to be measured on the glass slide under the four-point probe head with the epitaxial layer side up. Center the wafer so that no probe point is closer than one-eighth inch from the edge of the wafer. See Figure 1.

4.3 Set the constant current selector to 0.1mA.

4.4 Turn the constant current generator switch on.

4.5 Screw the four-point probe down on the wafer using the end ratchet until the proper contact causes the ratchet to slip.

4.6 Check to see if the constant current meter is indicating full scale. If not, raise the probe and repeat step 4.5

4.7 Switch the polarity of the current generator from plus to minus and observe the current reading for any variation.

4.8 If full scale current readings are obtained in both positions (i.e., plus and minus), read the indicated V/I on the voltmeter.

4.9 The V/I readings should be within 10% of each other when the polarity of the current generator is reversed. If this is not so, release the pressure on the probe head one-fourth turn of the ratchet at a time until the readings do agree within 10%.

4.10 Take three V/I readings on each check wafer, average and record. See Figure 2 for example.

5.   Calibration

   5.1   Probe Spacing

      5.1.1   Cover a 1" x 3" glass microscope slide with aluminum foil.

      5.1.2   Obtain an impression of the four-point probe points.

      5.1.3   Measure spacing with any optical comparator.

      5.1.4   Adjust spacing per probe manufacturer's instruction.

6.   Accuracy

   Obtainable accuracy is ± 10% with groove-and-stain thickness determination.

7.   Test Frequency

   This test should be performed on at least one check wafer from every epitaxial reactor run.

FOUR POINT PROBE – SET-UP

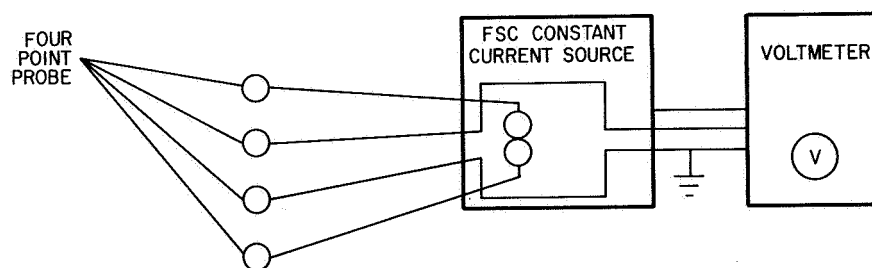
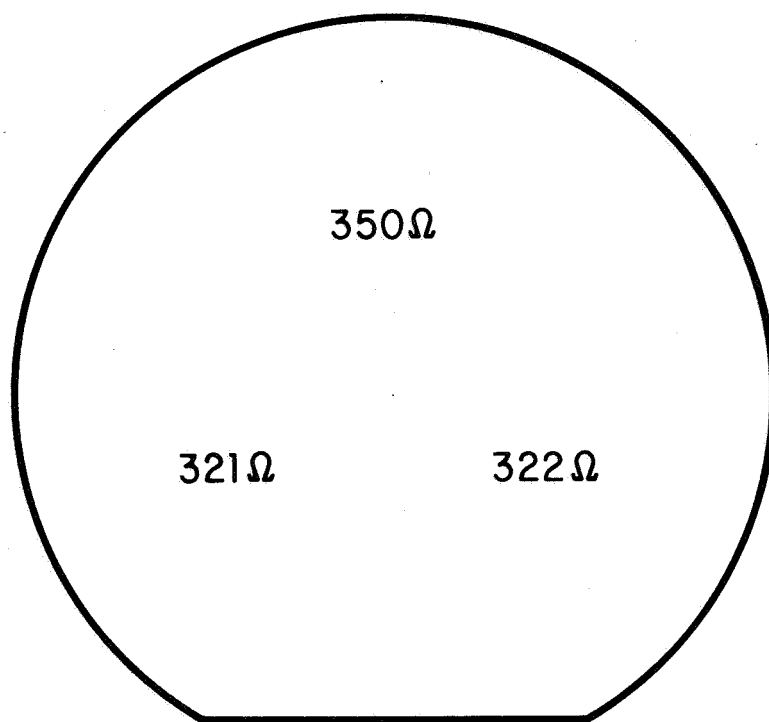Figure 1.

$350\,\Omega$

$321\,\Omega$ $322\,\Omega$

Figure 2. Sample Resistivity Calculation

$$\frac{V}{I} = \frac{350 + 321 + 322}{3} = 331$$

$$W = 10 \text{ microns} = 10^{-3} \text{ cm}$$

$$\rho = 4.53 \ W \ \frac{V}{I}$$

$$= 4.53 \times 10^{-3} \times 331$$

$$= 4.53 \times 10^{-3} \times 3.31 \times 10^{2}$$

$$= 1.5 \ \Omega \text{ cm}$$

Method 121

Epitaxial Layer Surface Defects

1.   Purpose   This method may be used to evaluate surface
condition of the epitaxial layer.

2.   Apparatus

2.1   Metallurgical Microscope
Bausch and Lomg, Model 31-20-68-38 (DMETR)
(or equivalent)

3.   Materials

3.1   Chromium Trioxide, Reagent grade.

3.2   Hydrofluoric Acid, Electronic grade.

3.3   Deionized Water.

4.   Procedure

4.1   Place wafer to be examined on microscope stage.

4.2   Using a minimum of 50x, scan surface of sample.

4.3   Note the number found of the following defects:

4.3.1   Stacking Faults   -   Thin, straight lines in a plane
forming one or more sides of equilateral triangles,
with parallel orientation.

4.3.2   Pyramids   -   Any pointed, convex defect of a
pyramidal or tripyramidal shape.

4.3.3 <u>Pits</u> - Any concave defect from etching or other cause.

4.3.4 <u>Granular Surface</u> - Epitaxial layer deposited rough or unpolished surface.

4.3.5 <u>Scratches</u> - Long scratches or gouges in the surface.

5. <u>Calibration</u>

None.

6. <u>Accuracy</u>

Not applicable.

7. <u>Test Frequency</u>

All wafers should be inspected for these defects.

Method 122

Epitaxial Process

(Substrate Temperature)

1.   Purpose   This method may be used to determine the substrate temperature during epitaxial deposition. It utilizes the comparison of infrared radiation (incandescence) of a filament of known resistivity and the object to be measured.

2.   Apparatus

    2.1   Optical Pyrometer
          Pyro Micro-Optical Pyrometer
          The Pyrometer Instrument Co., Inc.
          (or equivalent)

3.   Materials

Not applicable.

4.   Procedure

    4.1   Set the telescope a convenient distance from the epitaxial reactor to be measured. (less than 5 feet).

    4.2   Connect lead wires in series to terminals of telescope, meter and battery, in that order. See Figure 1.

    4.3   Focus the telescope:

        4.3.1   Set scale range knob and red filter knob at position No. 1.

        4.3.2   Turn rheostat up enough to cause the pyrometer lamp filament to become weakly luminous when looking through the ocular.

        4.3.3   Turn the ocular ring to bring the apex of the filament into focus.

1

4.3.4   Focus on the substrate to be measured by adjusting the distance knob.

4.3.5   Align the filament and substrate image.

4.4   Set red filter knob to position No. 2.

4.5   Set range scale to 1200-1500° C.

4.6   Adjust the rheostat until the filament blends with the substrate.

4.7   Read the substrate temperature directly from the meter.

4.8   Disconnect battery when measurement is complete.

5.   Calibration

5.1   Galvanometer Zero Calibration

5.1.1   Connect a precision milliameter in series with the circuit.

5.1.2   Adjust the rheostat until the meter pointer corresponds to the milliampere sensitivity points indicated on the scale.

5.1.3   Remove cover plate and turn zero adjuster until points coincide with meter readings.

6.   Accuracy

Accuracy obtained will be $\pm$ 2° C.

7.   Test Frequency

This test or an equivalent should be performed during each epitaxial deposition.
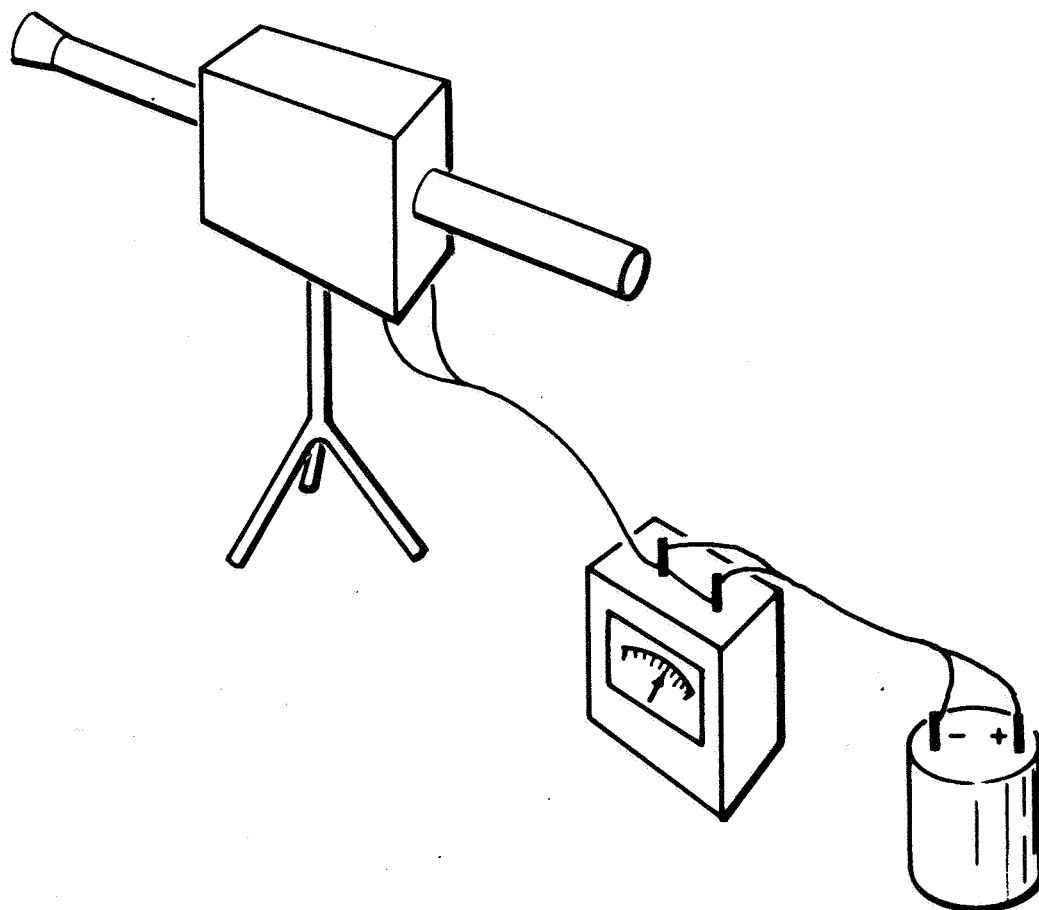
Figure 1. Optical Pyrometer

Method 123

Thickness of Passivating Layer
(Tolansky Interferometer)

1. Purpose   This test procedure is applicable to the measure-
                   ment of any thin film, whether transparent or not.
                   It utilizes the interference of monochromatic light
                   introduced into the optical system through a 95
                   percent mirror and reflected between that and
                   the metallized specimen. The two mirrors are
                   inclined to one another causing the interference
                   fringes to be normal to the edge of the passivating
                   layer. The horizontal displacement of any fringe
                   enables one to calculate the layer thickness by the
                   following relationship:

$$\frac{x_o}{D} = \frac{\frac{\lambda}{2}}{w}$$

Where x_o = Layer thickness

        λ = Wavelength of incident light

        w = Distance between fringes

        D = Distance any fringe is displaced
                See Figures 1 and 2.

2. Apparatus

    2.1 Metallurgical microscope, metalstar trinocular body
         AO No. 2200T-4.
         American Optical Company
         (or equivalent)

1

2.2   Polaroid Camera AO No. 1052A.
       American Optical Company
       (or equivalent)

2.3   Interferometer Jig
       Fairchild design
       See Figure 3.

2.4   Monochromatic light source

       2.4.1   Mercury, 5461Å
                LaPine Scientific Company, Model 216-01
                (or equivalent)

       2.4.2   Sodium, 5893Å (optional)
                LaPine Scientific Company, Model 215-96
                (or equivalent)

2.5   Hot plate, 6" x 6", electric
       Temco type 1900
       Corning, Pyroceram PC-35
       (or equivalent)

2.6   Polethylene beaker
       (any source)

3.   Materials

      3.1   Hydrofluoric acid, 49 percent Reagent grade.

      3.2   Acetic acid, glacial, Reagent grade.

      3.3   Trichloroethylene, Electronic grade.

      3.4   Acetone, Electronic grade.

      3.5   Apiezon wax.

      3.6   Slides, glass microscope, 1" x 3".

4.   Procedure

4.1   Preparation

4.1.1   Process a polished test chip through the passivation (oxidation, etc.) operation(s) to be evaluated.

4.1.2   Place a glass slide on a hot plate adjusted to a temperature slightly above the melting point of the apiezon wax (150 - 160°C).

4.1.3   Place the test chip on the heated slide with the polished side up.

4.1.4   Mask about one-fourth of the chip area with black wax.

4.1.5   Carefully remove the test chip from the glass slide.

4.1.6   Cool the chip under running water for 15 seconds.

4.1.7   Immerse the chip in a prepared solution of three parts acetic acid to two parts hydroflouric acid until all unmasked oxide is removed (four to eight minutes).

4.1.8   Rinse chip in running water for five to ten seconds.

4.1.9   Remove wax from chip with trichloroethylene.

4.1.10   Rinse test chip in acetone and allow to dry.

4.1.11   Evaporate a 1000Å silver or aluminum film over the film to be examined.

NOTE: While silver has a higher index of reflectivity, it must not be allowed to tarnish prior to measurement.

4.2   Measurement

4.2.1   Place the specimen on the platform, mirrored side up.

4.2.2   Rotate the specimen on the platform until the step to be measured is normal to the front edge of the fizeau plate.

4.2.3   Raise the platform until the specimen is in contact with fizeau plate by turning the knurled brass elevation nut. This will give maximum fringe spacing.

4.2.4   If a smaller fringe spacing is desired, the platform may be raised slightly, reducing the wedge angle, Θ, and as a result, fringe spacing.

4.2.5   Measure distance between fringes on the photo-micrograph with a precision rule. (w)

4.2.6   Measure distance which any fringe is displaced as it passes across the film step. (D)

4.2.7   Calculate film thickness, X_o, using the relationship:

$$\frac{X_o}{D} = \frac{\frac{\lambda}{2}}{w}$$

5.   **Calibration**

Not applicable.

6.   **Accuracy**

Accuracy obtainable increases with increasing film thickness.

6.1   Greater than 0.2 micron films, $\pm 10\%$.

6.2   Less than 0.2 micron films, $\pm 20\%$.

7.   **Test Frequency**

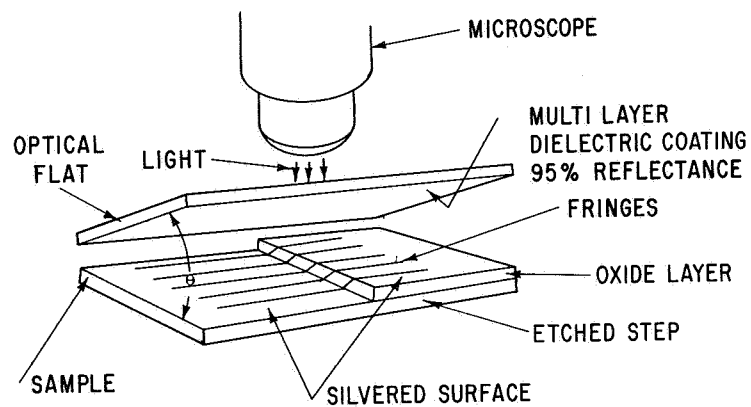This test should be performed periodically for each evaporator.

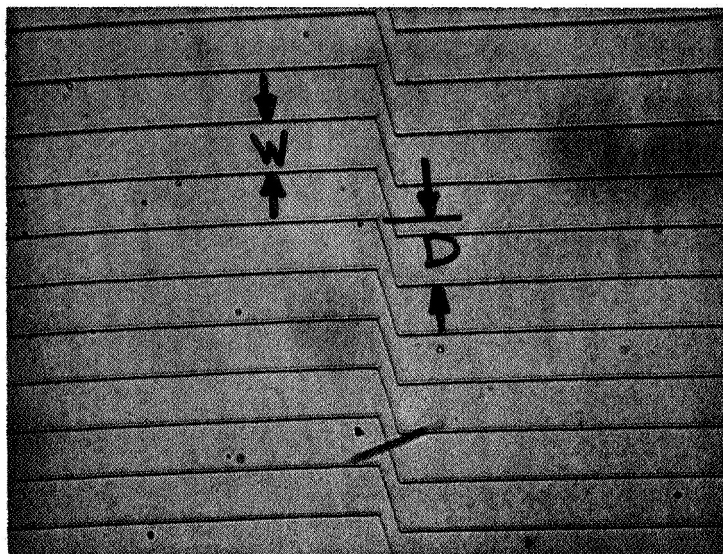Figure 1. Tolansky Interferometer Setup

Figure 2.   Film Thickness Measurement

$$\text{Sodium,} \quad \lambda = 5890\text{Å}$$

$$W = 0.26 \text{ inches}$$

$$X_0 = D \frac{\frac{\lambda}{2}}{W}$$

$$= \frac{0.34 \frac{5890}{2}}{0.26}$$

$$= \frac{3.4 \times 2.945 \times 10^2}{2.6 \times 10^{-1}}$$

$$= 3.92 \times 10^{-3}$$

$$= 3920 \text{ Å}$$

FIZEAU PLATE

SUBSTRATE WITH SILVERED THIN-FILM STEP

SUBSTRATE PLATFORM

NYLON SCREW IN VEE-SLOT

BRASS BASE

SIDE VIEW

PLATFORM PIVOT (FRONT AND REAR)

REAR SPRINGS

BRASS KNURLED NUT $\frac{3}{4} \times 20$ TPI ON THREADED SHAFT

FRONT VIEW

FIZEAU PLATE HOLDER

HOLE FOR TILT-ADJUSTMENT

TILT ADJUST SCREW (REAR PIVOT)

PIVOT PIN

TOP VIEW
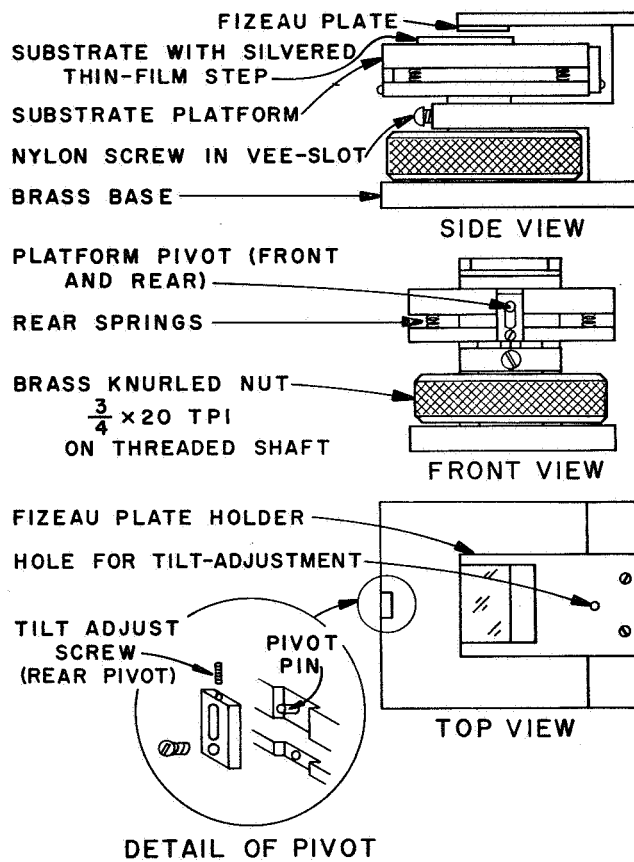
DETAIL OF PIVOT

Figure 3. Interferometer Jig

Method 124

Thickness of Passivating Layer
(Polychromatic Interference)

1. Purpose   This method may be used to measure the thickness
of thermally grown silicon dioxide. It utilizes
polychromatic light and the resultant reinforce-
ment and interference of the various colors. Shorter
wave lengths are affected first, so blue would
indicate a thinner film than red in the same spectral
order.

2. Apparatus

   2.1 Metallurgical Microscope.
        Bausen and Lomb Dynoptic, No. 31-20-68-37
        (or equivalent)

   2.2 Hot plate, 6" x 6", electric
        Temco, type 1900
        Corning, Pyroceram PC-35
        (or equivalent)

   2.3 Polyethylene Beaker
        (any source)

3. Materials

   3.1 Hydrofluoric acid, 49%, Reagent grade.

   3.2 Trichloroethylene, Electronic grade.

   3.3 Acetone, Electronic grade.

   3.4 Apiezon wax.

   3.5 Slides, glass microscope, 1" x 3".

1

4. Procedure

    4.1 Preparation

        4.1.1 Process a polished test chip through the oxidation operation(s) to be evaluated.

        4.1.2 Place a glass slide on a hot plate adjusted to a temperature slightly above the melting point of the apiezon wax (150-160°C).

        4.1.3 Place the test chip on the heated slide with polished side up.

        4.1.4 Mask about one-fourth of the chip area **with** black wax.

        4.1.5 Carefully remove the test chip from the glass slide.

        4.1.6 Etch chip in hydroflouric acid until all the oxide is removed from the unmasked area (2-3 minutes).

        NOTE: When all oxide is removed, wafer will appear shiny and gray.

        4.1.7 Rinse chip in flowing water for five to ten seconds.

        4.1.8 Remove wax from the test chip with trichloroethylene.

        4.1.9 Rinse test chip in acetone and allow to dry.

    4.2 Measurement

        4.2.1 Place the test chip on the microscope stage with the edge of the oxide film in the field of view.
        See Figure 1.

        4.2.2 Adjust magnification until the line between oxide and bare silicon areas expands into a fringe containing one or more spectrums. See Figure 2.

        4.2.3 Using Table I, the oxide thickness may be determined.

4.2.3.1   Above 4550 Å, "Fringes", spectrum boundaries, are counting as a passage from red to green. The absence of other colors will necessitate estimating thickness to the nearest one-half fringe (910 Å). Green will indicate the first one-half fringe and red the last.

5.   Calibration

Not applicable.

6.   Accuracy

6.1   From 1000-4550 Å., accuracy of ± 200 Å is obtainable

6.2   Above 4550 Å, accuracy is reduced to about ± 900 Å.

7.   Test Frequency

This test should be performed on a sample from each run at each oxidation operation.
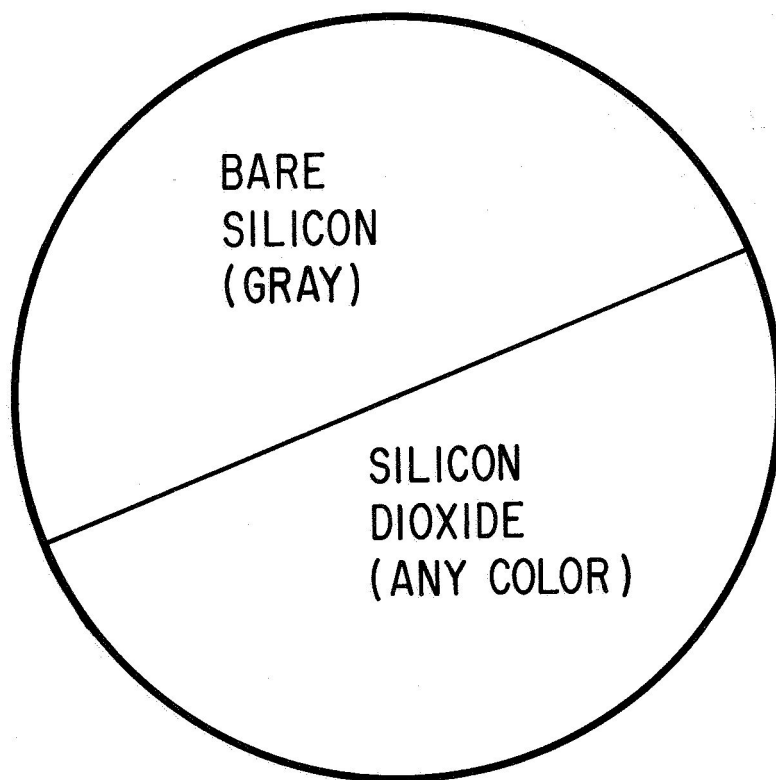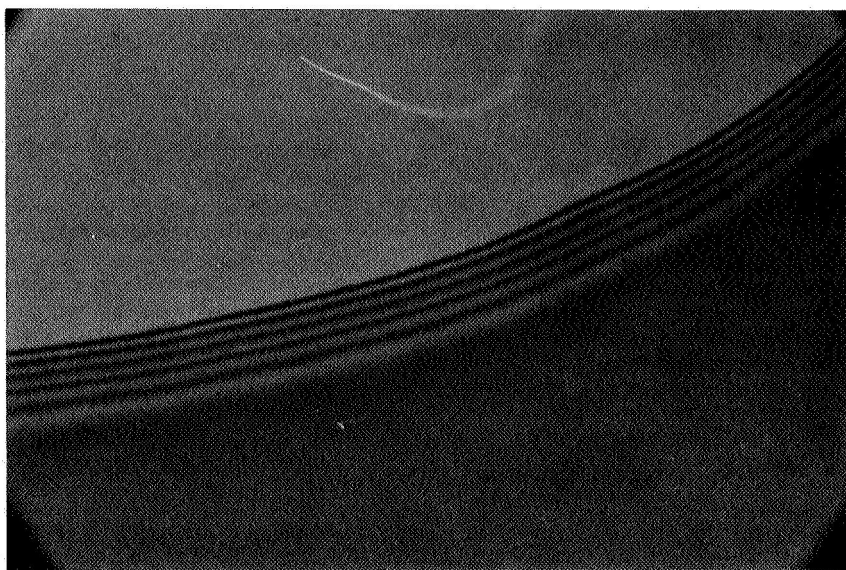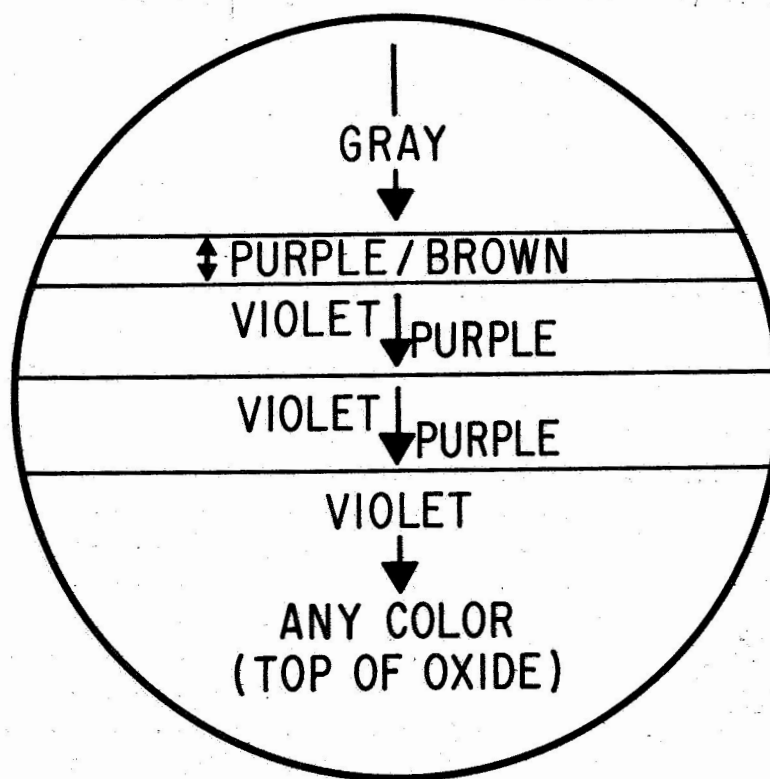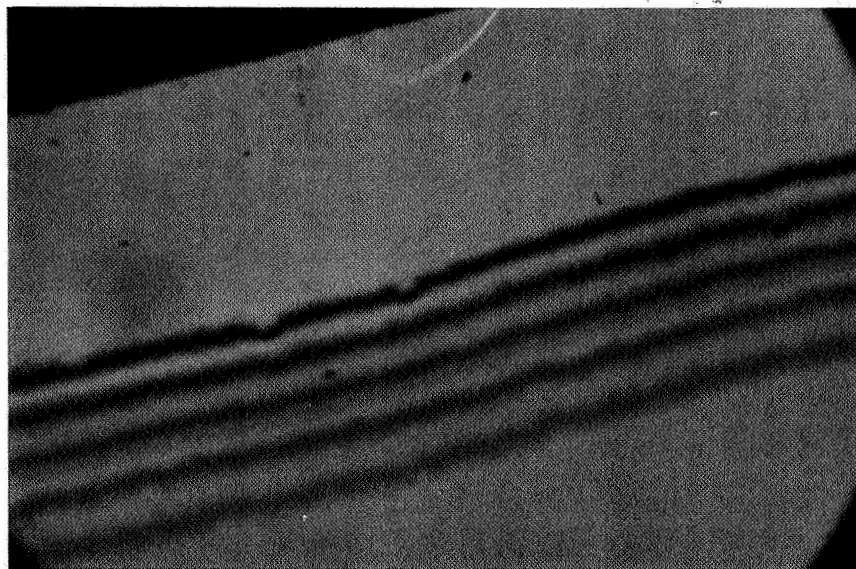
3

Figure 1. Oxide Step (Low Power)

Figure 2. Oxide Step (100 x Minimum)

TABLE I

Method 124

COLOR IN SPECTRUM	THICKNESS (Å)
Brownish-white	685
Clear Brown	733
Dark Brown	795
Red-Brown	850
Dark Purple	884
First Fringe	910
Dark Violet	925
Dark Blue	959
Clear Blue	1120
Clearish-Blue to Green	1610
Pale Blue-Green	1680
Pale Green	1760
Clear Yellow-Green	1860
Clear Yellow	1930
Golden-Yellow	2060
Orange	2410
Red	2550
Dark Purple	2650
Second Fringe	2730
Dark Violet	2745
Dark Blue	2779
Clear Blue	2940
Clearish-Blue to Green	3430
Pale Blue-Green	3500
Pale Green	3580
Clear Yellow-Green	3680
Clear Yellow	3750
Golden Yellow	3880
Orange	4230
Red	4370
Dark Purple	4470
Third Fringe	4550
Fourth Fringe	6370
Fifth Fringe	8190
Sixth Fringe	10020

Method 125

Thickness of Passivating Layer
(Monochromatic Interference)

1. Purpose   This test procedure may be used to measure a wide
range of silicon dioxide thicknesses. The interference
effect on reflected rays of monochromatic light at
the sloping edge of an oxide film causes a series of
lines which are equally spaced. To calculate the
thickness of a thin, transparent layer, backed by
an opaque surface, the following equation applies:

$$d = \frac{nf\,\lambda}{2\mu} - \frac{\lambda}{4\mu}$$

where d = Layer thickness

nf = Number of interference fringes

λ = Wave length of the incident light

μ = Index of refraction of the film

This method may be used on other transparent
passivating layers if the proper index of refraction
is used in the above equation.

2. Apparatus

   2.1   Metallurgical Microscope
         Bausch and Lomb Dynoptic, No. 31-20-68-37
         (or equivalent)

   2.2   Monochromatic Light Source

         2.2.1   Mercury, 5461 Å
                 LaPine Scientific Company, Model 216-01
                 (or equivalent)

         2.2.2   Sodium, 5893 Å (optional)
                 LaPine Scientific Company, Model 215-96
                 (or equivalent)

1

2.3 Hot plate, 6" x 6", electric
Temco, Type 1900
Corning, Pyroceram PC-35
(or equivalent)

2.4 Polyethylene Beaker
(any source)

3. Materials

3.1 Hydroflouric acid, 49%, Reagent grade.

3.2 Acetic Acid, glacial, Reagent grade.

3.3 Trichloroethylene, Electronic grade.

3.4 Acetone, Electronic grade.

3.5 Apiezon wax.

3.6 Slides, glass microscope, 1" x 3".

4. Procedure

4.1 Preparation

4.1.1 Process a polished test chip through the oxidation operation(s) to be evaluated.

4.1.2 Place a glass slide on a hot plate adjusted to a temperature slightly above the melting point of the apiezon wax (150-160°C).

4.1.3 Place the test chip on the heated slide with the polished side up.

4.1.4 Mask about one-fourth of the chip area with black wax.

4.1.5 Carefully remove the test chip from the glass slide.

4.1.6 Cool the chip under running water for fifteen seconds.

4.1.7 Immerse the chip in a prepared solution of three parts acetic acid to two parts hydroflouric acid until all unmasked oxide is removed (four to eight minutes).

2

4.1.8   Rinse chip in running water for five to ten seconds.

4.1.9   Remove wax from chip with trichloroethylene.

4.1.10   Rinse test chip in acetone and allow to dry.

4.2   **Measurement**

4.2.1   Place the test chip on the microscope stage with the edge of the oxide film in the field of view. See Figure 1.

4.2.2   Adjust the magnification until all interference fringes are distinct. See Figure 2.

4.2.3   Count the number of fringes and determine the layer thickness. For silicon dioxide and a mercury vapor lamp, Table I may be used. For other materials or light sources, use the equation in Section 1.

NOTE: It may be convenient to photograph thick layers and use the photographic film as a permanent record.

5.   **Calibration**

Not applicable.

6.   **Accuracy**

Accuracy will be $\pm$ 1/2 fringe, where:

$$\text{one fringe} = \frac{\lambda}{2\mu}$$

7.   **Test Frequency**

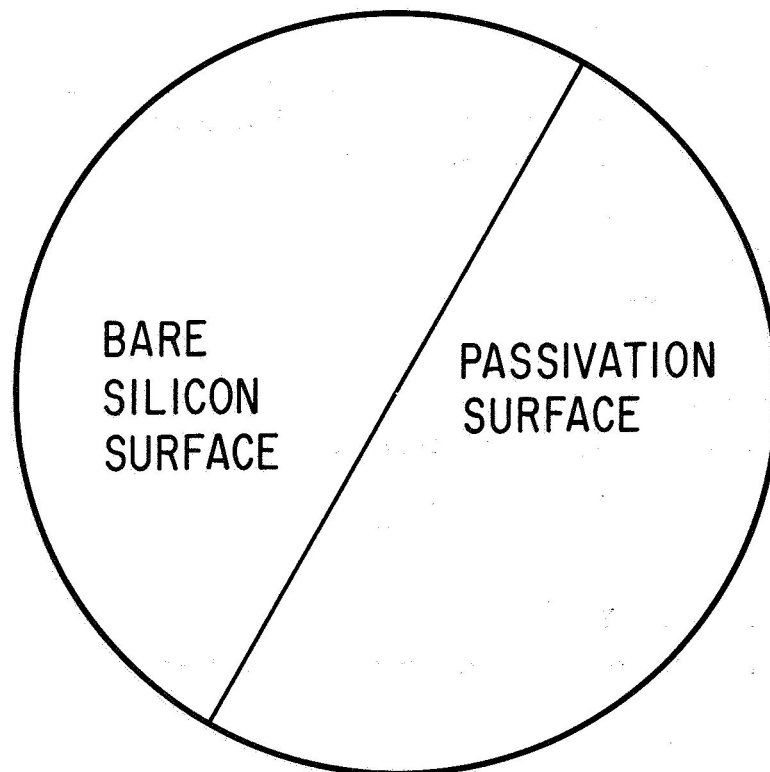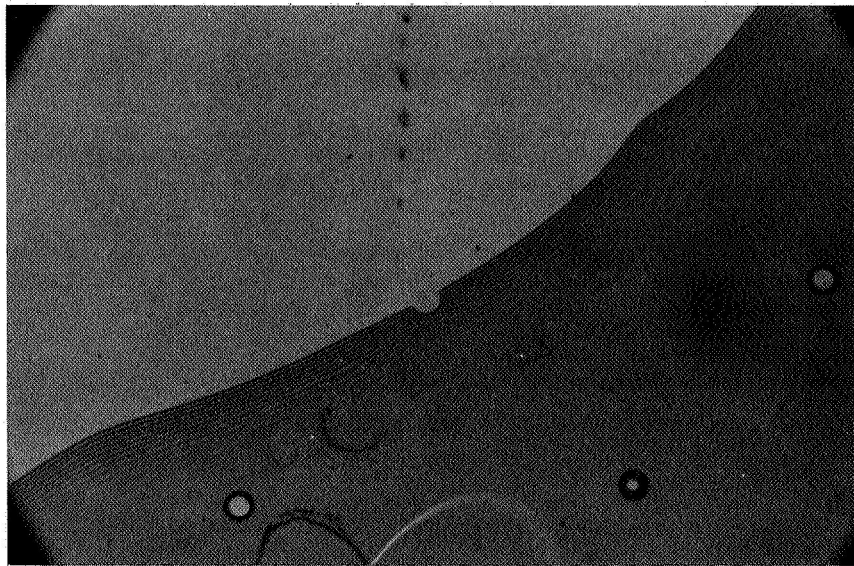Each run through the passivating operation should be sampled.
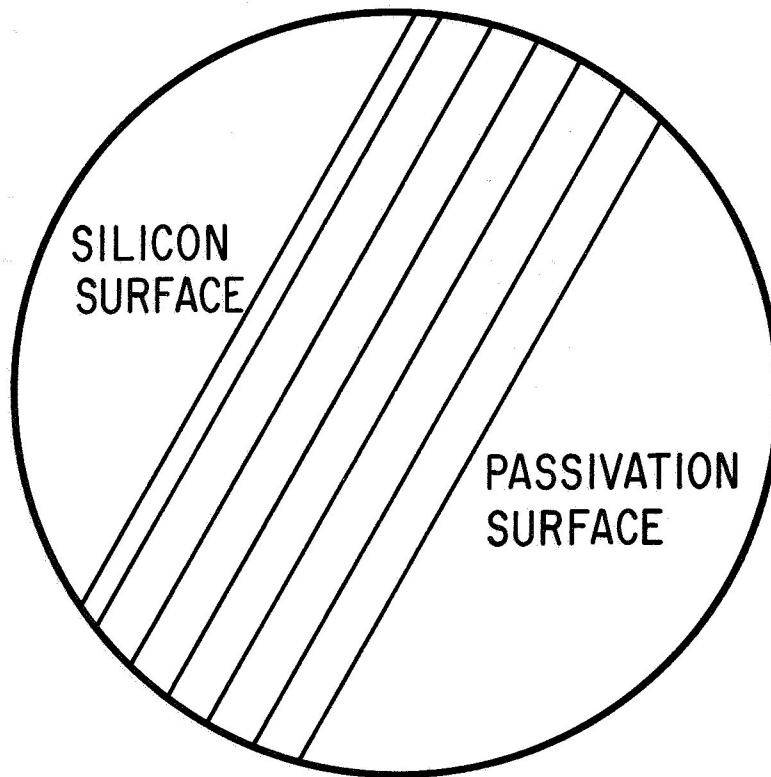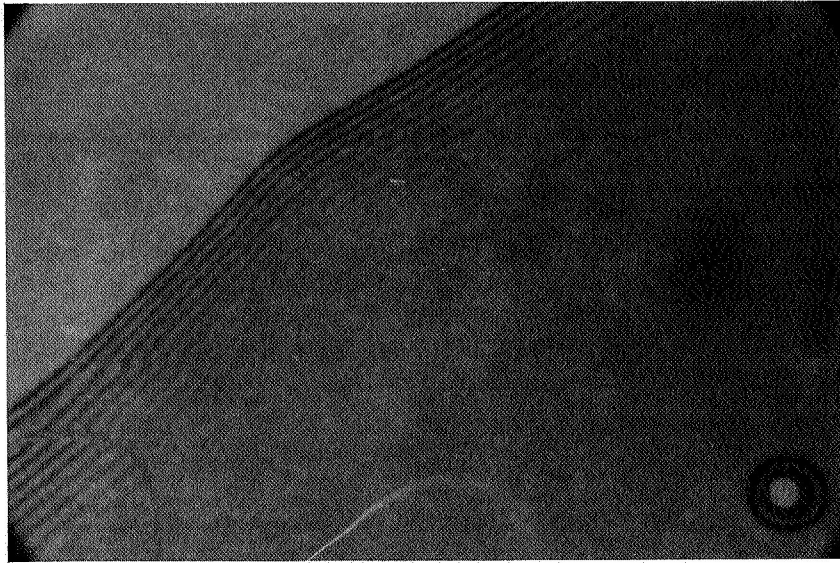
Figure 1. Oxide Step (Low Power)

4

Figure 2. Oxide Step (100 x Minimum)

Fringe Count Chart
Table I
Hg Light, $\lambda = 5460$ A, n = 1.5

Number of Fringes	Thickness in Microns	Number of Fringes	Thickness in Microns
1	.0910	19	3.3670
2	.2730	20	3.5490
3	.4550	21	3.7310
4	.6370	22	3.9130
5	.8190	23	4.0950
6	1.0010	24	4.2770
7	1.1830	25	4.4590
8	1.3650	26	4.6410
9	1.5470	27	4.8230
10	1.7290	28	5.0050
11	1.9110	29	5.1870
12	2.0930	30	5.3690
13	2.2750	31	5.5510
14	2.4570	32	5.7330
15	2.6390	33	5.9150
16	2.8210	34	6.0970
17	3.0030	35	6.2790
18	3.1850		

6

Method 126

Stability of Passivating Layer
(C-V Curve)

1.   <u>Purpose</u>   The purpose of this test is to determine the stability of the passivating layer as indicated by a metal-oxide-semiconductor capacitor. A capacitance-voltage plot will drift with the application of temperature and bias if mobile ions are present in the passivating layer.

2.   <u>Apparatus</u>

    2.1   X-Y Plotter
          Model 520 X-Y Recorder
          Honeywell
          (or equivalent)

    2.2   Capacitance Meter
          Model 130 L-C Meter
          Tektronix
          (or equivalent)

    2.3   Voltage Ramp
          Variable Span 10-50 volts
          Variable Rate 250-1000 milliseconds/volt
          (any source)

    2.4   Single-Point Probe, with heater
          (any source)   Figure 1

3.   <u>Materials</u>

    3.1   Metal Mask 0.030 inch diameter holes

    3.2   Polished substrates, N-Type

4.   <u>Procedure</u>

    General Note: Since passivating layer instability is primarily a function of mobile positive ions, cleanliness in all processes constitute a series of dependent variables. Therefore, it may be necessary to have duplicate equipment to facilitate problem location.

1

4. 1   Preparation

    4. 1. 1   Furnace Evaluation

        4. 1. 1. 1   Process a clean, polished substrate through the passivating furnace to be evaluated (1000-2000Å layer for SiO_2)

        4. 1. 1. 2   Allow substrate to cool.

        4. 1. 1. 3   Place wafer in an aluminum evaporator on known cleanliness.

        4. 1. 1. 4   Place the evaporation mask over the substrate.

        4. 1. 1. 5   Evaporate a series of 0. 030 inch dots on the test wafer.   Figure 2.

        4. 1. 1. 6   Back etch the substrate to expose the base material.

        4. 1. 1. 7   Evaporate a layer of aluminum upon the back of the sample.

        4. 1. 1. 8   Alloy the aluminumized wafer.

    4. 1. 2   Evaporator Evaluation

        4. 1. 2. 1   Obtain a substrate coated with a passivating layer of known stability.

        4. 1. 2. 2   Repeat steps 4. 1. 1. 4 through 4. 1. 1. 8

4. 2   Stability Measurement

    4. 2. 1   Place wafer on stage, dots up.

    4. 2. 2   Lower probe to dot surface.

    4. 2. 3   "Normalize" X-Y plotter with the pen   10 major divisions from the right side of the chart.

    4. 2. 4   Adjust pen to one-half major division from top of chart.

4.2.5   Note capacitance reading on L-C meter at
         normalized pen position.

4.2.6   Start sweep on voltage ramp.

4.2.7   Repeat 4.2.2 to 4.2.6 for several dots.

4.2.8   Apply a +10 volt bias to the first dot.

4.2.9   Turn heater block on and set temperature at 300°C.

4.2.10   Allow wafer to remain at temperature for a
         minimum of 3 minutes.

4.2.11   Return wafer to room temperature.

         NOTE: Once dot has been "drifted", do not
         allow it to remain at temperature without bias.

4.2.12   Repeat 4.2.2 to 4.2.7.

4.2.13   The voltage of the first plot will indicate magnitude
         of Q_{ss} (fixed surface state charge) and the difference
         in voltage between pre and post-drift plots will
         indicate Q_0 (mobile impurity ion charge). Figure 3.

         NOTE (1):   Since Q_{ss} is process dependent, all
         pre-drift plots should be close to one another.

         NOTE (2):   Three characteristics may be identified
         for each device: pre and post drift "Flat Band
         Voltage" (usually 90% of normalized capacitance)
         and voltage at which minimum capacitance is reached.

4.2.14   Where a high degree of contamination (Q_0) is
         present, the predrift plot will have a significant
         Q_0 component. In that case, repeat 4.2.8 to
         4.2.12 and Q_0 will be indicated by the difference
         between positive and negative drift plots.   Figure 4.

3

5. Calibration

X-Y recorder should be zeroed prior to each use by verifying zero volt position with voltage ramp "OFF".

6. Accuracy

Accuracy obtainable is $\pm$ 0.2 volt for pre-drift voltage and $\pm$ 0.4 voltage difference.

7. Test Frequency

Each passivation and diffusion furnace, and each evaporation should be monitored periodically.

PROBE

TEKTRONIX
130L-C
METER

HONEYWELL
MODEL
520 X-Y
RECORDER

✳
D.U.T.
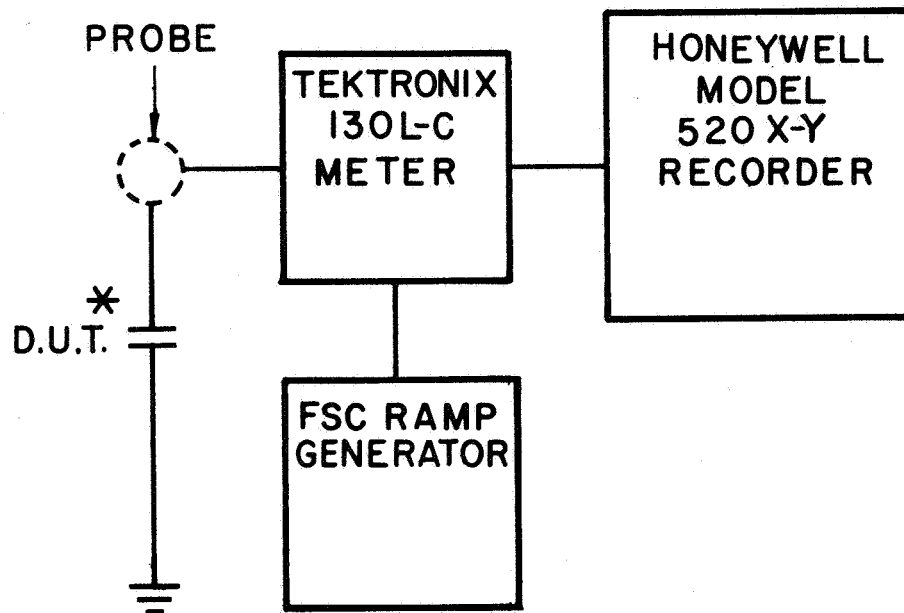
FSC RAMP
GENERATOR

✳ WAFER, METAL PADS

1. TEK 130 LC
   RANGE: 3-300 Pf $\pm$3%

2. HONEYWELL 520 $\pm$2%

3. FSC RAMP GEN.
   10-50 VOLTS $\pm$3%
   250-1000 VOLTS

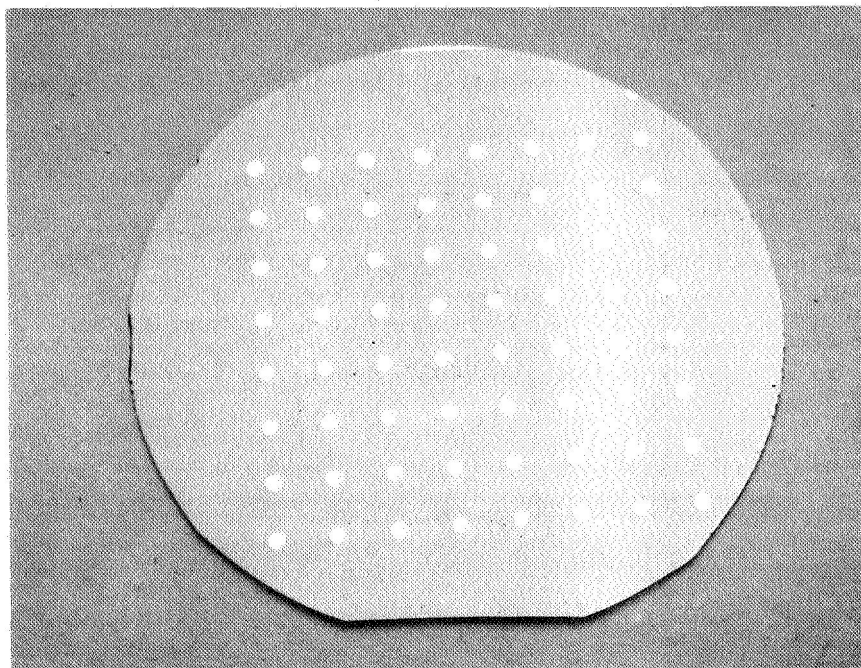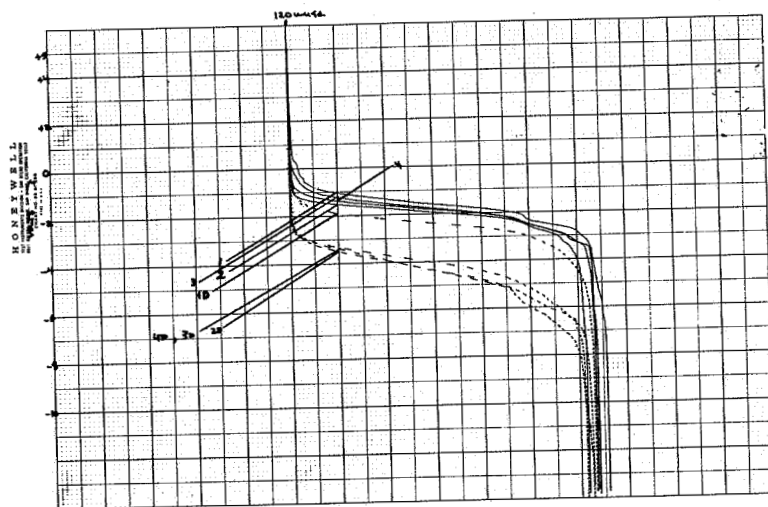Figure 1. C-V Plot Equipment

5

Figure 2. Test Wafer
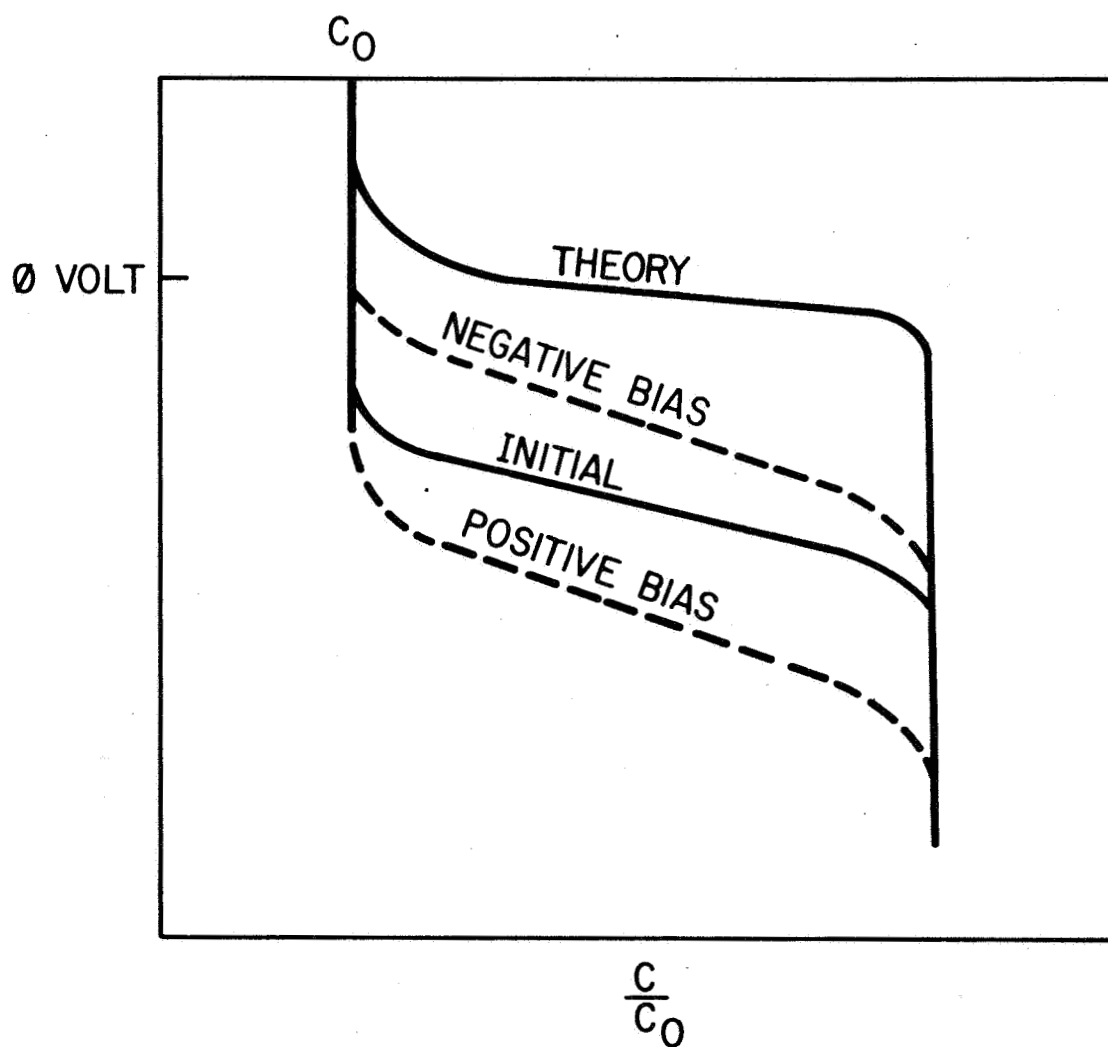
Figure 3.   Positive Drift Plot

Figure 4. Comparison of Positive and Negative Drift Plots

Method 127

Pinholes in Passivating Layer
(Silicon Etch)

1. Purpose   This method may be used to determine pinhole
                     density in the passivating layer. Although evolved
                     for silicon dioxide, it is applicable for other systems
                     with the proper substitution of etchant. It utilizes
                     the etching of silicon through the pinholes to enhance
                     their visibility for a single oxidation or by preferen-
                     tially etching doped areas in completed circuits.

2. Apparatus

    2.1 Metallurgical Microscope
         Bausch and Lomb, Model 31-20-68-38 (DMETR)
         (or equivalent)

3. Materials

    3.1 Chromium Trioxide, Reagent grade.

    3.2 Hydrofluoric acid, Electronic grade.

    3.3 Deionized water.

4. Procedure

    4.1 Single oxidation preparation.

         4.1.1 Mix a solution of Sirtl etch in the following proportions:

                A - 100ml deionized water
                         50 grams chromium trioxide

                B - 50ml hydrofluoric acid

NOTE: Solution may be stored after mixing.

1

4.1.2 Etch the passivated wafer a maximum of two minutes in 15 second intervals, until etched areas are visible (25°C). Figure 1.

NOTE: A one micron oxide layer will take approximately two (2) minutes; thinner film will take proportionately less time.

4.1.3 Rinse thoroughly in deionized water and dry.

4.2 Single oxidation measurement.

4.2.1 Using a microscope with a grid eyepiece, count the number of pinholes in one or more squares of the grid at each of nine locations on the wafer. See Figure 2.

4.2.2 Calculate the pinhole density as pits per square centimeter using the following equation:

$$\text{Density} = \frac{\text{Total No. Etched Areas}}{\text{No. Squares x Ares of one Square}}$$

4.3 Completed device preparation

4.3.1 Etch all metallization from wafer.

4.3.2 Etch wafer in hydrofluoric acid until all oxide is 1 removed.

4.3.3 Rinse thoroughly in deionized water.

4.3.4 Etch wafer for 30 seconds in the Sirtl etch of Paragraph 4.1.1

4.3.5 Rinse thoroughly in deionized water and dry. See Figure 3.

4.4 Device measurement.

4.4.1 Repeat 4.2.1 and 4.2.2 or count the number of pinholes per circuit at each of nine locations.

4.4.2 Calculate the number of pinholes per circuit as follows:

$$\text{Pinholes} = \frac{\text{Total Etched Areas}}{\text{No. of Devices Counted}}$$

2

5.   <u>Calibration</u>

Determine the area of each grid square by measuring with a stage micrometer at the magnification to be used.

6.   <u>Accuracy</u>

Accuracy obtainable is $\pm$ 10%.

7.   <u>Test Frequency</u>
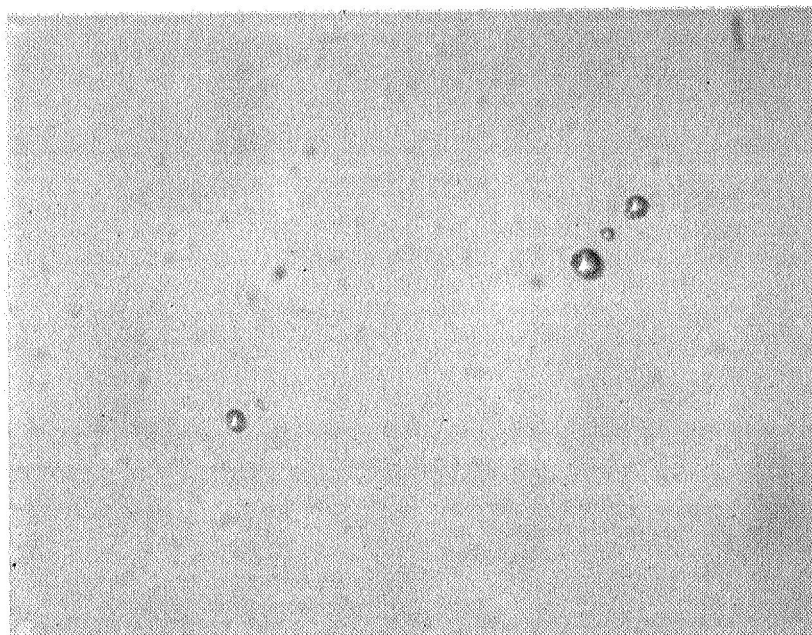
Test should be performed periodically.

Figure 1.   Pinholes Etched Through Oxide Layer
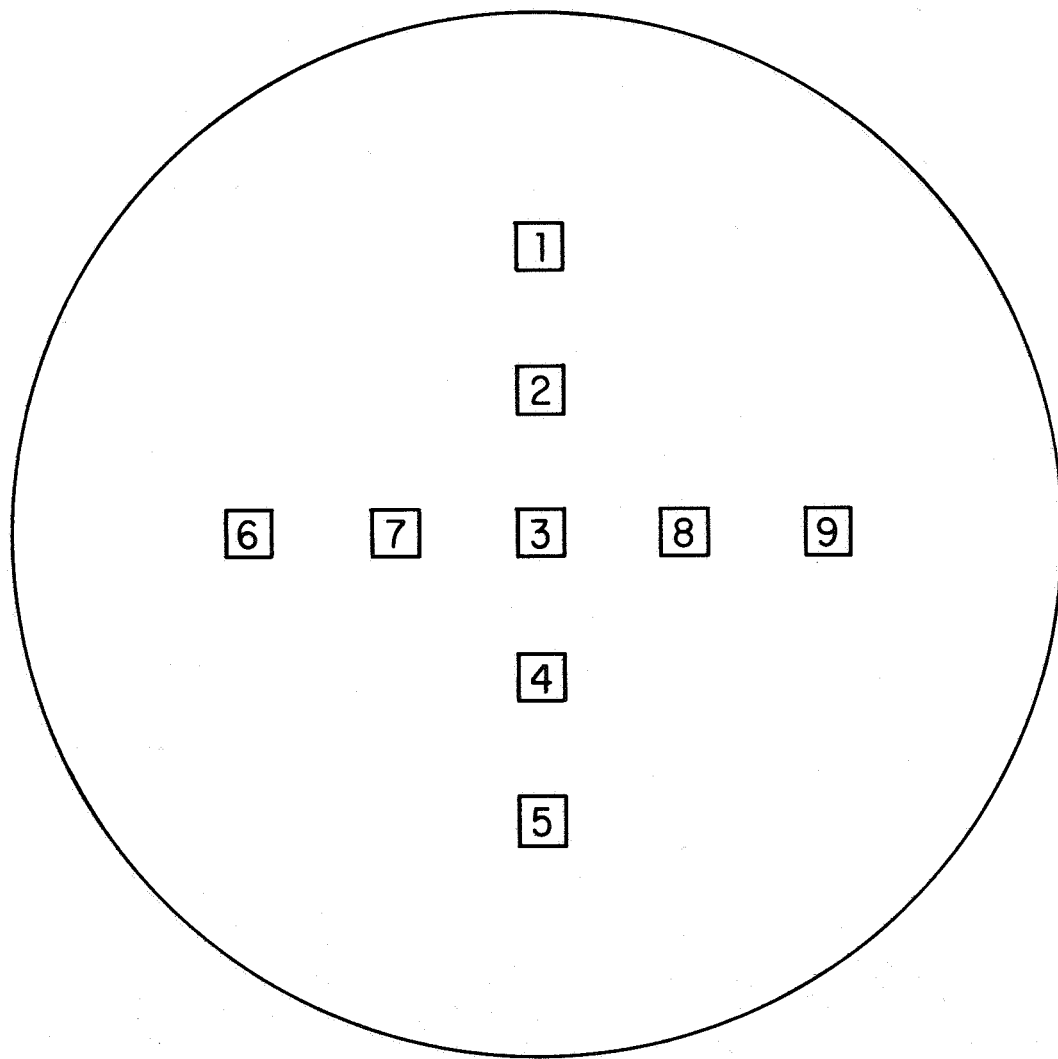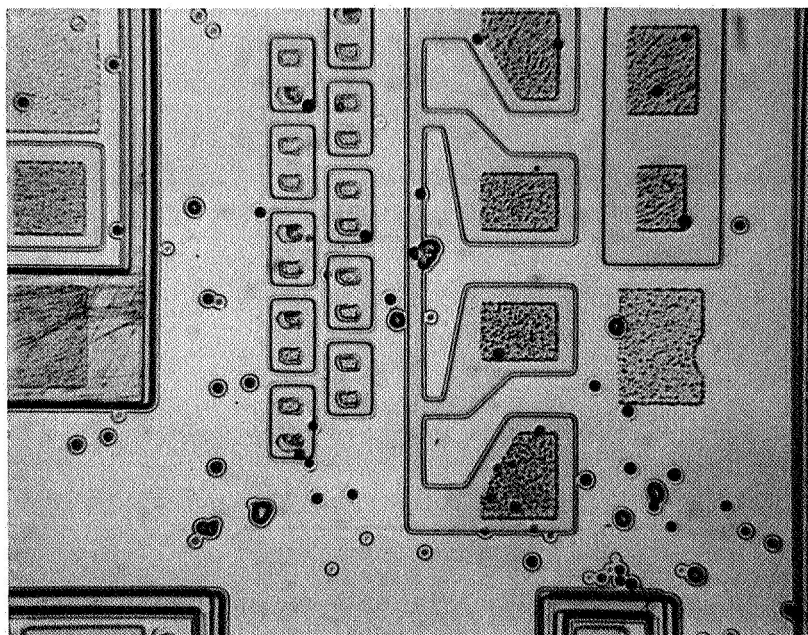
Figure 2. Sampling Pattern

Figure 3.   Pinholes in Completed Devices

Method 128

Photoresist Process
(Minimum Line Width)

1. <u>Purpose</u>   The purpose of this test method is to accurately measure the minimum line width etched in the passivating layer.

2. <u>Apparatus</u>

   2.1   Metallurgical Microscope
         Bausch and Lomb
         Dynoptic No. 31-20-66-38 (DMETR)
         (or equivalent)

   2.2   Watson Lens (Filar) 2x
         Model 1014, London
         (or equivalent)

3. <u>Materials</u>

   None.

4. <u>Procedure</u>

   4.1   Place the wafer to be measured upon the microscope stage.

   4.2   Set the counter and vernier to "zero".

   4.3   Turn the counter to the nearest whole number where one edge of the second image just touches or does not quite reach the opposite side of the primary image. If the second image moves in any direction other than normal to the line to be measured, rotate the Watson lens until normalcy is achieved.   Figure 1.

   4.4   Adjust the vernier until the two opposite sides just touch.

   4.5   Read the width of the line in whole units and tenths. Compare with calibration to obtain mils.

         NOTE: Most Watson lens, used with a 40x objective, will show approximately 20 units/mil.

1

5. <u>Calibration</u>

    The Watson lens should be calibrated by placing a B and L
    precision stage micrometer No. 31-16-99 in the apparatus and
    comparing the number of units per mil.

6. <u>Accuracy</u>

    Accuracy obtainable is $\pm$ 0. 1 unit or 0. 005 mil or about 3%
    on a 0. 00025 inch resistor.

7. <u>Test Frequency</u>

    This test should be performed on a sample wafer from every
    photomask run.

Method   129

Photoresist Process
(Thickness of Photoresist Film)

1.   Purpose   This test method may be used to measure the
thickness of a photoresist film on the substrate.
It utilizes the interference of rays of monochromatic
light reflected from the polished substrate surface
to a sloping edge of a photoresist pattern.   The
following relationship is applicable:

$$d \ = \ \frac{nf\,\lambda}{2\mu} - \frac{\lambda}{4\mu}$$

where   d = Layer thickness

nf = Number of interference fringes

λ = Wave length of incident light

μ = Index of refraction of photoresist film.

2.   Apparatus

2.1   Metallurgical Microscope
Bausch and Lomb Model 31-20-68-38 (DMETR)
(or equivalent)

2.2   Interference Filter, Transmission Type, 5500Å
Bausch and Lomb No. 42-47-57
(or equivalent)

2.3   Photoresist Station
(process to be evaluated)

3. <u>Materials</u>

    3.1   Photoresist

    3.2   Photoresist Developer

    3.3   Photomask with pattern

4. <u>Procedure</u>

    4.1   Preparation

        4.1.1   Obtain a clean, polished substrate which has not been passivated.

        4.1.2   Process wafer through standard photomasking process, except mask and coated substrate shall not be pressed together and wafer should not be baked after development.

    4.2   Measurement

        4.2.1   Place the sample upon the microscope stage.

        4.2.2   Insert filter and adjust magnification to 200x.

        4.2.3   Examine the edge of any pattern with straight lines.

        4.2.4   Starting at the substrate surface, count the number of fringes.

               NOTE: A dark resist surface indicates a half fringe and a light surface is a whole fringe. See Figures 1 - 7.

        4.2.5   Apply the formula from Paragraph 1 or Table I to determine the thickness in $\overset{\circ}{A}$ units.

5. <u>Calibration</u>

Not applicable.

6.   Accuracy

Accuracy obtainable should be $\pm$ 1/2 fringe, or 910Å.

7.   Test Frequency

This test should be performed periodically on each process-photoresist combination.
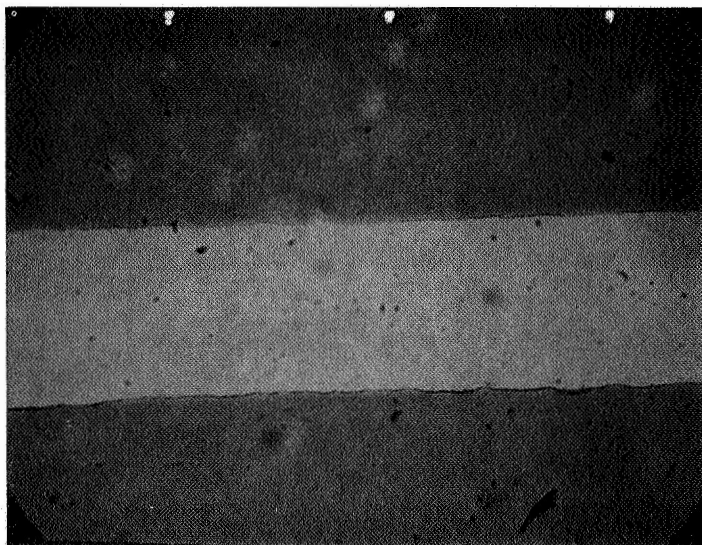
3

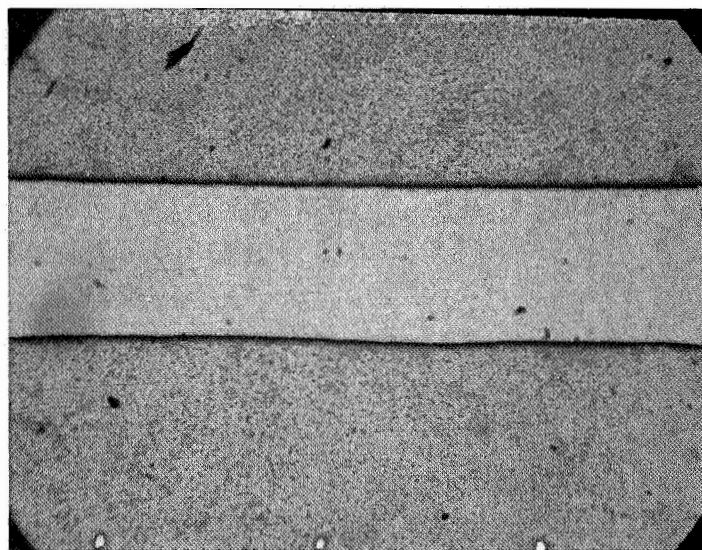Figure 1. One-half Fringe KMER Coating 200X

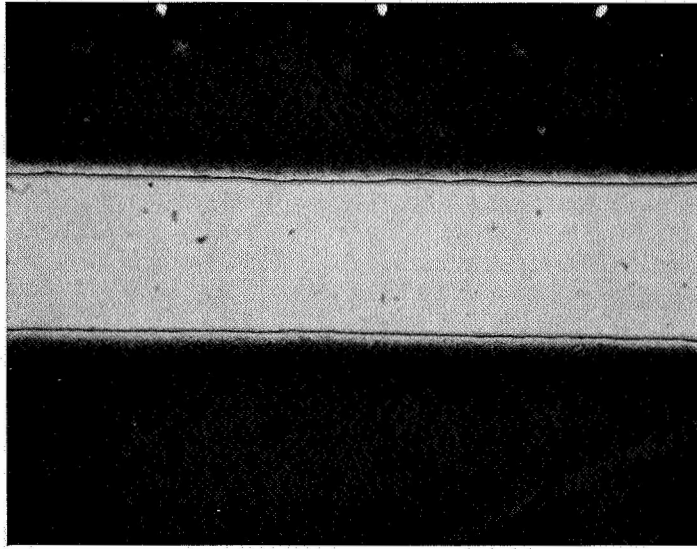Figure 2. One Fringe KMER Coating 200X

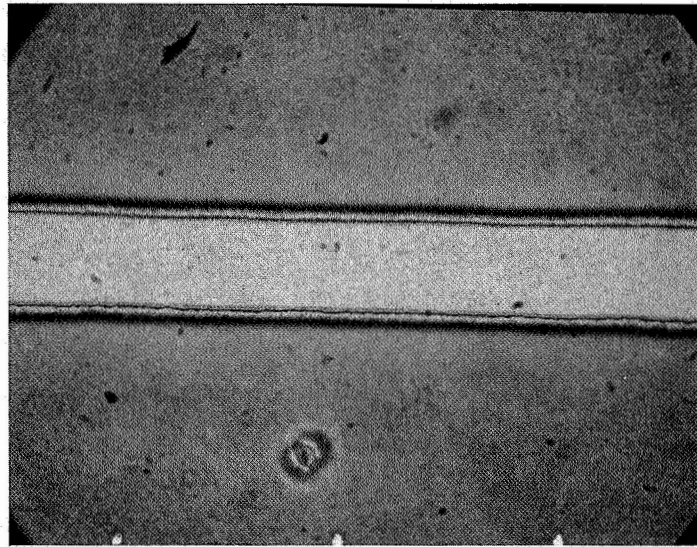Figure 3.   One and one-half Fringes KMER Coating 200X
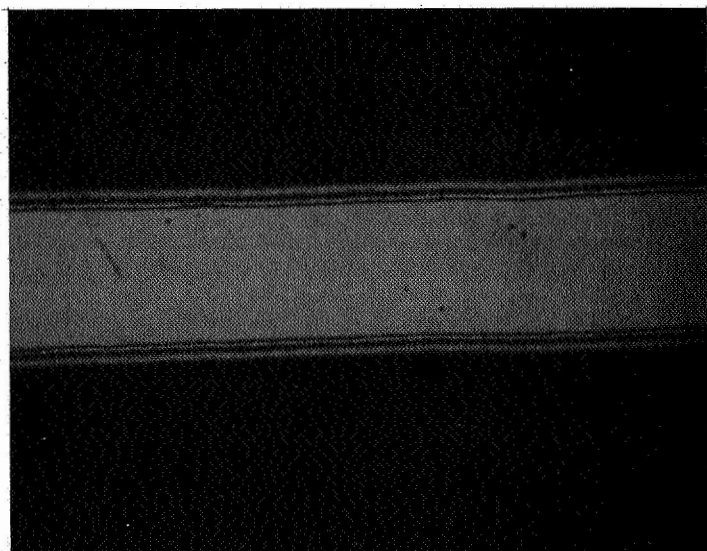

Figure 4.   Slightly Less Than Two Fringes KMER 200X
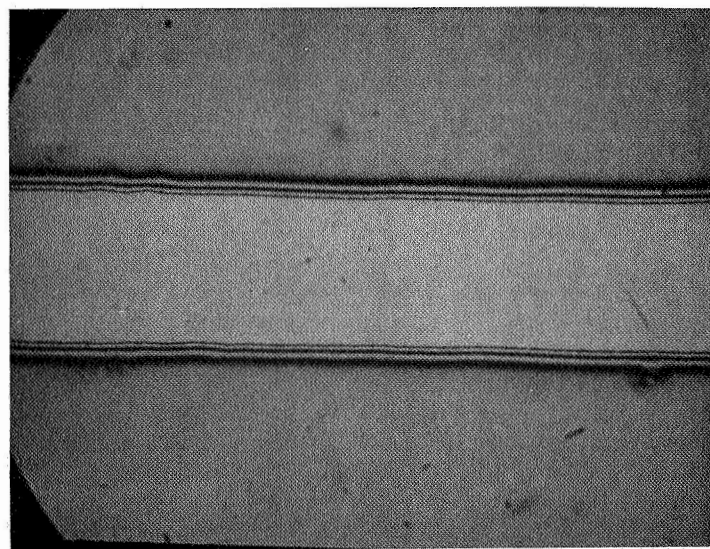
Figure 5.   Two and one-half Fringes 200X
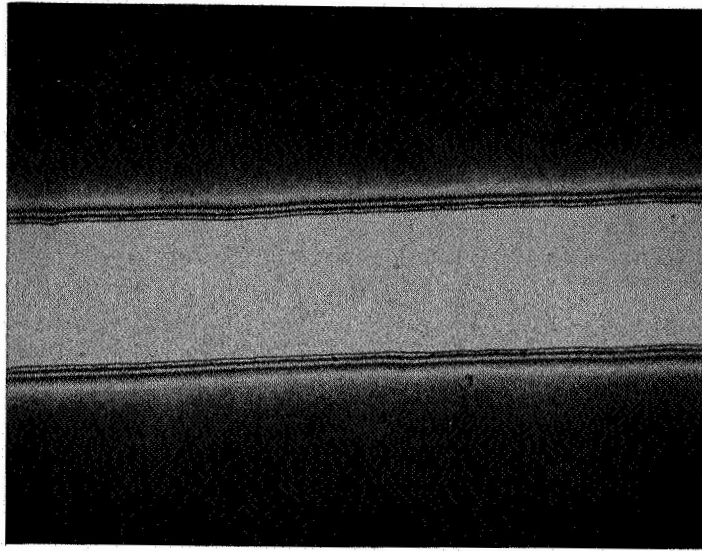

Figure 6.   Three Fringes 200X

6

Figure 7.   Three and one-half Fringes   200X

Fringe Count Chart
Table I
Hg Light, $\lambda = 5460$ A, n = 1.5

Number of Fringes	Thickness in Microns	Number of Fringes	Thickness in Microns
1	.0910	19	3.3670
2	.2730	20	3.5490
3	.4550	21	3.7310
4	.6370	22	3.9130
5	.8190	23	4.0950
6	1.0010	24	4.2770
7	1.1830	25	4.4590
8	1.3650	26	4.6410
9	1.5470	27	4.8230
10	1.7290	28	5.0050
11	1.9110	29	5.1870
12	2.0930	30	5.3690
13	2.2750	31	5.5510
14	2.4570	32	5.7330
15	2.6390	33	5.9150
16	2.8210	34	6.0970
17	3.0030	35	6.2790
18	3.1850		

Method 130

Photoresist Process
(Pinholes in Film)

1. Purpose   The purpose of this method is to determine the
density of pinholes in the photoresist film.   It is
accomplished by measuring the number of resist-
caused pinholes in the passivating layer of a
polished substrate.

2. Apparatus

2.1   Metallurgical Microscope
Bausch and Lomb, Model 31-20-68-38 (DMETR)
(or equivalent)

2.2   Photoresist Station
(process to be evaluated)

3. Materials

3.1   Passivation Etch

3.2   Photoresist

3.3   Photoresist Developer

3.4   Photoresist Stripping Solution

3.5   Photomask, 0.025 x 0.025 inch island.

4. Procedure

4.1   Preparation

4.1.1   Obtain a polished, passivated substrate.

4.1.2   Process wafer through standard photomasking
process using the mask called out in 3.5

4.1.3   Etch grid pattern through passivating layer.

1

4. 1. 4   Strip photoresist from wafer.

4. 1. 5   Rinse wafer in deionized water and dry.

4. 2   Measurement

4. 2. 1   Place sample wafer on microscope stage.

4. 2. 2   Adjust magnification to 200X.

4. 2. 3   Count pinholes in sixteen random squares.

NOTE: A pinhole is defined as a ring of light or dark field, or a hole with a flat, silver-grey base in light field.   Fig. 1

4. 2. 4   Divide total number of pinholes found in 4. 2. 3 by 100 for the pinhole density per square inch.
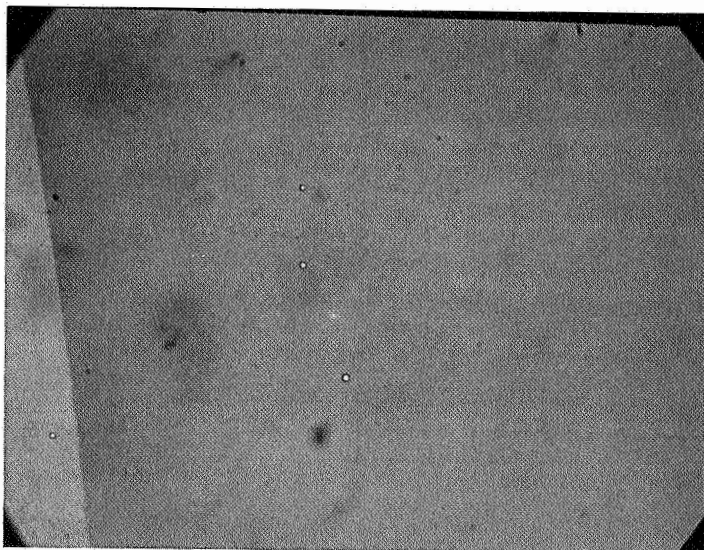
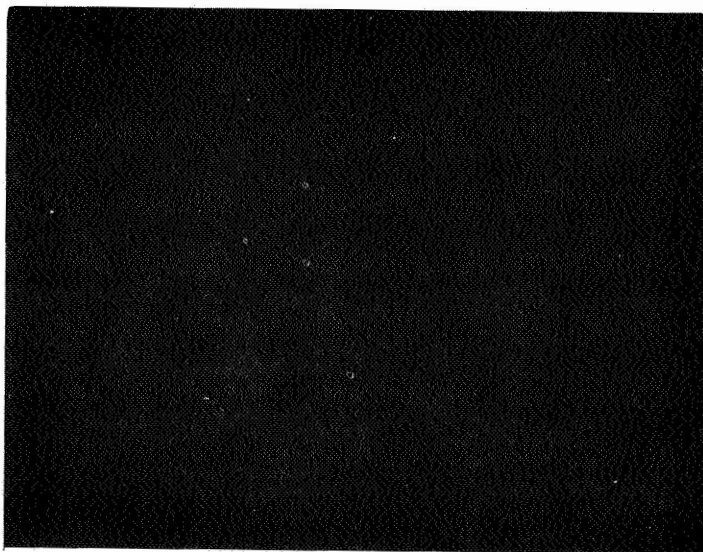5.   Calibration

Not applicable.

6.   Accuracy

Accuracy obtainable should be at least $\pm$ 10% of pinhole count.

7.   Test Frequency

This test should be performed periodically on each process-photoresist combination.

Light Field

Dark Field

Figure 1.   Oxide Pinholes

Method 131

Photoresist Process
(Light Intensity)

1. <u>Purpose</u>   This method may be used to obtain reproducible light intensity in the photoresist process. A stable radiometer is used to calibrate a mercury light source which is the source of calibration for any small-area production lightmeter. The wavelength of interest is the 4050Å mercury line.

2. <u>Apparatus</u>

   2. 1   Mercury Source Lamp, Adjustable Mirror and Focus
       (any source)

   2. 2   Plywood Screen, 3' x 4' x 1/2' Dull Black with
       3 1/2" x 5 1/2" Baffled Aperture

   2. 3   Water Filter for Paragraph 2. 2

   2. 4   Narrow-Bandpass Filter Combination
       Corning, Color Specification 5-62
       (or equivalent)

   2. 5   Aluminum Filter Holder, Black, 10" x 10" x 1/8" with
       1 1/2" Circular Baffled Aperture

   2. 6   Shutter
       (any source)

   2. 7   Wideband Calibrated Radiometer
       Eppley Thermopile No. 6965
       (or equivalent)

1

2.8 Window, BaF$_2$
Eppley
(or equivalent)

2.9 Window, Quartz
GE Type 101
(or equivalent)

2.10 Lightmeter, Small Area
(any source)

3. Materials

None.

4. Procedure

4.1 Turn out the exposing light source and allow it to warm up.

4.2 Place the light meter sensing head on the wafer stage. See Figure 1.

4.3 Note the intensity as indicated by the meter.

4.4 Scan the wafer stage, noting uniformity of intensity.

4.5 Adjust exposure optical system to obtain maximum uniformity.

4.6 With the sensing head in the center of the stage, adjust exposure intensity to the desired level.

5. Calibration

Calibrate the reference light source and production lightmeter as follows:

5.1 Set up the optical bench as shown in Figure 2.

5.2 Filter sequence from source to detector should be either yellow-blue-violet, or blue-yellow-violet.

5.3   Turn on source light and allow it to warm up.

5.4   Adjust source mirror and focus to deliver less than 10% intensity variation over a 2 cm. diameter area on the optical axis.

5.5   Adjust intensity to the reference level.

5.6   Swing thermopile off axis to expose device under test.

5.7   Note reading of test device.

5.8   Adjust zero of test device until its current reading agrees with its original reading at the calibration intensity.

6.   <u>Accuracy</u>

Accuracy obtainable depends upon manufacturer.

7.   <u>Test Frequency</u>

Production exposure equipment should be adjusted daily.   Light meter should be calibrated periodically.
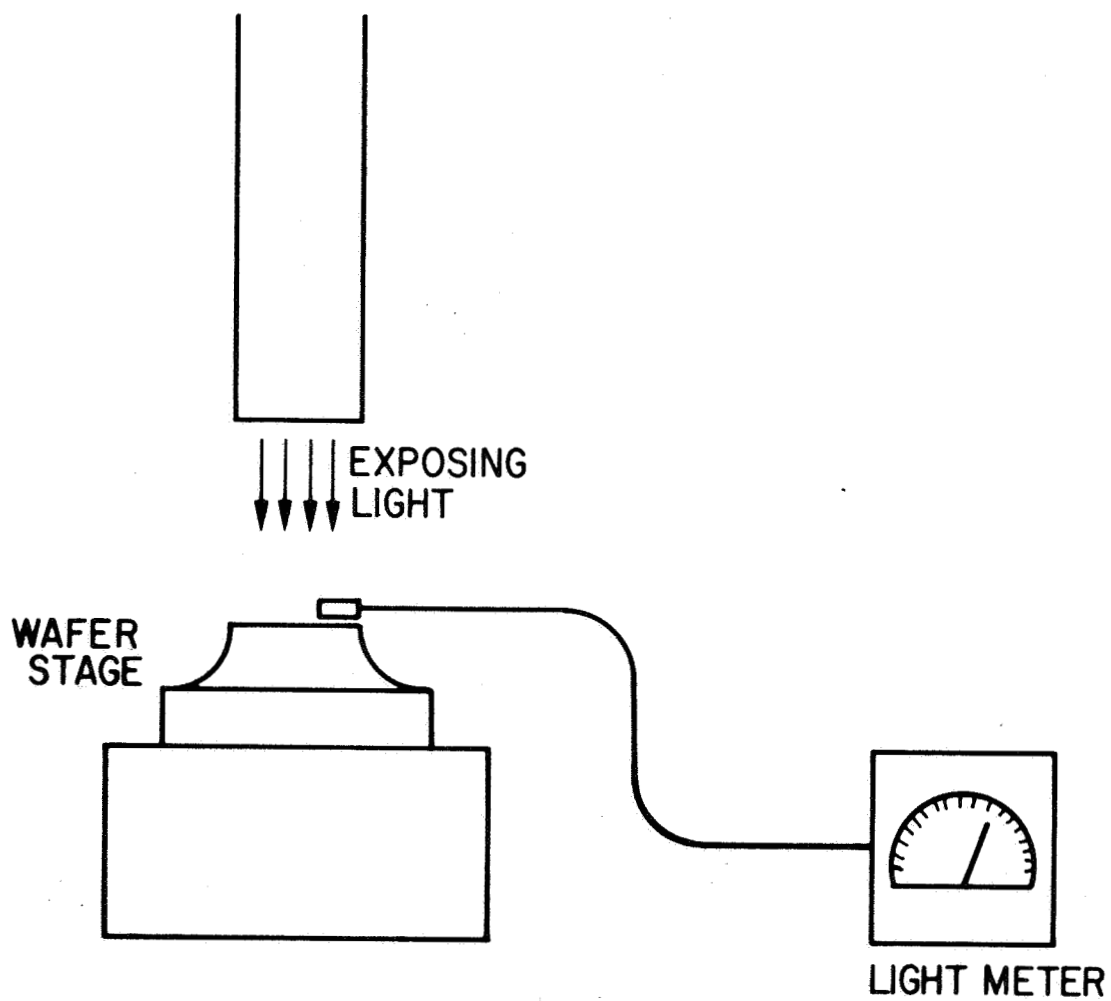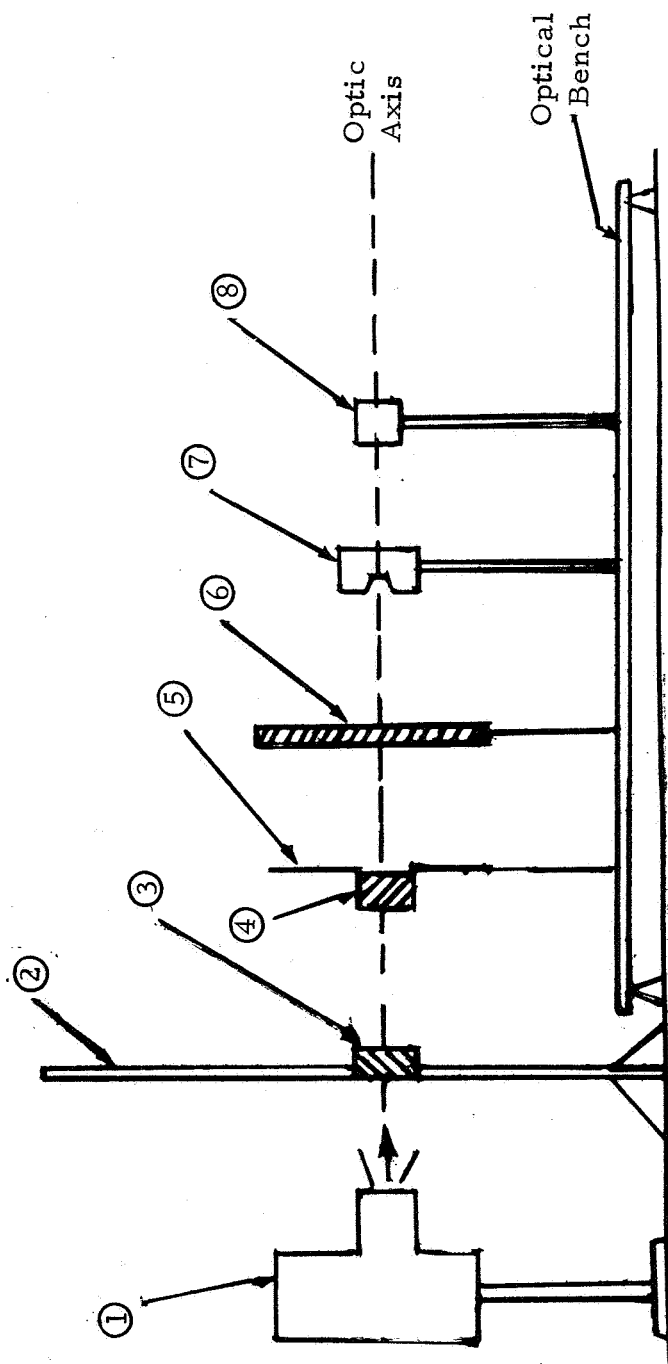
Figure 1. Exposing Light Calibration

Figure 2. Optical Bench Setup for Calibration of Photoresist Light- Meters at 4050 Å

5

Method 132

Photoresist Process
(Spinner RPM)

1. Purpose   This test may be used to determine the speed of a
             spinner used to apply a thin, uniform film of
             photoresist. It utilizes a stroboscope to synchronize
             with the spinner, then its speed is measured directly
             by the flashing rate required to hold the image
             stationary.

2. Apparatus

    2.1 Stroboscope
         Type 1531.A Strobotac
         General Radio
         (or equivalent)

3. Materials

    None.

4. Procedure

    4.1 Open the stroboscope case and plug the power connector
         into a receptacle.

    4.2 Pivot the reflector assembly to an upright position.

    4.3 Turn the power switch on and allow 10 seconds for
         warm up.

    4.4 Aim the light beam at the spinner to be calibrated.

    4.5 Turn the spinner on and adjust control to approximately
         the speed desired.

    4.6 Select the speed range which is applicable.

    4.7 Rotate the RPM control until the spinner image stops.
         This is the speed of the spinner.

1

NOTE: If multiple images occur, the stroboscope is set at an even multiple of the fundamental speed and should be slowed until only one image is visible.

4.8   Adjust the stroboscope to the spinner speed desired.

4.9   Increase or decrease the spinner speed until one stationary image is again obtained.

4.10   Record the spinner control setting and the delivered RPM.

5.   Calibration

Adjust the calibration for any given power-line frequency as follows:

5.1   Allow a 10 minute warm-up.

5.2   Turn the range switch to 670-1410 RPM.

5.3   Set the RPM dial to 3600 RPM (for 60 cycle service).

5.4   Adjust the screw-driver control marked "HIGH CAL" until the on - off pattern of the neon indicator lamp stops or nearly stops.

5.5   Set the RPM dial to 900 RPM (for 60 cycle service) and repeat 5.4 for the "LOW CAL" screw-driver adjustment.

5.6   Return RPM dial to 3600 RPM and repeat 5.4.

6.   Accuracy

Accuracy obtainable after calibration is $\pm$ 1%.

7.   Test Frequency

Photoresist spinners should be calibrated periodically per this or equivalent methods.

Method 133

Junction Formation (Depth)

(Monochromatic Interference)

1.　Purpose　The purpose of this test is to measure the depth of diffused junctions. It employs the interference of monochromatic light reflected between the beveled surface of the applicable structure and a thin, flat glass slide.

2.　Apparatus.

2.1　Metallurgical microscope
Metalstar trinocular body AO No. 2200T-4
American Optical Company
(or equivalent)

2.2　Polaroid camera AO No. 1052A
American Optical Company
(or equivalent)

2.3　Monochromatic light source

2.3.1　Mercury, 5461 Å, green filter
LaPine Scientific Co. Model 216-01
(or equivalent)

2.3.2　Sodium, 5893 Å (optional)
LaPine Scientific Co. Model 215-96
(or equivalent)

2.4　High intensity light fixture
Sun Gun II
Eastman Kodak
(or equivalent)

2.5　High intensity bulb
3400K movie lamp type DWY
Sylvania Electric
(or equivalent)

1

2. 6 Hot plate, 6" x 6", Electric
   Temco, type 1900
   Corning, Pyroceram, PC-35
   (or equivalent)

2. 7 Polyethylene beaker,
   (any source)

2. 8 Glass plate, 6" x 6",
   (any source)

3. Materials

3. 1 Hydrofluric acid, 49%, reagent grade

3. 2 Nitric acid, concentrated, reagent grade

3. 3 Acetic acid, glacial, reagent grade

3. 4 Trichloroethylene, electronic grade

3. 5 Acetone, electronic grade

3. 6 Apiezon wax

3. 7 Polishing compound, 1 micron, Linde "A"

3. 8 Cover glass, microscope 24 x 30 mm, No. 1 1/2 thinness
   Corning or equivalent

4. Procedure

4. 1 Preparation

   4. 1. 1 Place an angle section block, (Figure 1), on a hot
      plate adjusted to a temperature slightly above the
      melting point of apiezon wax (150 - 160°C).

   4. 1. 2 Place a small amount of wax in the sample niche.

   4. 1. 3 Insert the structure to be sectioned into the sample
      niche, pattern up.

      Note: For ease of measurement, passivating layer
      should be removed.

4.1.4   With tweezers or applicators, orient the junction over the edge of the bevel and seat the sample.

4.1.5   Remove the block from the hot plate and allow to cool.

4.1.6   Mix a slurry of Linde "A" and water.

4.1.7   Place a quantity of the slurry on a flat glass plate.

4.1.8   Invert the angle block and place the 5° bevel against the glass plate.

4.1.9   Adding Linde "A" as necessary, polish the specimen to a microscopically smooth finish.

4.1.10   Mix a junction stain of the following composition:

$$1 \, HF : 3 \, HNO_3 \; : \; 20 \, HAc$$

4.1.11   Rinse the mounted specimen thoroughly in deionized water and blow dry with a nitrogen gun.

4.1.12   Place the cleaned specimen in the staining apparatus, (Figure 2), or beneath a "Sun Gun".

4.1.13   Illuminate the specimen for 15 seconds.

4.1.14   Prior to turning off the light, place the 1:3:20 staining solution on the specimen, using a cotton-tipped applicator.

4.1.15   Allow the stain to remain on the sample for 5 - 10 seconds.

4.1.16   Turn off the light and quickly rinse in DI water.

4.1.17   Examine the specimen for adequate junction delineation. Additional polishing or staining may be necessary.

4.1.18   Return mounted specimen to the hot plate until the wax melts.

4.1.19   Clean the dismounted specimen with TCE and acetone. Allow to dry.

4.2   Measurement

    4.2.1   Place the specimen on the microscope stage with a microscope cover glass over the junction. See Figure 3.

    4.2.2   Adjust magnification and focus until the junction (s) of interest and interference fringes are clear.

    4.2.3   Take a photo micrograph.

    4.2.4   Starting with the top surface, count the number of fringes to the junction, or just short of it if the junction lies between fringes.

    4.2.5   If the junction is not on a whole fringe, measure the distance between fringes, W, with a precision rule.

    4.2.6   Measure the distance from the last fringe to the junction, D.

    4.2.7   Calculate the junction depth, x_j, from the following equation:

$$x_j = n_f \left(\frac{\lambda}{2} \right) + \frac{D}{W} \left(\frac{\lambda}{2} \right)$$

    where n_f = number of fringes

              λ = wave length of incident light

See Figure 4.

5.   Calibration

Not applicable.

6.   Accuracy

Accuracy obtainable is $\pm$ 0.1 micron.

7.   Test Frequency

This test should be performed on a sample from each run after each diffusion.
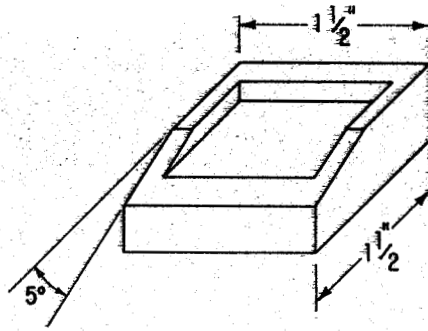
Figure 1.   Angle Section Block

THE APPARATUS SKETCHED BELOW IS SUGGESTED
IN ORDER TO FACILITATE HANDLING REPRODUCIBILITY
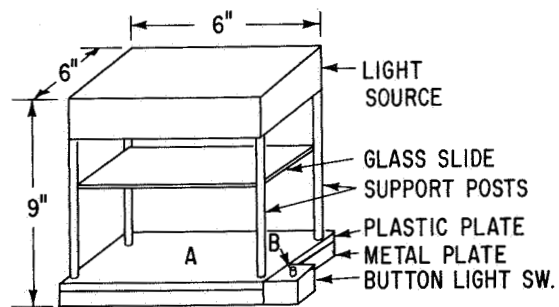IN TECHNIQUE.
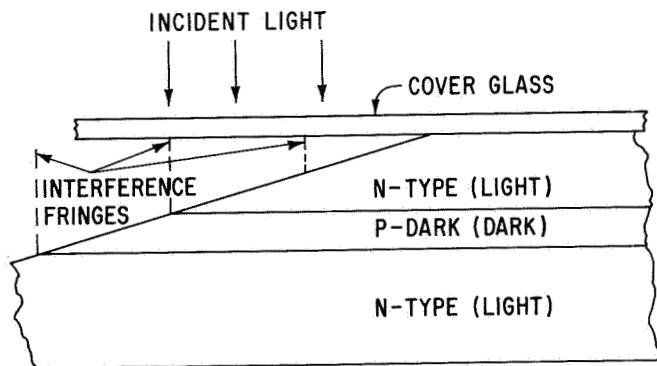

Figure 2.   Staining Fixture

Figure 3.   Measurement Setup

P-TYPE | N-TYPE | TOP SURFACE

INTERFERENCE
FRINGES

D   W
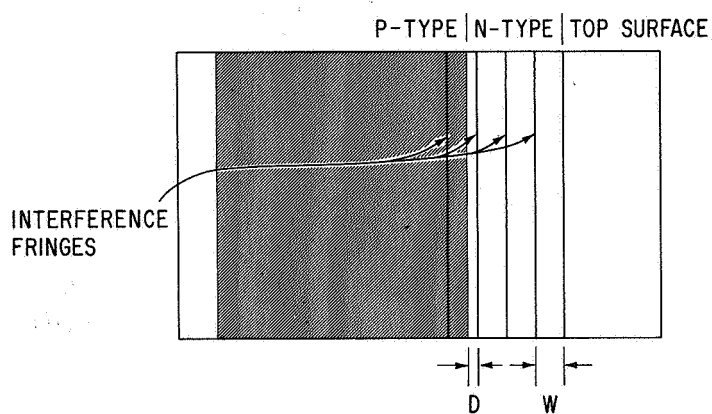
EXAMPLE: Hg LIGHT, $\lambda = 5460$ Å
         W = 0.300 INCH
         D = 0.100 INCH

$$x_j = n_f \left(\frac{\lambda}{2} \right) + \frac{D}{W} \left(\frac{\lambda}{2} \right)$$

$$= 3 \left(\frac{5460}{2} \right) + \frac{0.100}{0.300} \left(\frac{5460}{2} \right)$$

$$= 8190 + 910$$

$$= 9100 \text{ Å}$$

$$= .91 \text{ MICRON}$$

Figure 4.   Junction Depth Measurement

Method 134

Junction Formation (Base Width)
(Monochromatic Interference)

1.   Purpose   The purpose of this test is to measure the distance
between two successive P-N junctions. It employs
the interference of monochromatic light reflected
between the beveled surface of the applicable
structure and a thin, flat glass slide.

2.   Apparatus

2.1   Metallurgical Microscope
Metalstar Trinocular Body AO No. 2200T-4
American Optical Company
(or equivalent)

2.2   Polaroid Camera AO No. 1052A
American Optical Company
(or equivalent)

2.3   Monochromatic light source.

2.3.1   Mercury, 5461A, green filter.
LaPine Scientific Company, Model 216-01
(or equivalent)

2.3.2   Sodium, 5893°A (optional)
LaPine Scientific Company, Model 215-96
(or equivalent)

2.4   High Intensity Light Fixture, Sun Gun II
Eastman Kodak
(or equivalent)

2.5   High intensity bulb, 3400 K movie lamp, type DWY.
Sylvania Electric
(or equivalent)

2.6   Hot plate, 6" x 6", electric
Temco, Type 1900
Corning, pyroceram, PC-35
(or equivalent)

1

2.7   Polyethylene beaker
(any source)

2.8   Glass plate, 6" x 6"
(any source)

3.   Materials

3.1   Hydrofluoric acid, 49 %, Reagent grade.

3.2   Nitric acid, concentrated, Reagent grade.

3.3   Acetic acid, glacial, Reagent grade.

3.4   Trichloroethylene, Electronic grade.

3.5   Acetone, Electronic grade.

3.6   Apiezon wax.

3.7   Polishing compound, 1 micron, Linde "A".

3.8   Cover glass, microscope 24 x 30 mm No. 1-1/2 thinness.
Corning, or equivalent.

4.   Procedure

4.1   Preparation

4.1.1   Place an angle section block, (Figure 1), on a hot
plate adjusted to a temperature slightly above the
melting point of apiezon wax (150-160°C) .

4.1.2   Place a small amount of wax in the sample niche.

4.1.3   Insert the structure to be sectioned into the sample
niche, pattern up.

NOTE: For ease of measurement, passivating
layer should be removed.

4.1.4   With tweezers or applicators, orient the junction
over the edge of the bevel and seat the sample.

4.1.5   Remove the block from the hot plate and allow to cool.

2

4. 1. 6   Mix a slurry of Linde "A" and water.

4. 1. 7   Place a quantity of the slurry on a flat glass plate.

4. 1. 8   Invert the angle block and place the 5° bevel against the glass plate.

4. 1. 9   Adding Linde "A" as necessary, polish the specimen to a microscopically smooth finish.

4. 1. 10   Mix a junction stain of the following composition:

$$1\,HF : 3\,HNO_3 : 20\,HA_c$$

4. 1. 11   Rinse the mounted specimen thoroughly in deionized water, and blow dry with a nitrogen gun.

4. 1. 12   Place the cleaned specimen in the staining apparatus, Figure 3, or beneath a "Sun Gun".

4. 1. 13   Illuminate the specimen for fifteen seconds.

4. 1. 14   Prior to turning off the light, place the 1:3:20 staining solution on the specimen, using a cotton-tipped applicator.

4. 1. 15   Allow the stain to remain on the sample for five to ten seconds.

4. 1. 16   Turn off the light and quickly rinse in DI water.

4. 1. 17   Examine the specimen for adequate junction delineation. Additional polishing or staining may be necessary.

4. 1. 18   Return mounted specimen to the hot plate until the wax melts.

4. 1. 19   Clean the dismounted specimen with TCE and actene. Allow to dry.

3

4.2 Measurement

 4.2.1 Place the specimen on the microscope stage with a microscope cover glass over the junction. See Figure 3.

 4.2.2 Adjust magnification and focus until the junction (s) of interest and interference fringes are clear.

 4.2.3 Starting with the top surface, count the number of fringes to the first junction, or just short of it if the junction lies between fringes n'f.

 4.2.4 If the junction is not on a whole fringe, measure the distance between fringes, w, with a precision rule.

 4.2.5 Measure the distance from the last fringe to the junction "D".

 4.2.6 Repeat Steps 4.2.3 and 4.2.5 for the next junction.

 4.2.7 Calculate the base width, Δx, from the following equation:

$$\Delta x = \left[nf\left(\frac{\lambda}{2}\right) + \frac{D}{w}\left(\frac{\lambda}{2}\right)\right]$$

$$- \left[n'f\left(\frac{\lambda}{2}\right) + \frac{D}{w}\left(\frac{\lambda}{2}\right)\right]$$

See Figure 4.

5. Calibration

Not applicable.

6. Accuracy

Accuracy obtainable is $\pm$ 0.1 micron.

7. Test Frequency

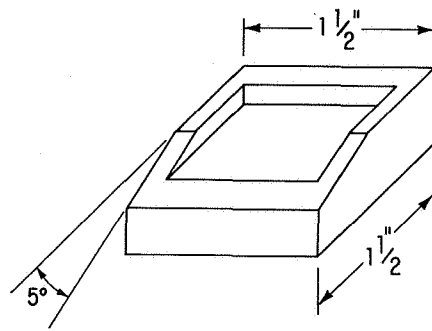This test should be performed on a sample from each run.

4

Figure 1.   Angle Section Block

THE APPARATUS SKETCHED BELOW IS SUGGESTED
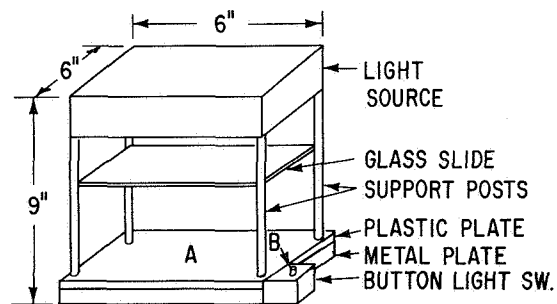IN ORDER TO FACILITATE HANDLING REPRODUCIBILITY
IN TECHNIQUE.

Figure 2.   Staining Fixture

Figure 3.   Measurement Setup

5
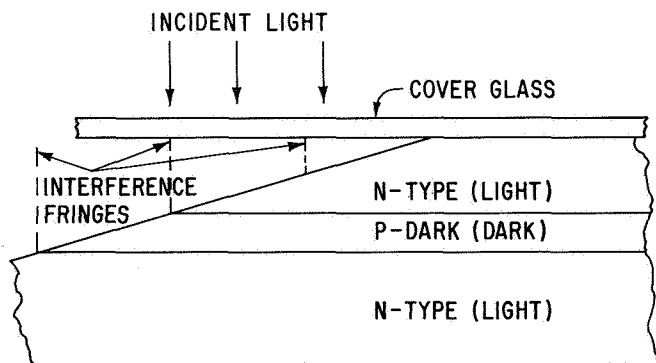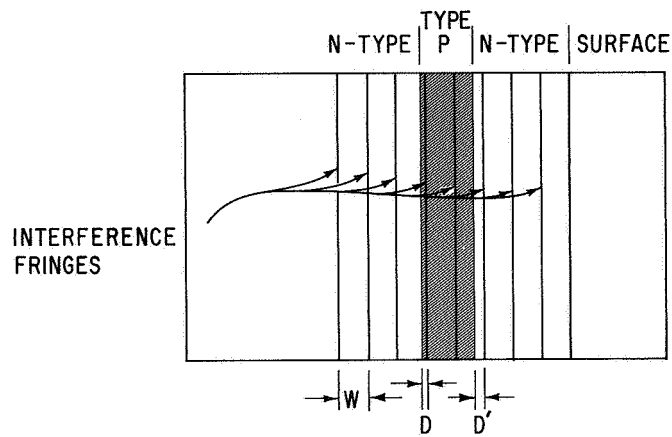
EXAMPLE: Hg LIGHT, $\lambda = 5460$ A, GREEN FILTER

W = 0.300 INCH

D = 0.050 INCH

D = 0.100 INCH

Δx = BASE WIDTH

$$\Delta x = \left[n_f \left(\frac{\lambda}{2} \right) + \frac{D}{W} \left(\frac{\lambda}{2} \right) \right] - \left[n'_f \left(\frac{\lambda}{2} \right) + \frac{D'}{W} \left(\frac{\lambda}{2} \right) \right]$$

$$= \left[5 \left(\frac{5460}{2} \right) + \frac{0.050}{0.300} \left(\frac{5460}{2} \right) \right] - \left[3 \left(\frac{5460}{2} \right) + \frac{0.100}{0.300} \left(\frac{5460}{2} \right) \right]$$

$$= \left[13650 + 455 \right] - \left[8190 + 910 \right]$$

$$= 14105 - 9100$$

$$= 5005 \overset{\circ}{A} = .50 \text{ MICRON}$$

Figure 4.   Junction Depth Measurement

Method 135

Junction Formation
(Sheet Resistance)

1. Purpose   The purpose of this test is to measure the sheet
               resistance of any structure, whether formed by
               an initial doping or the final diffusion. A lapped
               test chip of opposite type from the dopant is checked
               for voltage drop across a four-point probe utilizing
               a constant-current power supply.

2. Apparatus

    2.1 Four-point probe, 0.050-inch spacing.
         (any source)

    2.2 Power supply, constant current
         0.1, 1.0, and 10 mA ranges.
         (any source)

    2.3 Voltmeter, digital
         Fairchild 7100
         (or equivalent)

3. Materials

    3.1 Hydrofluoric acid, 49 percent, Reagent grade.

    3.2 Silicon slices, P and N type, lapped.

4. Procedure

    4.1 Preparation

        4.1.1 Process a lapped slice, of opposite type from the
               dopant concentration under evaluation, through the
               predeposition and/or diffusion operation to be
               measured.

               NOTE: The test chip should have a surface area
               in excess of one-half square inch.

1

4.1.2   Allow the test chip to cool to room temperature.

4.1.3   Etch the chip until all doped oxide is removed, approximately ten seconds in concentrated hydrofluoric acid.

4.1.4   Rinse the chip in deionized water and blow dry with a nitrogen gun.

4.2   Measurement

4.2.1   Place the test chip upon the stage of the four-point probe.   See

NOTE: If the furnace operation utilizes an upright wafer position, then either side may be measured. Test chips processed through horizontal operations must be probed on the surface exposed to doping.

4.2.2   Lower the probe until it touches the sample lightly.

4.2.3   Record the voltmeter reading.

4.2.4   Reverse polarity and note that both values are approximately the same.

4.2.5   If readings differ significantly, increase probe pressure slightly until agreement is reached.

4.2.6   If the current source is 100μA, 1 mA, 10 mA, etc., the voltmeter will read directly in sheet resistance with application of the proper decimal point.   Example:

$$I = 100\,\mu A$$
$$V = 50\,\mu A$$

$$\frac{V}{I} = \frac{50}{100} = 0.5\ \Omega/\square$$

5.   Calibration

5.1   Probe Spacing

5.1.1   Cover a 1" x 3" glass microscope slide with aluminum foil.

5.1.2   Obtain an impression of the four probe points.

5.1.3   Measure spacing with any optical comparator.

5.1.4   Adjust spacing per probe manufacturer's instruction.

6.   <u>Accuracy</u>

Accuracy obtainable is approximately $\pm$ 10%.

7.   <u>Test Frequency</u>

This test should be performed after each predeposition or diffusion.

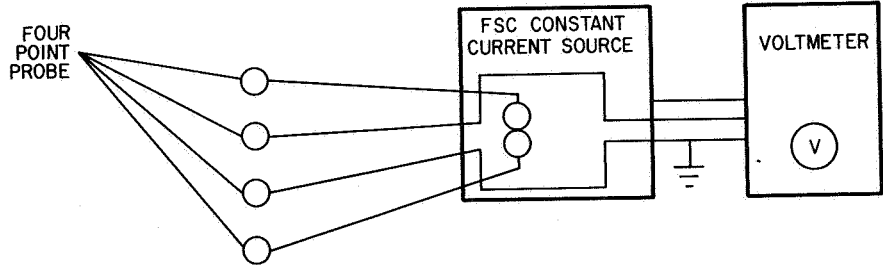FOUR POINT PROBE – SET-UP

Figure 1.

Method 136

Junction Formation
(Furnace Temperature Profile)

1.   <u>Purpose</u>   This test is applicable to the temperature profiling of diffusion, oxidation or alloying furnaces. It utilizes a thermocouple and millivolt potentiometer.

2.   <u>Apparatus</u>

      2.1   Millivolt Potentiometer
            Leeds and Northup
            Model No. 8662 or 8686
            (or equivalent)

      2.2   Quartz Thermocouple Sheath
            6 mm
            (any source)

      2.3   Platinum-Rhodium Thermocouple
            (any source)

3.   <u>Materials</u>

   None.

4.   <u>Procedure</u>

      4.1   Position Potentiometer in front of furnace so that thermocouple will be able to be moved within the furnace tube as required.

      4.2   Insert thermocouple and thermocouple sheath into that furnace until the end of the sheath is flush with the end of the quartz tube.

      4.3   Connect thermocouple to potentiometer. Make sure that the red lead is connected to the terminal marked with the minus sign (-) and the other lead connected to the terminal marked with the plus sign (+).

1

4.4 Check to see if all gases usually flowing through the furnace except the source, are flowing at their usual rates of flow.

4.5 Allow thermocouple and potentiometer to stand for 10 minutes for temperature to stabilize.

4.6 Calibrate thermocouple prior to use. Paragraph 5.

4.7 Find temperature-millivolt equivalent of expected furnace temperature from temperature-millivolt equivalent chart and set the main scale of the potentiometer to read this value.

Example: 1000°C =   10.471

4.8 Place the end of the thermocouple at the first location of interest and allow 30 seconds for the temperature to stabilize.

NOTE: Usually it is most convenient to commence at the point furthest from the furnace mouth.

4.9 Tap the "L" key and note the deflection on the galvanometer. Adjust the setting on the main scale until little or no deflection appears. Repeat using "H" key.

4.10 Convert the final millivolt reading back to temperature by using the temperature-millivolt equivalent chart.

Example: 10.445 millivolts = 998°C

4.11 Record the temperature for that point after making a correction to any thermocouple error.

4.12 Repeat 4.8 to 4.11 until profile is completed.

4.13 At the completion of profiling disconnect thermocouple as follows:

4.13.1   Model 8662

4.13.1.1   Place metal bar across two terminals in upper corner.

4.13.1.2   Push lamp switch off.

4.13.1.3   Disconnect thermocouple leads.

2

4.13.2   Model 8686

        4.13.2.1   Turn function switch to "Galv. off" position.

        4.13.2.2   Disconnect thermocouple leads

        4.13.2.3   Close lid of potentiometer.

4.14   Slide thermocouple back into thermocouple sheath, remove both from furnace and place in storage tube fastened to the furnace provided for that specific thermocouple.

5.   Calibration

5.1   Thermocouple should be checked for error against a melting point standard.

5.2   Potentiometer

5.2.1   Model 8662

        5.2.1.1   Pull lamp switch up.   Figure 1.

        5.2.1.2   Check to make sure that metal bar is across two terminals in upper corner of potentiometer.

        5.2.1.3   Adjust "zero adjust" knob until galvanometer is balanced at zero.

        5.2.1.4   Loosen terminals holding metal bar and position bar so that it is away from one of the terminals.   Figure 2.

        5.2.1.5   Place "snap switch in "S. C. " position. "

        5.2.1.6   Tap the "Low" key and note deflection. Adjust "Coarse knob on side of case until there is little or no deflection on the galvanometer when the "Low" key is depressed. "

5.2.1.7   Tap the "High" key and note deflection. Adjust the fine knob on the side of the case until there is no deflection.

5.2.1.8   Reposition snap switch in "EMF" position.

5.2.1.9   Note temperature on thermometer taped to case.   Figure 3.

5.2.1.10   Find millivolt equivalent on temperature-millivolt equivalent chart.

       Example: 27°C   =   0.154 MV

5.2.1.11   With the "Reference Junction" knob, adjust the "Reference Junction" scale to read the temperature-millivolt equivalent value in black.

5.2.2   Model 8686

5.2.2.1   Turn function switch to "standarized" position.   Figure 1.

5.2.2.2   Make sure both "L" and "H" keys are in the up position.

5.2.2.3   Check zero reading.   Adjust with the coarse and fine "zero adjust" knobs until the galvanometer is balanced at zero.

5.2.2.4   Check if function switch is still in "standarized" position.   Figure 2.

5.2.2.5   PUSH the "L" key and note deflection. Adjust "Battery Coarse" knob until there is little or no deflection, when "L" key is depressed.

5.2.2.6   PUSH the "H" key and note deflection. Adjust "Battery Fine" knob until there is no further deflection when "H" key is depressed.
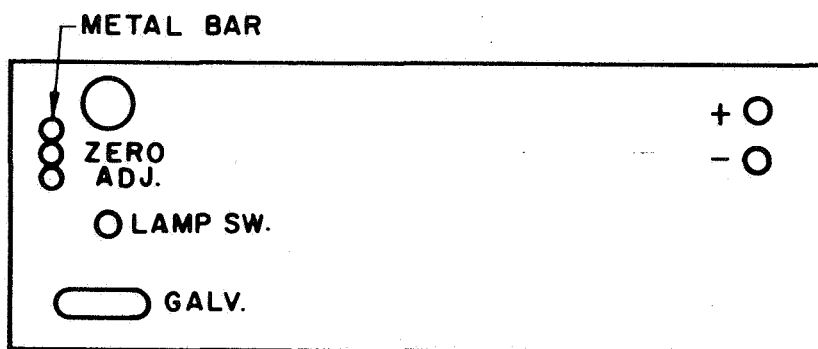
5.2.2.7   Note temperature on thermometer taped to case. Figure 3.

5.2.2.8   Find millivolt equivalent on temperature-millivolt equivalent chart.

5.2.2.9   Turn function switch to "Ref. Jct." position.

5.2.2.10   Using knob "C", adjust the scale to read the temperature millivolt equivalent.

5.2.2.11   Tap the "L" key and note deflection on galvanometer. Adjust the "Reference Junction" knob until there is no further deflection when "L" key is depressed.

5.2.2.12   Repeat using "H" key.

5.2.2.13   Turn the function switch to "T. C." measure.

6.   <u>Accuracy</u>

Accuracy obtainable is $\pm$ 1°C.

7.   <u>Test Frequency</u>

This test should be performed at least once per working day.

METAL BAR

ZERO
ADJ.

LAMP SW.

GALV.

+

−

MODEL 8662

ZERO ADJ. GALV.

STANDARDIZE
FUNCTION SWITCH

L   H

+

−

MODEL 8686

Figure 1

METAL BAR

+
−

COARSE
KNOB

GALV   L H   SNAP SWITCH

FINE
KNOB

MODEL 8662

BATTERY
COARSE   FINE

GALV.

+
−

L H

MODEL 8686

Figure 2

REFERENCE JUNCTION SCALE + ◯

THERMOMETER ⊂▭⊃ - ◯

REFERENCE
JUNCTION ◯

MODEL 8662

REFERENCE JUNCTION

GALV.

◯ +

◯ -

FUNCTION SW.

L   H

C

REFERENCE SET   SCALE

MODEL 8686

Figure 3

8

REFERENCE JUNCTION SCALE
+ =
IO
-

THERMOMETER
8

9
REFERENCE JUNCTION ADJUST

MAIN SCALE
14

I3
MAIN ADJUST

SNAP SWITCH
5

I2

LOW HIGH KEYS
6
8

ZERO ADJUST
2

METAL BAR
4

LAMP SWITCH
I

GALVANOMETER
3
0 I

7

Model 8662

Figures 1 through 3

Model 8686

Figures 1 through 3

Method 137

Junction Formation
(Flow Profile of Gases Around Slice Holder)

1. Purpose   This method may be used to evaluate the uniformity
                 of gas flow about the slice holder, both vertically
                 and horizontally. It is applicable to those furnace
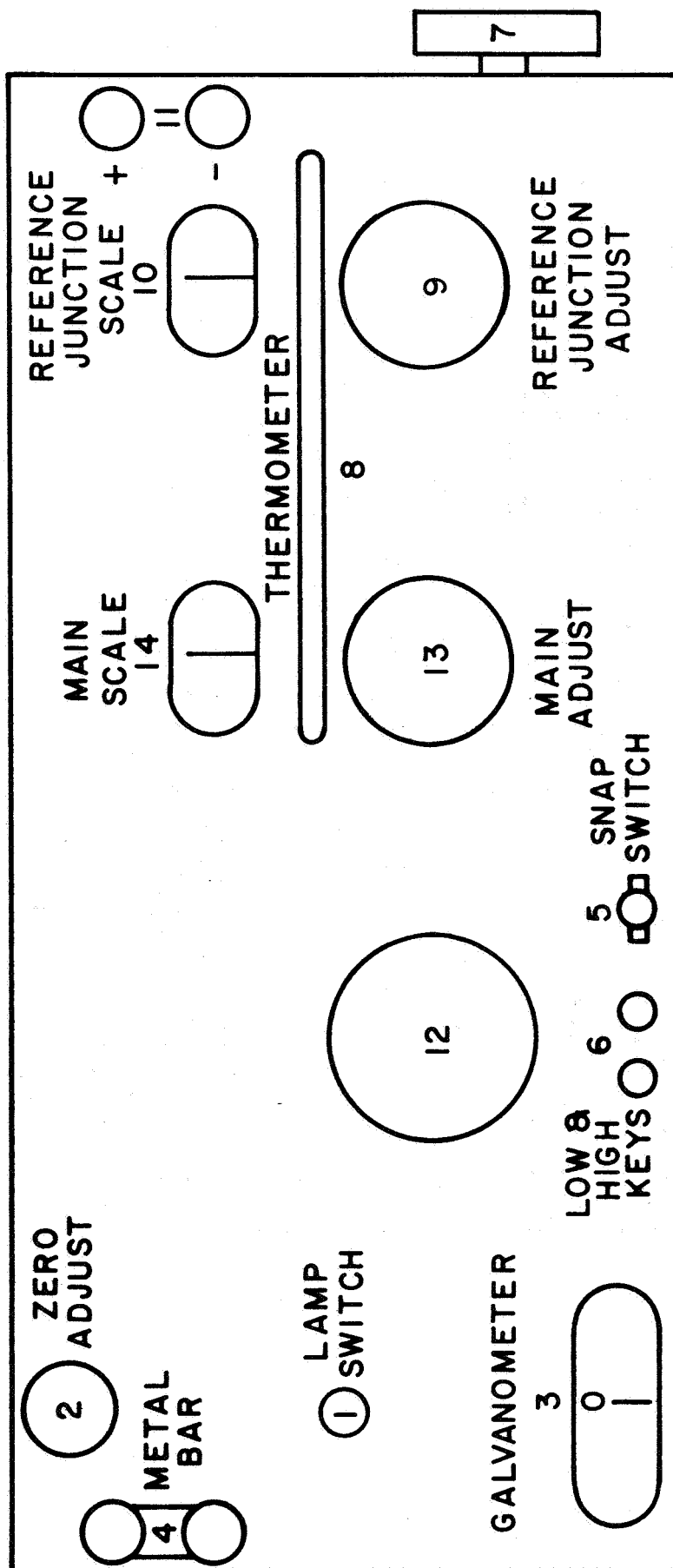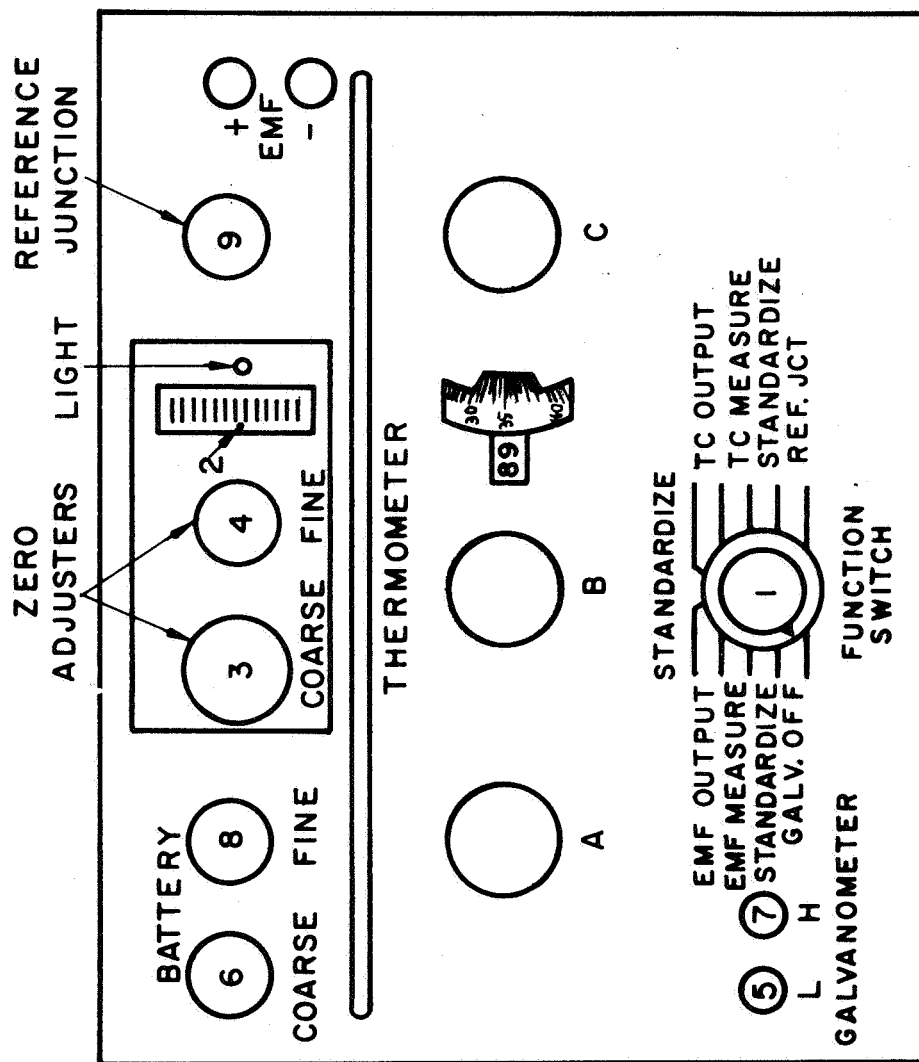   operations where the slice is doped and utilizes
                 uniform sheet resistance as the indicator for
                 gas flow.

2. Apparatus

   2.1   Four-point probe, 0.050-inch spacing.
         (any source)

   2.2   Power supply, constant current
         0.1, 1.0, 10 mA ranges
         (any source)

   2.3   Voltmeter, digital
         Fairchild 7100
         (or equivalent)

3. Materials

   3.1   Hydrofluoric acid, 40%, Reagent grade.

   3.2   Silicon slices, P and N type, lapped.

4. Procedure

   4.1   Preparation

         4.1.1   Process lapped slices, of opposite type from the
                 dopant concentration under evaluation, through the
                 predeposition and/or diffusion operation to be
                 measured.

                 NOTE: Samples should be placed uniformly about
                 the slice holder and may have numbers scribed
                 upon them for ease of identification. See Figure 1.

4.1.2   Allow the test wafers to cool to room temperature.

4.1.3   Etch the wafers until all doped oxide is removed, approximately ten seconds in concentrated hydrofluoric acid.

4.1.4   Rinse the wafers in deionized water and blow dry with a nitrogen gun.

4.2   <u>Measurement</u>

4.2.1   Place the test wafers upon the stage of the four-point probe. See Figure 2.

NOTE: If the furnace operation utilizes an upright wafer position, then either side may be measured. Test wafers processed through horizontal operations must be probed on the surface exposed to doping.

4.2.2   Lower the probe until it touches the sample lightly.

4.2.3   Record the voltmeter reading.

4.2.4   Reverse polarity and note that both values are approximately the same.

4.2.5   If readings differ significantly, increase probe pressure slightly until agreement is reached.

4.2.6   If the current source is 100 μA, 1 mA, 10 mA, etc., the voltmeter will read directly in sheet resistance with application of the proper decimal point. Example:

$$I = 100 \ \mu A$$

$$V = 50 \ \mu V$$

$$\frac{V}{I} = \frac{50}{100} = 0.5 \ \Omega/\square$$

4.2.7   Read $\frac{V}{I}$ in five locations on each slice as shown in Figure 3.

4.2.8   Row, column and vertical average may be used to give a dopant pattern throughout the slice holder.

5. Calibration

    5.1   Probe Spacing

        5.1.1   Cover a 1" x 3" glass microscope slide with aluminum foil.

        5.1.2   Obtain an impression of the four probe points.

        5.1.3   Measure spacing with any optical comparator.

        5.1.4   Adjust spacing per probe manufacturer's instruction.

6. Accuracy

Accuracy obtainable is approximately $\pm 10\%$.

7. Test Frequency

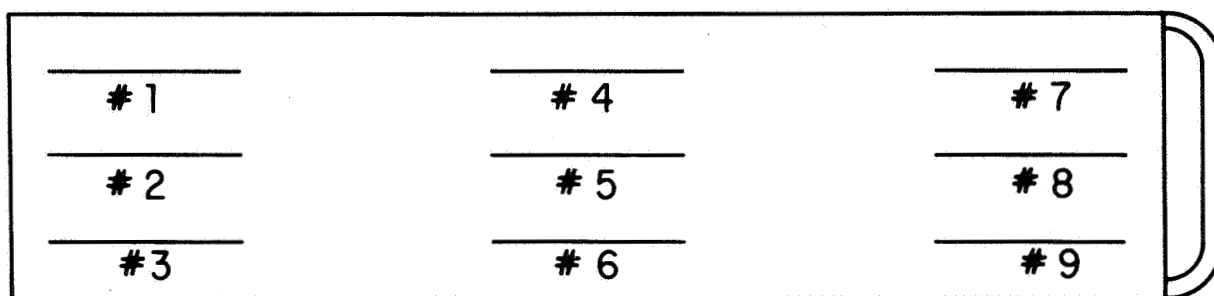This test should be performed periodically for each predeposition furnace.

Figure 1. Sample Position in Boat

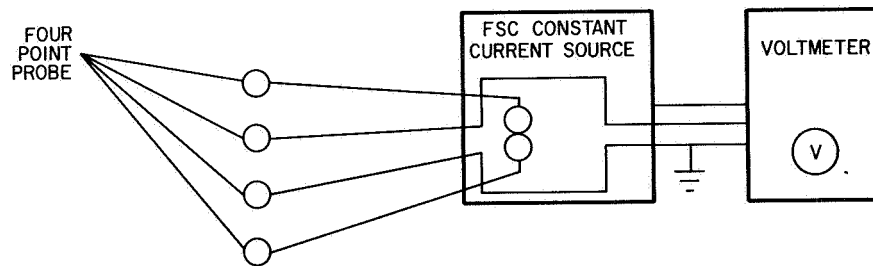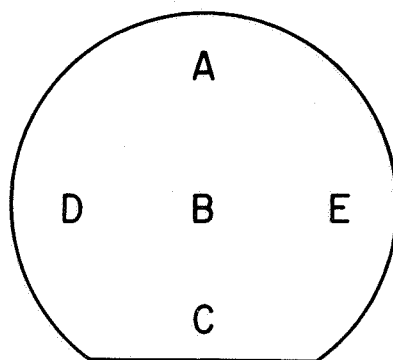FOUR POINT PROBE – SET-UP

Figure 2.

Figure 3. Sampling Pattern

Method 138

Diode Isolation
(Breakdown Voltage)

1.   Purpose   The purpose of this method is to determine that
the isolation technique will deliver an avalanche
voltage greater than maximum working voltage.

2.   Apparatus

2. 1   Two-point Prove, with micro-manipulator
(any source)

2. 2   Transistor Curve Tracer
Fairchild 6200
Tektronix 575
(or equivalent)

3.   Materials

Not applicable.

4.   Procedure

4. 1   Obtain integrated circuit wafer after base photomask
etching.

4. 2   Place the wafer upon the probe stage.   Figure 1.

4. 3   Select a circuit and probe the base cut-outs in any pair
of adjoining isolation "islands".

4. 4   Read the isolation breakdown voltage from the voltmeter.

4. 5   Reverse the polarity of the power supply and note any
change in voltage.

NOTE: This is particularly important where "buried
collectors" are present and masking misalignment during
isolation may cause premature breakdown.

1

4.6   Repeat 4.3 through 4.5 for the remaining isolation islands of the circuit selected in 4.3, being careful to test all adjacent "pairs".

5.   Calibration

Calibrate curve tracer per manufacturer's instructions.

6.   Accuracy

Accuracy obtainable will be ± one small grid division on the curve tracer.

7.   Test Frequency

Each fabrication run should be sampled after isolation diffusion.
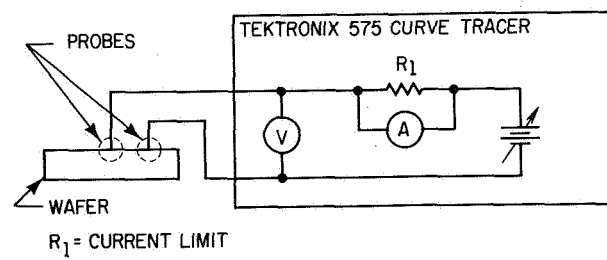
Figure 1. Diode Isolation (Breakdown Voltage)

Method 139

Dielectric Isolation
(Breakdown Voltage)

1. Purpose   The purpose of this method is to determine the
              voltage at which electrical breakdown of a speciman
              of electrical insulating material between two
              electrodes occurs under prescribed conditions
              of test.

2. Apparatus

    2.1 Ball Point Probes and Curve Tracer
         Tektronix 575
         (or equivalent)

    2.2 Transformers
         2KVA
         (any source)

    2.3 Circuit-Interrupting Device
         (any source)

    2.4 Motor Driven Autotransformer (AC)
         (any source)

    2.5 Insulated High Voltage Probes
         Anodicator Model 50
         R. O. Hull Co.
         (or equivalent)

3. Materials

    Not applicable.

1

4. **Procedure**

4. 1   Prepare wafer with metallized contact on back surface and metal pads on isolation islands for probing. Wafer may be probed with "ball probes" without metal pads. Figure 1.

4. 2   Definitions:

4. 2. 1   <u>Dielectric Breakdown Voltage</u>   The voltage at which electrical breakdown of a specimen of electrical insulating material between two electrodes occurs under prescribed conditions of test.

4. 2. 2   <u>Dielectric Strength</u>   The ratio of dielectric breakdown voltage to the thickness of an insulating material.

4. 2. 3   <u>Flashover</u>   An electric discharge around the edge or over the surface of electrical insulation.

4. 3   Method - Short Time Test - The voltage shall be increased from zero to breakdown at a uniform rate. The rate of rise shall be 100, 500, 1000 or 3000 V/sec, depending on the total test time required and the voltage-time characteristic of material. For the rate applicable to a given material, reference shall be made to the test method for that material.

4. 4   Slow-Rate-of-Rise Test - An initial voltage shall be applied, approximately equal to 50% of the breakdown voltage in the short-time test, or as specified in the material specification. The voltage shall then be increased at a uniform rate, as stated in the material specifications, up to the point of breakdown. The specified rate should be such as to give approximately the same voltage-time exposure of the test specimen as provided in the step-by-step test.

4. 5   Rate-of-Rise - The rate-of-rise of voltage shall not, for the short-time test, vary more than $\pm 20\%$ from the specified rate at any point. It may be calculated from measurements of time required to raise the voltage between two selected values. Voltage control shall be obtained as indicated in voltage control equipment.

4.6   Step-by Step Test - Unless otherwise specified, an initial voltage equal to 50% of the breakdown voltage $\pm 5\%$, as obtained on the short time test, shall be applied to the test specimen. The voltage shall then be increased in equal increments and held for periods of time specified in the various material specifications. The change from each step to the next higher shall be made as rapidly as possible and the time of change included in the succeeding test interval.

NOTE: The means used to obtain the various voltage steps shall not introduce voltage transiants that increase the peak value more than 10%.

5.   Calibration

Calibration of equipment as per manufacturer's specifications.

6.   Accuracy

As obtained from manufacturer's specifications on monitoring equipment.

7.   Test Frequency

Each fabrication run should be sampled after isolation process.

DIELETRIC ISOLATION (Breakdown Voltage)
(D.C. METHOD)

GOLD BALL PROBES

TEKTRONIX 575 CURVE TRACER

R_1

V

A

WAFER

R_1 = CURRENT LIMIT

(A.C. METHOD)

PROBES

ANODICATOR – MODEL 50

R_1

V_{AC}

A_{AC}

A.C. VOLTS

WAFER
METALIZED ON
BOTTOM SIDE
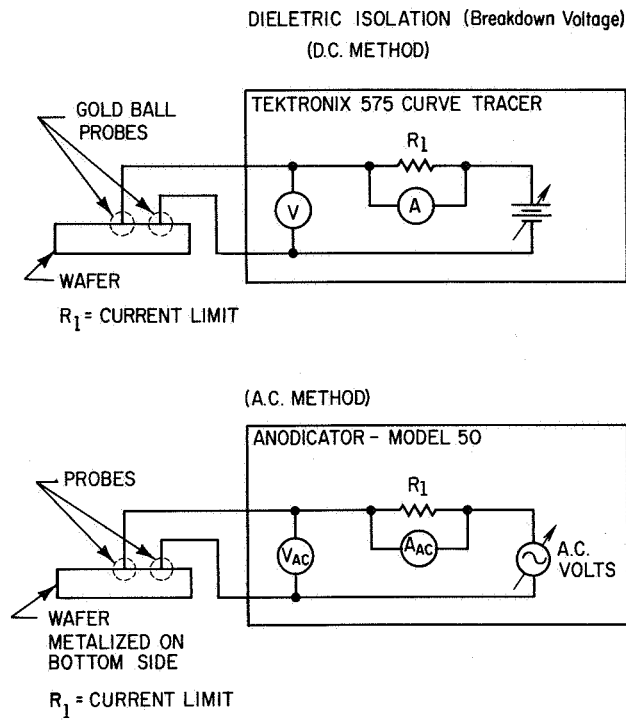
R_1 = CURRENT LIMIT

Figure.1.

Method 140

Isolation Leakage

1. Purpose   The purpose of this method is to determine a means of evaluating leakage current from one Isolation Island to another.

2. Apparatus

    2.1   Two-point probe, with micro-munipulator
           (any source)

    2.2   Leakage Tester
           Wiltron, Model 205
           (or equivalent)

    2.3   Picoammeter
           Keithly, Model 416A
           (or equivalent)

3. Materials

    Not applicable.

4. Procedure

    4.1   Obtain integrated circuit wafer after base photomask etching.

    4.2   Place the wafer upon the probe stage. Included in Figure 1.

    4.3   Select a circuit, and probe the base cut-outs in any pair of adjoining isolation "Islands".

    4.4   Read the isolation leakage current on the picoammeter.

    4.5   Reverse the polarity of the power supply and note any change in current.

         NOTE: This is particularly important where "buried collectors" are present. Masking misalignment during isolation may cause premature breakdowns, thus increase in current.

1

4.6 Repeat Steps 4.3 through 4.5 for the remaining isolation islands of the circuit selected in 4.3. Test isolations in adjacent "pairs".

5. <u>Calibration</u>

Calibrate equipment as per manufacturer's specifications.
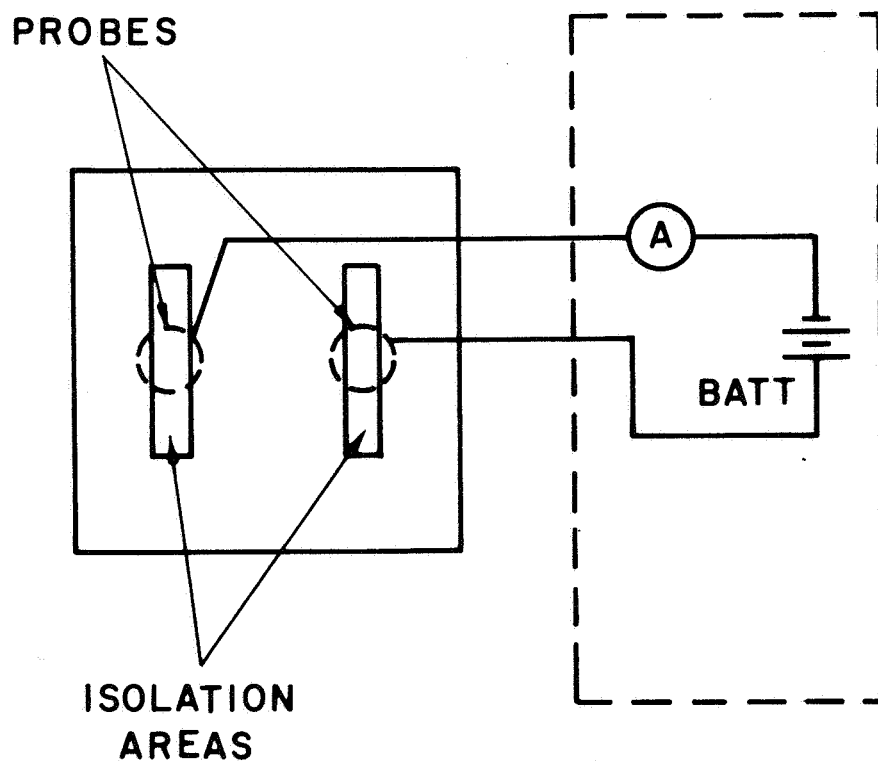
6. <u>Accuracy</u>

Accuracy will be manufacturer's specification on monitoring equipment.

7. <u>Test Frequency</u>

Each fabrication run should be sampled after isolation diffusion.

ISOLATION LEAKAGE

Figure 1. Isolation Leakage Setup

NOTES:

1. AMMETER KEITHLEY MODEL 416-A.

2. V_{CC} SOURCE; ANY GOOD COMMERCIAL BATTERY.

3. COMPLETE SYSTEM SHOULD BE SHIELDED.

3

Method 141

Thickness of Metallization
(Tolansky Interferometer)

1. <u>Purpose</u>   This test procedure is applicable to the measure-
ment of any thin film. It utilizes the interference
of monochromatic light introduced into the optical
system through a 95% mirror and reflected between
that and the metallized specimen. The two mirrors
are inclined to one another, causing the interference
fringes to be normal to the edge of the measured
layer. The horizontal displacement of any fringe
enables one to calculate the layer thickness by
the following relationship:

$$\frac{x_o}{D} = \frac{\frac{\lambda}{2}}{w}$$

Where x_o = Film thickness

λ = Wavelength of incident light

w = Distance between fringes

D = Distance any fringe is displaced.
See Figures 1 and 2.

2. <u>Apparatus</u>

2.1 Metallurgical microscope
Metalstar trinocular body AO No. 2200T-4
American Optical Co.
(or equivalent)

2.2 Polaroid camera AO No. 1052A
American Optical Co.
(or equivalent)

1

2.3   Interferometer jig
Fairchild design
See Figure 3.

2.4   Monochromatic light source

    2.4.1   Mercury, 5461Å
LaPine Scientific Co. Model 216-01
(or equivalent)

    2.4.2   Sodium, 5893Å (optional)
LaPine Scientific Co. Model 215-96
(or equivalent)

2.5   Hot plate, 6" x 6", electric
Temco, type 1900
Corning, Pyroceram PC-35
(or equivalent)

2.6   Polyethylene beaker
(any source)

3.   **Materials**

3.1   Hydrofluoric acid, 49%, reagent grade

3.2   Acetic acid, glacial, reagent grade

3.3   Trichloroethylene, electronic grade

3.4   Acetone, electronic grade

3.5   Apiezon wax

3.6   Slides, glass microscope, 1" x 3"

4.   **Procedure**

4.1   Preparation

    4.1.1   Process a polished test chip through the metallization operation to be evaluated.

    NOTE: Form a step in the film either by etching or "shadowing" with a glass slide during evaporation.

2

4.1.2 Evaporate a 1000Å silver or aluminum film over the film to be examined.

NOTE: While silver has a higher index of reflectivity, it must not be allowed to tarnish prior to measurement.

4.2 Measurement

4.2.1 Place the specimen on the platform, mirrored side up.

4.2.2 Rotate the specimen on the platform until the step to be measured is normal to the front edge of the Fizeau plate.

4.2.3 Raise the platform until the specimen is in contact with the Fizeau plate by turning the knurled brass elevation nut. This will give maximum fringe spacing.

4.2.4 If a smaller fringe spacing is desired, the platform may be raised slightly, reducing the wedge angle, θ, and, as a result, fringe spacing.

4.2.5 Make a photomicrograph.

4.2.6 Measure distance between fringes on the photo-micrograph, with a precision rule. (w)

4.2.7 Measure distance which any fringe is displaced as it passes across the film step. (D)

4.2.8 Calculate film thickness, x_o, using the relationship

$$\frac{x_o}{D} = \frac{\frac{\lambda}{2}}{w}$$

5. <u>Calibration</u>

Not applicable.

6. <u>Accuracy</u>

Accuracy obtainable increases with increasing film thickness.

6.1   For films greater than 0.2 microns, ±10%.

6.2   For films less than 0.2 microns, ±20%.

7. <u>Test Frequency</u>
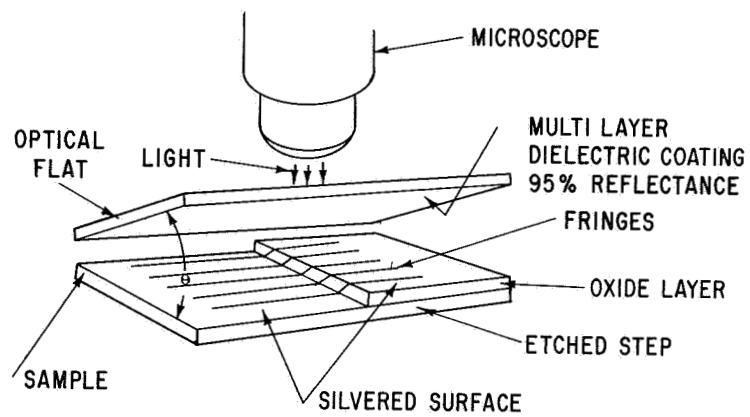
This test should be performed on a periodic basis.

Figure 1.   Tolansky Interferometer Setup
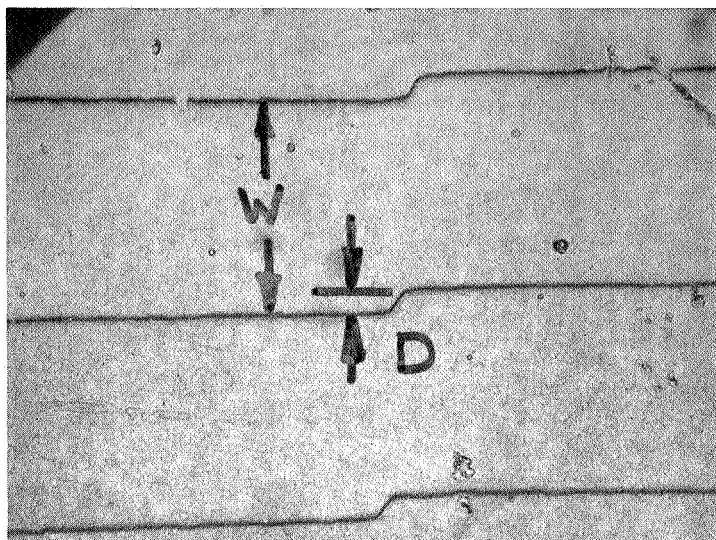
Figure 2. Film Measurement

Sodium, $\lambda = 5890\,\overset{\circ}{A}$

W = 1.12 inches

D = 0.14 inches

$$X_o = D \; \frac{\frac{\lambda}{2}}{W}$$

$$= 0.14 \; \frac{\frac{5890}{2}}{1.12}$$

$$= \frac{1.4 \times 2.945 \times 10^2}{1.12}$$

$$= 3.4 \times 10^2$$

$$= 340\,\overset{\circ}{A}$$

NOTE: A fixed error of 30 - 50 $\overset{\circ}{A}$ becomes significant at this thickness range.

FIZEAU PLATE

SUBSTRATE WITH SILVERED
THIN-FILM STEP

SUBSTRATE PLATFORM

NYLON SCREW IN VEE-SLOT

BRASS BASE

SIDE VIEW

PLATFORM PIVOT (FRONT
AND REAR)

REAR SPRINGS

BRASS KNURLED NUT
$\frac{3}{4} \times 20$ TPI
ON THREADED SHAFT

FRONT VIEW

FIZEAU PLATE HOLDER

HOLE FOR TILT-ADJUSTMENT

TILT ADJUST
SCREW
(REAR PIVOT)

PIVOT
PIN

TOP VIEW

DETAIL OF PIVOT
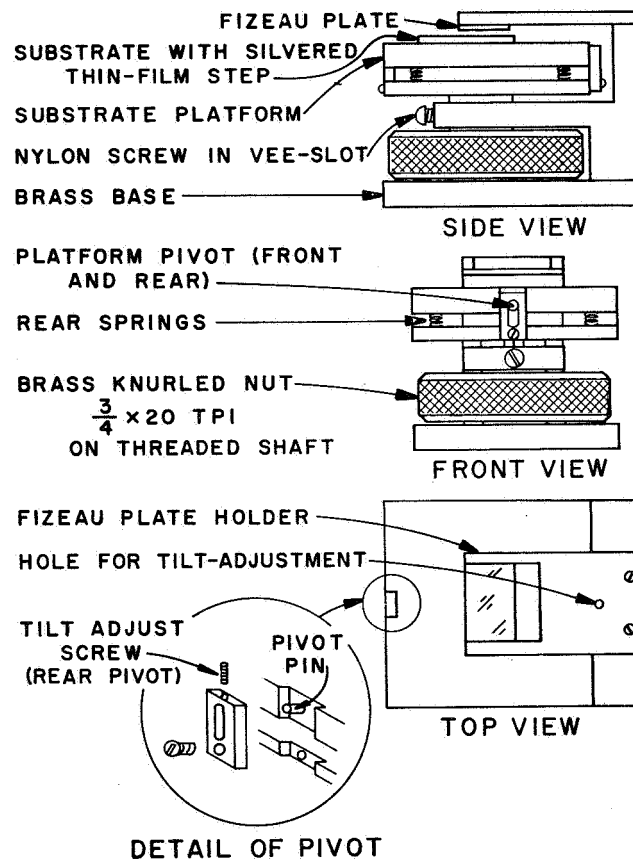
Figure 3. Interferometer Jig

7

Method 142

Thickness of Metallization
(Sheet Resistance)

1. Purpose   This procedure may be used for the indirect
                   determination of a single metal evaporated film.
                   It utilizes the measurement of a sheet resistance
                   from which the film thickness is calculated using
                   the following equation:

$$w = \rho \; \frac{\ln 2}{\pi \frac{V}{I}} \quad \text{(For } w \to \text{Zero)}$$

Where: w = Film thickness in cm.

          ρ = Bulk resistivity of metal in Ω cm.

          $\dfrac{V}{I}$ = Sheet resistance.

2. Apparatus

    2.1 Four-point probe, 0.050-inch spacing.
         (any source)

    2.2 Power supply, constant current,
         0.1, 1.0, 10mA ranges.
         (any source)

    2.3 Voltmeter, Digital
         Fairchild 7100
         (or equivalent)

3. <u>Materials</u>

   3.1   Glass slides, 1" x 3"

4. <u>Procedure</u>

   4.1   Coat glass slides according to the process under evaluation.

   4.2   Place the slide to be measured upon the probe stage. See Figure 1.

   4.3   Lower the probe until it touches the sample lightly.

   4.4   Record the voltmeter reading.

   4.5   If the current source is 100μA, 1mA, 10mA, etc., the voltmeter will read directly in sheet resistance with application of the proper decimal point.

   4.6   Using the formula from Para. 1, calculate the film thickness.

Example:
$$\frac{V}{I} = 0.006\Omega$$

Film - Aluminum

$$\rho = 2.72 \times 10^{-6}\ \Omega\text{-cm}, 25°, \text{Aluminum}$$

$$w = \rho\ \frac{\ln 2}{\pi\frac{V}{I}}$$

$$= \frac{2.72 \times 10^{-6} \times .693}{\pi \times .006}$$

$$= \frac{2.72 \times 10^{-6} \times 6.93 \times 10^{-1}}{\pi \times 6 \times 10^{-3}}$$

$$= \frac{2.72 \times 6.93 \times 10^{-4}}{\pi \times 6}$$

$$= 1 \times 10^{-4}\text{cm}$$

$$= 1\ \text{micron}$$

$$w = 10^4\ \overset{\circ}{A}$$

2

5.   <u>Calibration</u>

    5.1   Probe spacing

        5.1.1   Cover a 1" x 3" glass microscope slide with aluminum foil.

        5.1.2   Obtain an impression of the four probe points.

        5.1.3   Measure spacing with any optical comparator.

        5.1.4   Adjust spacing per probe manufacturer's instructions.

6.   <u>Accuracy</u>

Accuracy obtainable is approximately $\pm 10\%$.

7.   <u>Test Frequency</u>

This test should be performed on a sample slide from every evaporation.
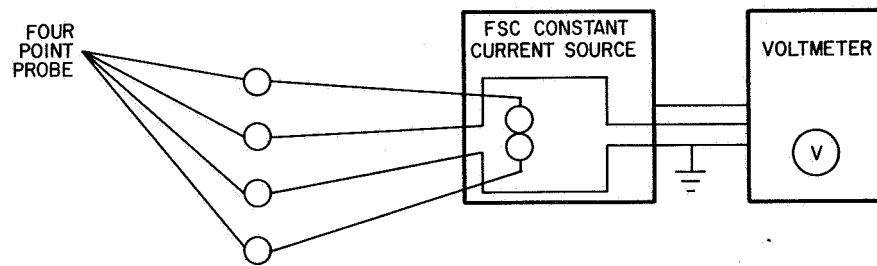
FOUR POINT PROBE – SET-UP

Figure 1.

4

Method   143

Metallization Adhesion

(Pressure-Sensitive Tape)

1.   Purpose   This method may be used to evaluate adhesion of the metallization film to the substrate.   It utilizes a pressure-sensitive tape to remove metal with poor adhesion followed by a microscopic examination.

2.   Apparatus

    2.1   Metallurgical microscope
        Bausch and Lomb dynoptic No. 31-20-68-38
        (or equivalent)

    2.2   Hot plate, 6" x 6", electric
        Corning, Pyroceram PC-35
        (or equivalent)

3.   Materials

    3.1   Apiezon wax

    3.2   Slides, glass microscope, 1" x 3"

    3.3   Pressure-sensitive tape, Scotch, 3/4", No. 810

4.   Procedure

    4.1   Preparation

        4.1.1   Process a polished, passivated substrate or a clean glass slide through the metallization operation to be evaluated.

        Note: For a slide, omit 4.1.2 through 4.1.5

        4.1.2   Place a glass slide on a hot plate set a temperature slightly higher than the melting point of apiezon wax (150-160°C).

        4.1.3   Add a small quantity of wax to the slide.

1

4.1.4   Place the sample upon the slide, metallization up, and seat it in the wax.

4.1.5   Remove the slide from the hot plate and allow it to cool.

4.1.6   Apply one end of a four (4) inch length of pressure-sensitive tape to the metallized surface. Insure contact across the maximum sample dimension with no voids or bubbles.

4.1.7   Hold the slide firmly against a solid surface and grasp the free end of the tape.

4.1.8   Apply a force normal to the substrate surface and smoothly strip the tape from the metallization.

4.1.9   The tape may be applied to a clean slide for preservation.

4.2   Inspection

4.2.1   Place the sample on the stage of a metallurgical microscope.

4.2.2   At 100x, scan the metallized surface for any voids or missing metal.

5.   Calibration

Not applicable.

6.   Accuracy

This method should detect areas where metal is removed which are approximately 0.0005 square inches.

7.   Test Frequency

7.1   Evaluation of glass slides should be done for each evaporation.

7.2   Substrate testing should be on a periodic basis.

Method 144

Stability of Metallization

1. Purpose   This method may be used to evaluate the stability
              of circuit metallization. It utilizes a high
              temperature storage test to detect formation of
              intermetallic compounds and a high temperature
              D-C bias test to observe "Electro-Migration".
              The test device is manufactured as process
              control devices are fabricated on a standard
              integrated circuit wafer.

2. Apparatus

    2.1 High Temperature Storage Oven
         300°C   air ambient
         (any source)

    2.2 High Temperature D-C Bias Chamber
         200°C, I_F = 100mA per device
         (any source)

    2.3 Curve Tracer
         Fairchild 6200
         (or equivalent)

3. Materials

    None

4. __Procedure__

    4.1   Test Device Manufacture

        4.1.1   Fabricate one or more test devices on each standard production wafer. See Figure 1.

        4.1.2   After dicing, separate test devices from production.

        4.1.3   Process through standard device assembly.

        4.1.4   Electrically screen test devices for continuity.

    4.2   Intermetallic Formation (Gold-Aluminum)

        4.2.1   Store this group of test devices at 300°C for approximately 200 hours.

        4.2.2   Cool to room temperature.

        4.2.3   Monitor conductance at 10 - 20mA. Full scale. Any slope greater than 20Ω will indicate intermetallic formation.

    4.3   Electro-Migration

        4.3.1   Place devices in chamber at 200°C under D-C bias which forces a current density of about 10^6 amperes/cm^2 through each sample.

        4.3.2   Store for approximately 200 hours.

        4.3.3   Test for continuity at 10mA. Opens will be failures.

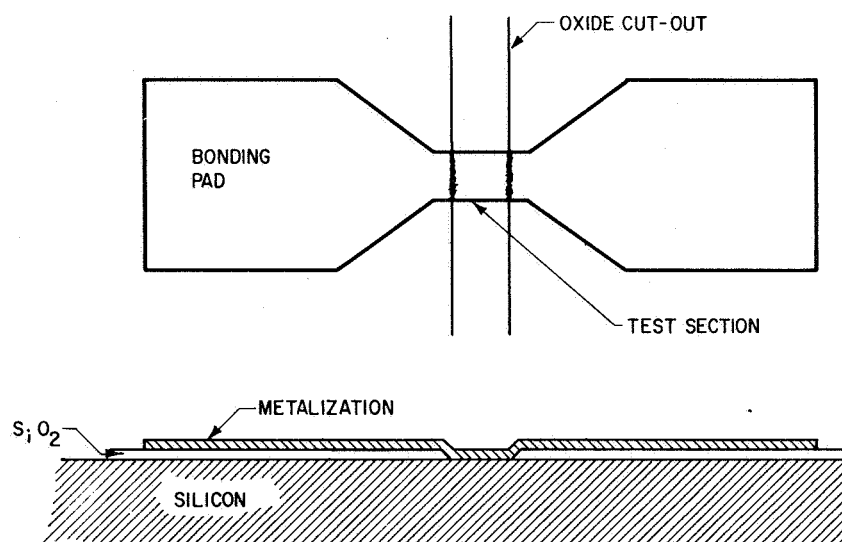5. __Accuracy__

Not applicable. Current density for 4.3 should be set to deliver 10 - 20% open circuits.

6   __Calibration__

Not applicable.

7.   <u>Test Frequency</u>

This test should be performed periodically.

For Current Density ~ 10^6 Amperes/cm^2
Metol Thickness = 10,000 Å
Test Section Width = 0.0004 inch
Current (D.C.) = 100mA

Figure 1.   Metallization Test Device

Method 145

Specific Resistivity of Metallization

1. <u>Purpose</u> This method may be used to indirectly measure the specific resistivity of a given evaporated metal film. It utilizes the comparison of measured and calculated thicknesses of the film.

$$\rho_s = \frac{w}{x_o} \qquad \rho \leq 1$$

Where ρ_s = Specific resistivity

x_o = Absolute thickness, by Tolansky interferometer

w = Calculated thickness, by sheet resistivity

2. <u>Apparatus</u>

2.1 Metallurgical microscope
Metalstar trinocular body, AO No. 2200T-4
American Optical Co.
(or equivalent)

2.2 Polaroid camera, AO No. 1052A
American Optical Co.
(or equivalent)

2.3 Interferometer jig
Fairchild design

2.4　Monochromatic light source

　　2.4.1　Mercury, 5461 Å
　　　　　LaPine Scientific Co. Model 216-01
　　　　　(or equivalent)

　　2.4.2　Sodium, 5893 Å (optional)
　　　　　LaPine Scientific Co. Model 215-96
　　　　　(or equivalent)

2.5　Four-point probe, 0.050 inch spacing
　　　(any source)

2.6　Power supply, constant current
　　　0.1, 1.0, 10 mA ranges
　　　(any source)

2.7　Voltmeter, Digital
　　　Fairchild 7100
　　　(or equivalent)

2.8　Hot plate, 6" x 6", electric
　　　Temco, Type 1900
　　　Corning, Pyroceram PC-35
　　　(or equivalent)

2.9　Polyethylene beaker
　　　(any source)

3.　Materials

　3.1　Hydrofluoric acid, 49% Reagent grade

　3.2　Acetic acid, glacial, Reagent grade

　3.3　Trichloroethylene, Electronic grade

　3.4　Acetone, Electronic grade

　3.5　Apiezon **wax**

　3.6　Slides, glass microscope, 1" x 3"

4. <u>Procedure</u>

    4.1   Preparation $(\frac{V}{I})$

        4.1.1   Process a polished test chip through the metallization operation to be evaluated.

                NOTE.   Form a step in the film either by etching or "shadowing" with a glass slide during evaporation.

    4.2   Measurement $(\frac{V}{I})$

        4.2.1   Place the chip to be measured upon the probe stage.   See Figure 1.

        4.2.2   Lower the probe until it touches the sample lightly.

        4.2.3   Record the voltmeter reading.

        4.2.4   If the current source is $100\mu A$, $1mA$, $10mA$, etc., the voltmeter will read directly in sheet resistance with application of the proper decimal point.

        4.2.5   Using the formula below, calculate the film thickness.   Example: $\frac{V}{I} = 0.006\Omega$

              Film - aluminum

$$\rho = 2.72 \times 10^{-6} \Omega - cm, \ 25°C$$

$$w = \frac{\rho \ln 2}{\pi \frac{V}{I}}$$

$$= \frac{2.72 \times 10^{-6} \times .693}{\pi \times .006}$$

$$= \frac{2.72 \times 10^{-6} \times 6.93 \times 10^{-1}}{\pi \times 6 \times 10^{-3}}$$

$$= \frac{2.72 \times 6.93 \times 10^{-4}}{\pi \times 6}$$

$$= 1 \times 10^{-4} \, cm$$

$$= 1 \ micron$$

$$w = 10^{4} \, \mathring{A}$$

3

4.3   Preparation (Tolansky interferometer)

  4.3.1   Evaporate a 1000Å silver or aluminum film over the sample.

    NOTE: While silver has a higher index of reflectivity, it must not be allowed to tarnish prior to measurement.

4.4   Measurement (Tolansky interferometer)

  4.4.1   Place the specimen on the platform, mirrored side up.   See Figure 2.

  4.4.2   Rotate the specimen on the platform until the step to be measured is normal to the front edge of the Fizeau plate.

  4.4.3   Raise the platform until the specimen is in contact with the Fizeau plate by turning the knurled brass elevation nut.   This will give maximum fringe spacing.

  4.4.4   If a smaller fringe spacing is desired, the platform may be raised slightly, reducing the wedge angle, θ, and, as a result, fringe spacing.   See Figure 3.

  4.4.5   Make a photomicrograph.

  4.4.6   Measure distance between fringes on the photomicrograph with a precision rule (W).   Figure 4.

  4.4.7   Measure the distance which any fringe is displaced as it passes across the film step. (D)

  4.4.8   Calculate film thickness, x_o, using the relationship:

$$\frac{x_o}{D} = \frac{\frac{\lambda}{2}}{w}$$

Example: Mercury light, $= 5460\,\overset{\circ}{A}$

$W = 0.350$ inch

$D = 1.50$ inch

$$x_o = \frac{2730}{0.350} \times 1.50$$

$$x_o = 11700\,\overset{\circ}{A}$$

4.5   Resistivity calculation

    4.5.1   Using the electrically and visually determined thickness, specific resistivity may be calculated as:

$$\rho_s = \frac{w}{x_o}$$

Example: $w = 10,000\,\overset{\circ}{A}$

$x_o = 11,700\,\overset{\circ}{A}$

$$\rho_s = \frac{10,000}{11,700}$$

$$\rho_s = 0.85$$

5.   <u>Calibration</u>

    5.1   Probe spacing

        5.1.1   Cover a 1" x 3" glass microscope slide with aluminum foil.

        5.1.2   Obtain an impression of the four probe points.

        5.1.3   Measure spacing with any optical comparator.

        5.1.4   Adjust spacing per probe manufacturer's instructions.

6. <u>Accuracy</u>

Accuracy obtainable is approximately ± 20%.

7. <u>Test Frequency</u>
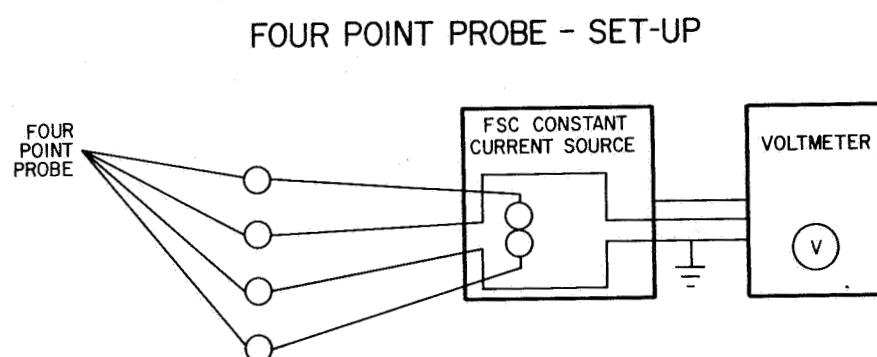
This test should be performed on a periodic basis.
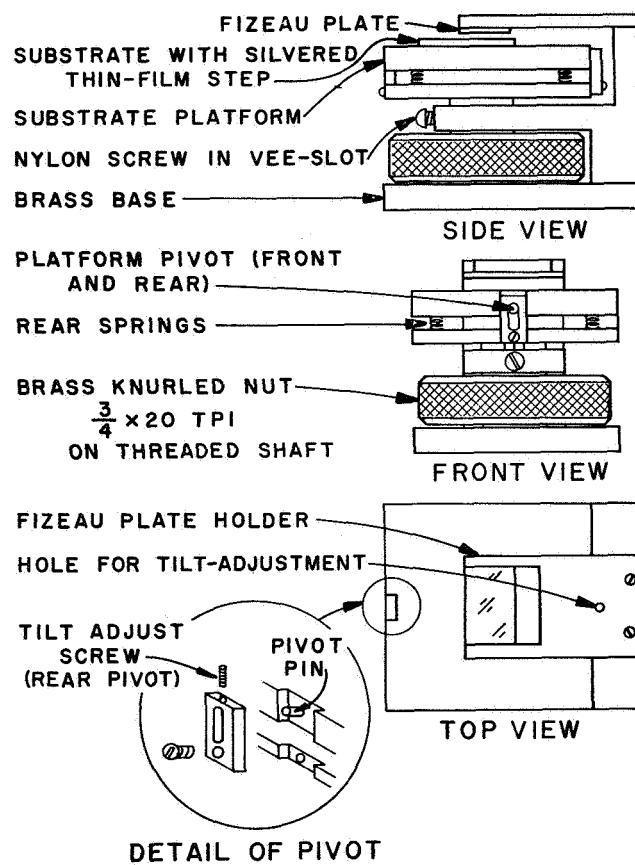
FOUR POINT PROBE - SET-UP

Figure 1.
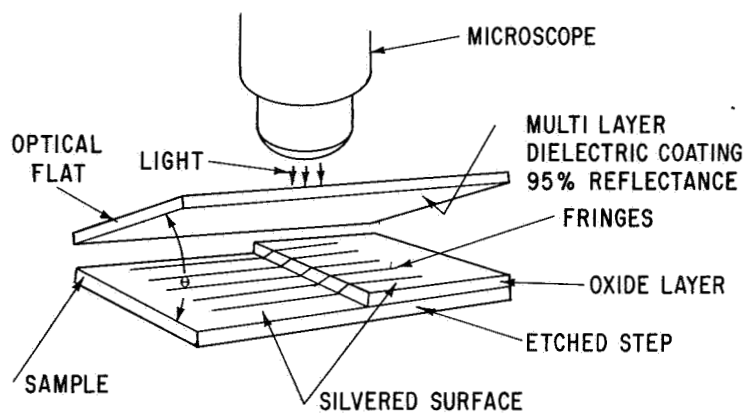
FIZEAU PLATE

SUBSTRATE WITH SILVERED
THIN-FILM STEP

SUBSTRATE PLATFORM

NYLON SCREW IN VEE-SLOT

BRASS BASE

SIDE VIEW

PLATFORM PIVOT (FRONT
AND REAR)

REAR SPRINGS

BRASS KNURLED NUT
$\frac{3}{4} \times 20$ TPI
ON THREADED SHAFT

FRONT VIEW

FIZEAU PLATE HOLDER

HOLE FOR TILT-ADJUSTMENT

TILT ADJUST
SCREW
(REAR PIVOT)

PIVOT
PIN

TOP VIEW

DETAIL OF PIVOT

Figure 2.   Interferometer Jig

8

Figure 3. Tolansky Interferometer Setup
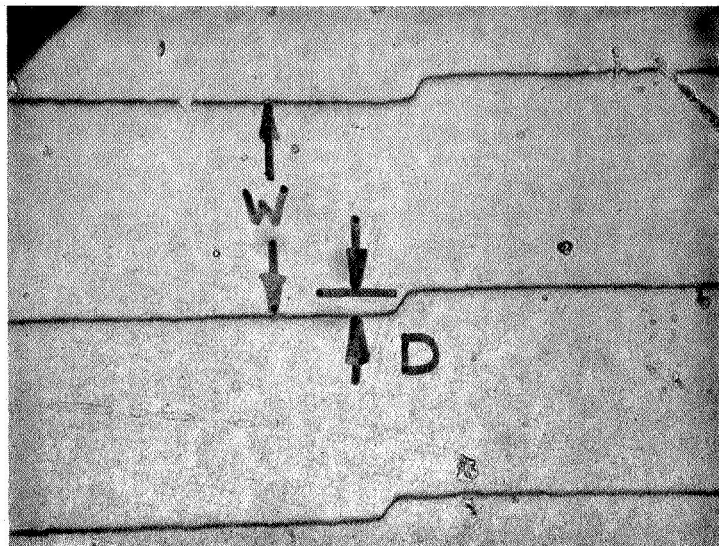
Figure 4. Film Measurement

Sodium, $\lambda = 5890\,\text{Å}$

$W = 1.12$ inches

$D = 0.14$ inches

$$X_o = D\ \frac{\frac{\lambda}{2}}{W}$$

$$= 0.14\ \frac{\frac{5890}{2}}{1.12}$$

$$= \frac{1.4 \times 2.945 \times 10^2}{1.12}$$

$$= 3.4 \times 10^2$$

$$= 340\,\text{Å}$$

NOTE: A fixed error of 30 - 50 Å becomes significant at this thickness range.

10

Method 146

Quality of Ohmic Contact

1. Purpose   The purpose of this test is to determine that an ohmic contact exists between aluminum inter-connections and the diffused structure. It employs evaluation of a series of diffused resistors.

2. Apparatus

    2.1 Transistor Curve Tracer
         Fairchild 6200
         Tektronix 575
         (or equivalent)

    2.2 Two-point Probe with micro-manipulator
         (any source)

3. Materials

    3.1 Silicon wafer with diffused and metallized test pattern.
         Figure 1.

4. Procedure

    4.1 Obtain wafer with test pattern after metallization alloy.

    4.2 Place wafer upon the probe stage. Figure 2.

    4.3 Probe one pad with the emitter probe and one with the collector probe.

    4.4 The oscilloscope trace should be a straight line through the origin with a finite slope. Figure 3.

    4.5 A vertical line (short) indicates excessive alloying and a horizontal line indicates either a rectifying contact or an open.

1

5. Calibration

    5.1 Calibrate the curve tracer per manufacturer's instructions.

    5.2 A typical trace should be obtained by placing a 1-10 K Ω resistor across the probes.

6. Accuracy

    Adjustment of current and voltage scales to deliver a 45° slope will provide maximum accuracy.

7. Test Frequency

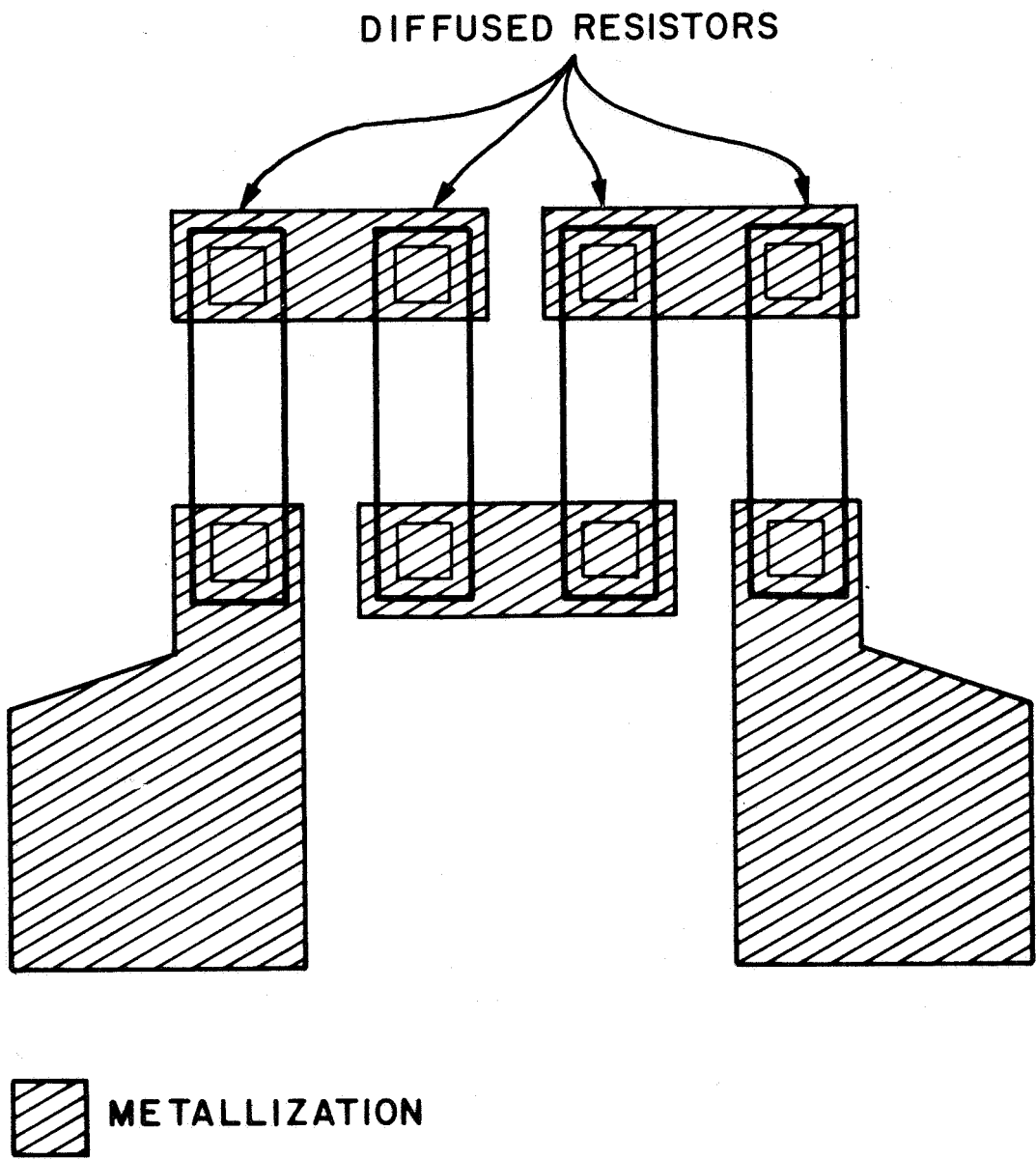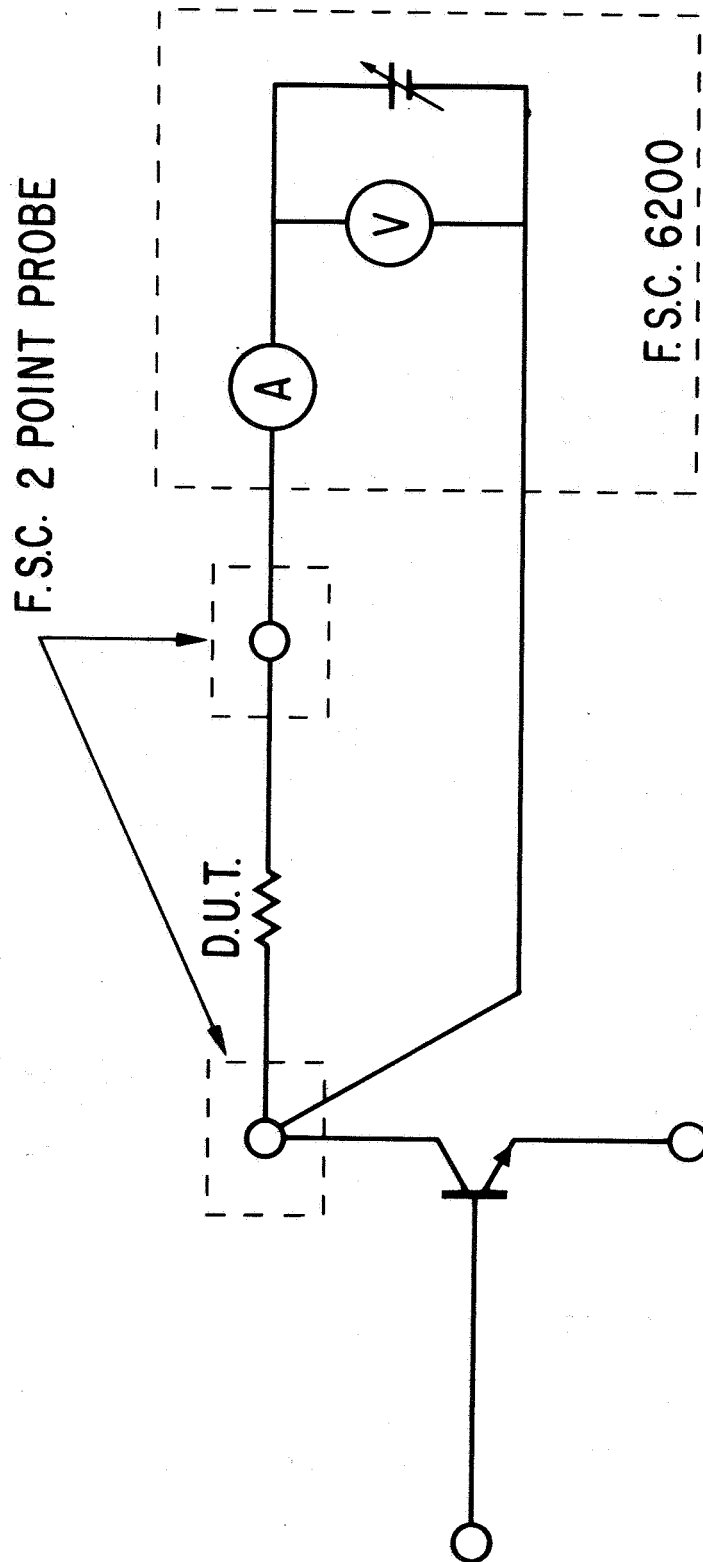   Each wafer should be sampled at final wafer test.

DIFFUSED RESISTORS

METALLIZATION

Figure 1.   Test Pattern

3

Figure 2. Resistor Check

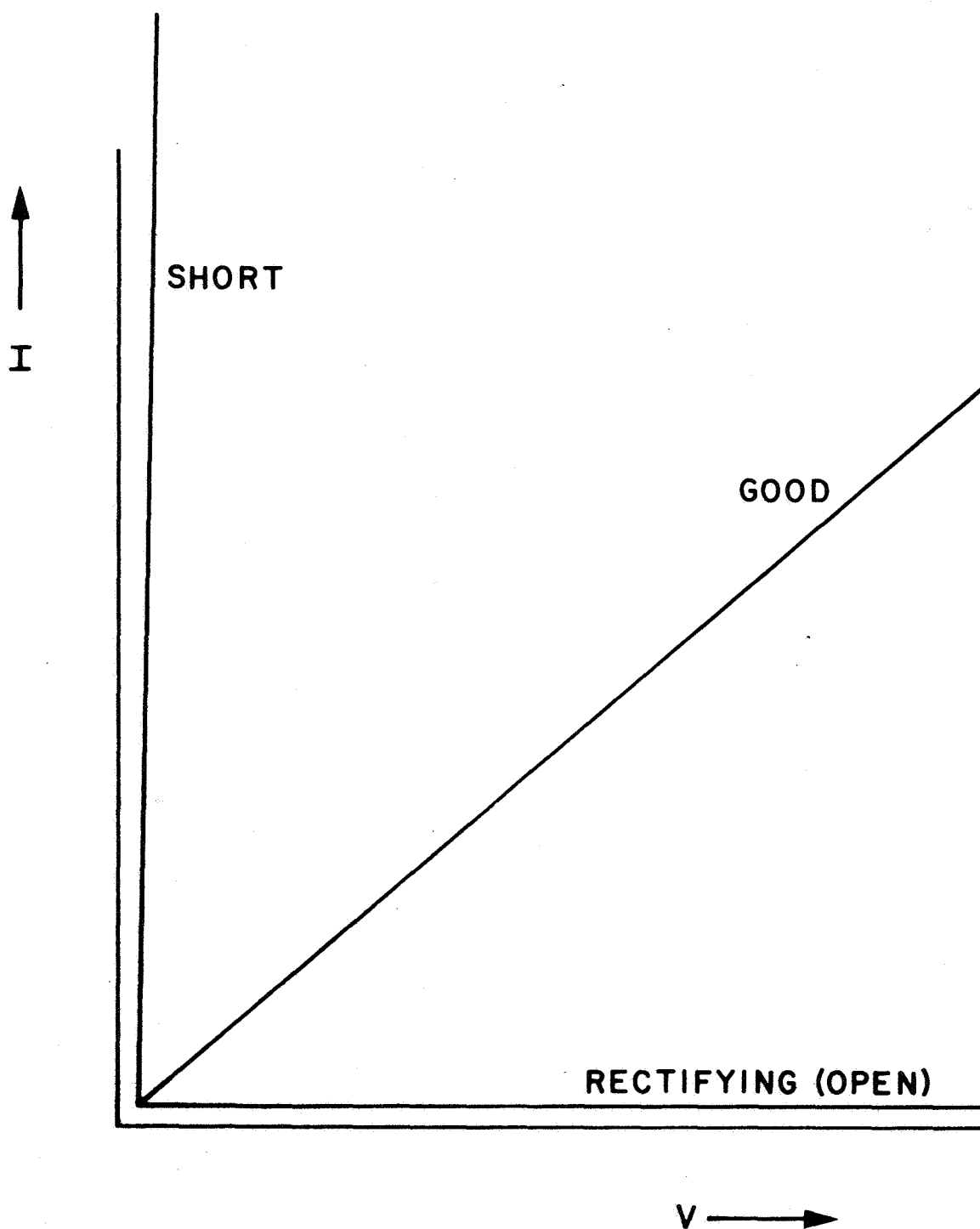F.S.C. 2 POINT PROBE

F.S.C. 6200

D.U.T.

4

Figure 3. Oscilloscope Trace

Method 147

Cross Sectional Uniformity
of Metallization

1.   Purpose   The purpose of this test method is to evaluate the
uniformity of cross section of the metallized
interconnections and bonding pads.

2.   Apparatus

2.1   Metallurgical Microscope
Bausch and Lomb 31-20-68-38 (DMETR)
(or equivalent)

3.   Materials

3.1   Glass microscope slides, 1" x 3".

4.   Procedure

4.1   Place the alloyed, metallized wafer upon a clean glass
slide on the microscope stage.

4.2   Adjust the magnification to 150x and scan the wafer for
the following defects:

4.2.1   Geometry - Adherence to design dimensions and
shape.

4.2.2   Scratches - Scratches which reduce the designed
cross-sectional area.

NOTE: A scratch with oxide, substrate, etc.,
showing through will usually be deeper and more
severe than one with metal covering the bottom
of the damaged area. Figure 1.

4.2.3   Alignment - Registration of metallized inter-
connections with the passivating layer cut-outs.
Figure 2.

1

4. 2. 4   Undercutting - Failure of the metallization-photoresist interface resulting in the width at the interconnection top being significantly narrower than the width in contact with the passivated substrate.   Figure 3.

4. 2. 5   Voids - Holes in the metallization film which significantly reduce the cross-sectional area either by their individual size or density.

4. 2. 6   Cut-Out Continuity - Cracking, narrowing or discernible thinning of interconnections at the passivating layer cut-out.   Figure 4.

5.   Calibration.

Not applicable.

6.   Accuracy

6. 1   Scratches and cracks greater than 1 micron.

6. 2   Voids greater than 2 microns.

6. 3   Geometry alignment and undercutting within designed tolerance.

7.   Test Frequency

Every wafer should be sampled prior to the dicing operation and all circuits should be inspected.
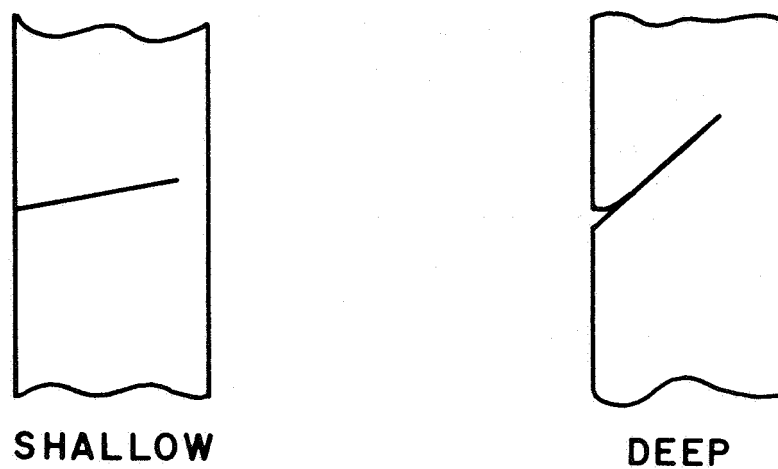
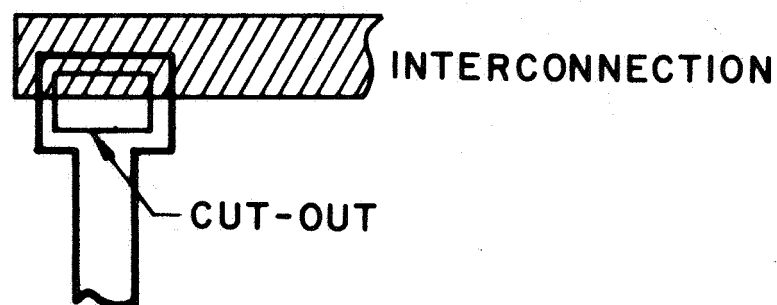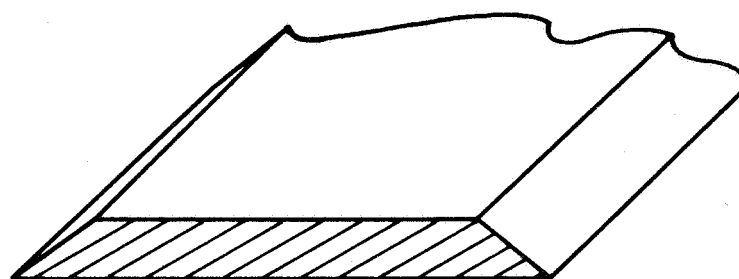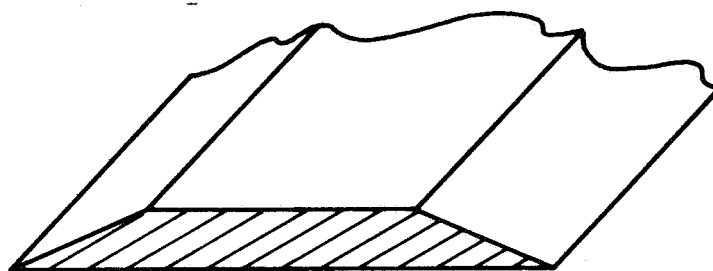Figure 1.   Interconnection Scratches

Figure 2.   Alignment

NORMAL

UNDERCUT

Figure 3. Interconnection Undercutting
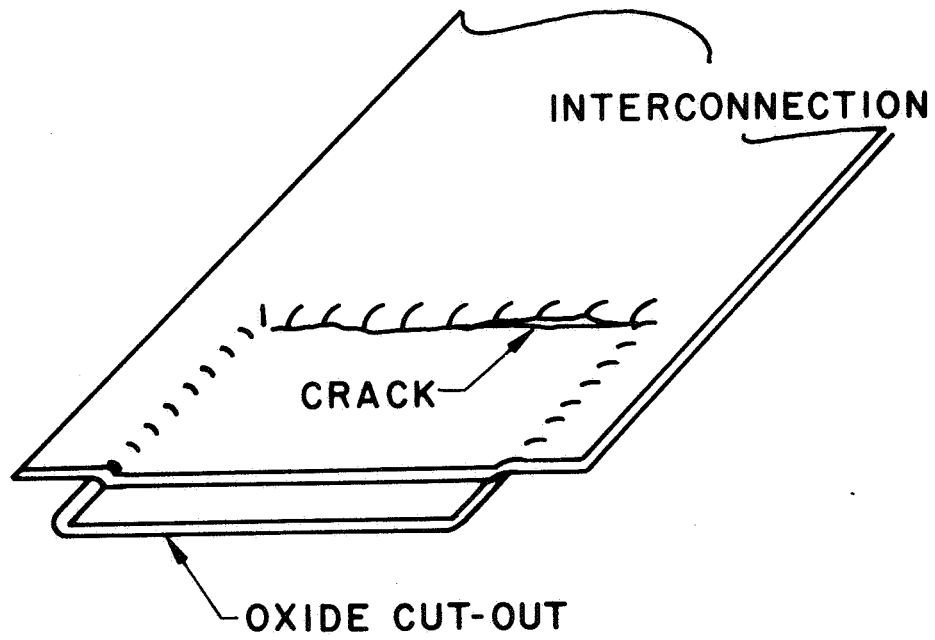
4

Figure 4. Cut Out Continuity

Method 148

Pull Strength of Interconnection Bonds

1.   Purpose   This method may be used to evaluate wire-wire
                    bond system.   It treats the die bond, package
                    bond and connecting wire as one component.

2.   Apparatus

     2.1 Pull Test Fixture. See Figures 1 and 2.
          (or equivalent)

     2.2 Gram Gauge
          ARPO Gram Gauge (0-25 grams), Scherr-Tunico Distributor
          (or equivalent)

     2.3 Binocular Microscope, 45X
          (any source)

3.   Materials

     None.

4.   Procedure

     4.1 Adjust heater block to desired temperature (25° - 125°C)
          and allow to stabilize.

          NOTE: Production monitoring will normally be at room
          temperature.

     4.2 Place adapter on heater block for package to be tested
          (Flat Pak, TO-5, etc) .

4.3   Focus microscope on lead system.

4.4   Insure recorder hand of gram gauge is at zero.

4.5   Using the micromanipulator, position the small wire hook under the arch of the bond system to be tested.

4.6   Raise the gram gauge slowly until the bond system fails. This will be caused by one of the following:

    4.6.1   <u>Wire</u> - Wire parts due to excessive tension.

    4.6.2   <u>Light Bond</u> - Bond is lifted, intact, from bonding area.

    4.6.3   <u>Broken Bond</u> - Bond fails, leaving residue of wire on bonding area.

4.7   Repeat Paragraph 4.4 to 4.6 for all bonds to be evaluated.

4.8   Note reading and failure mode.

5.   <u>Calibration</u>

5.1   Monitor elevated temperature with a chromel-alumel thermocouple attached to the proper package, in a method similar to die-attach temperature measurement.

5.2   Check the gram gauge by hanging a 5 or 10 gram laboratory weight from the lever arm ("paddle") and noting correlation.

6.   <u>Accuracy</u>

Accuracy obtained will be $\pm$ one small division of the gram gauge.

7.   <u>Test Frequency</u>

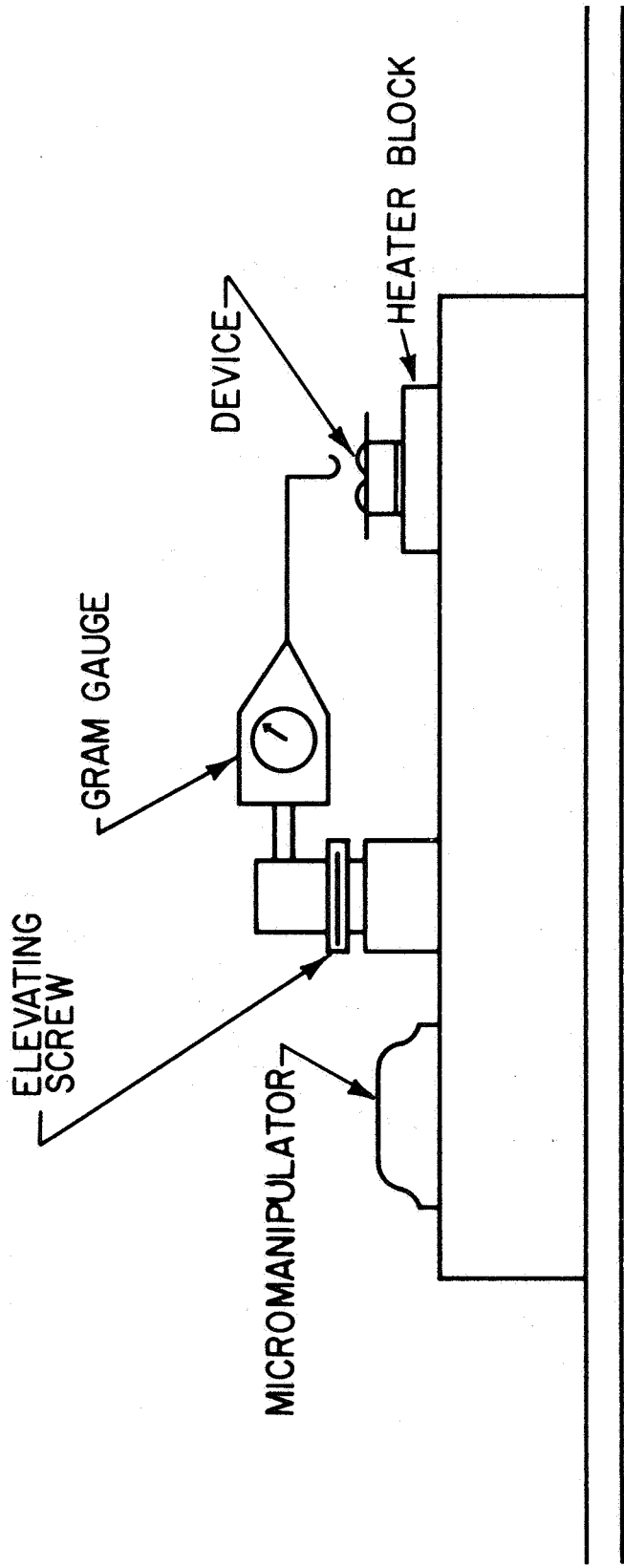All bonding stations should be monitored periodically.

Figure 1. Test Fixture

3

GRAM GAUGE PADDLE

CONNECTING WIRE

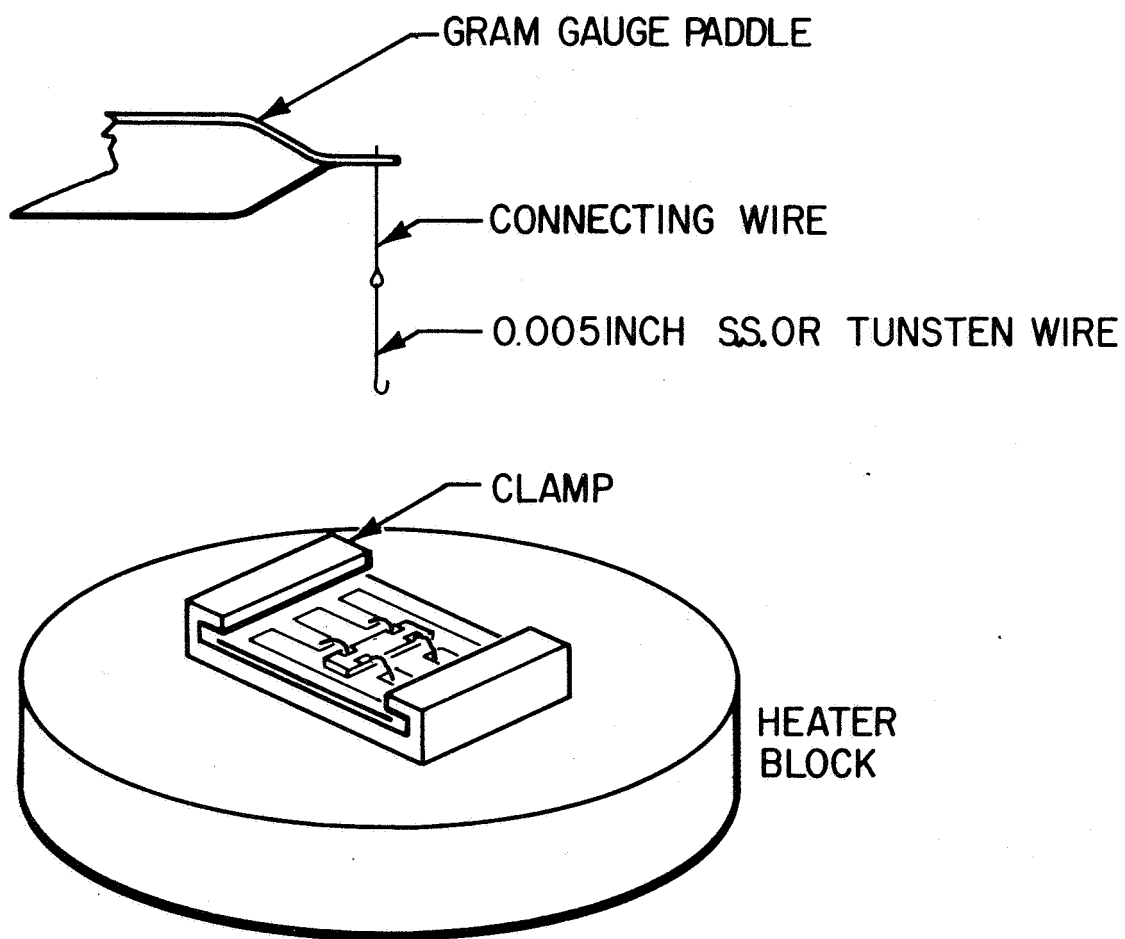0.005INCH S.S. OR TUNSTEN WIRE

CLAMP

HEATER
BLOCK

Figure 2. Test Detail

4

Method 149

Moisture Content
(Dry Box Sealing)

1.   Purpose   This test is applicable to the determination of moisture
content of the ambient trapped during dry-box sealing
operations.

2.   Apparatus

2. 1   Moisture Monitor
Model 26-301 or 26-303
Consolidated Electrodynamics Corp.
(or equivalent)

2. 2   Diaphragm Pump
Dyna-Pump Model 2
(or equivalent)

3.   Materials

None.

4.   Procedure

4. 1   The moisture monitor should be connected to sample the
dry-box and entry chamber as shown in Figure 1.

4. 2   Set by-pass flow at 600-800 cc. per minute.

4. 3   Adjust sample flowmeter to exactly 50 cc per minute.

4. 4   By use of the appropriate valves, connect the moisture
monitor with the location to be sampled.

4. 5   Turn the scale selector to "100x" and allow 5 minutes for
stabilization.

4. 6   If the needle has less than one-third of full scale deflection,
turn selector to the next lowest scale.

1

4.7   Repeat 4.6 until maximum definition. is obtained.

4.8   Multiply scale reading by the selector factor for moisture content in parts per million (by volume). See Figure 2.

5.   Calibration

Calibration should be as noted in the manufacturer's instructions.

6.   Accuracy

Accuracy obtainable should be ± 10% at about 100 PPM.

7.   Test Frequency

Moisture content of the dry-box should be monitored during sealing and at least the following times:

7.1   Entry, prior to introducing parts into dry-box.

7.2   Dry-box after opening to admit parts

7.3   Dry-box, after discharging sealed units.

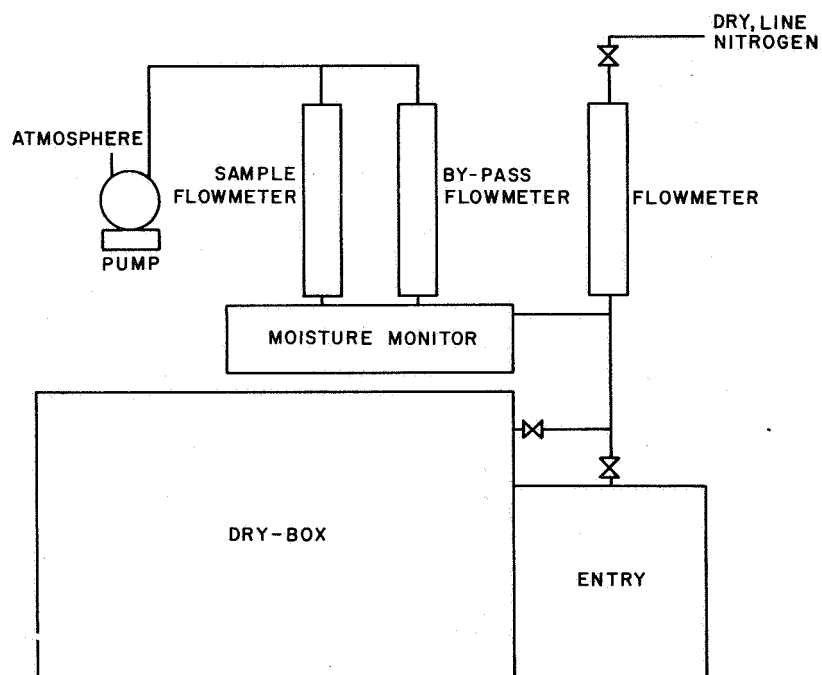7.4   Line cases, to verify dryness.

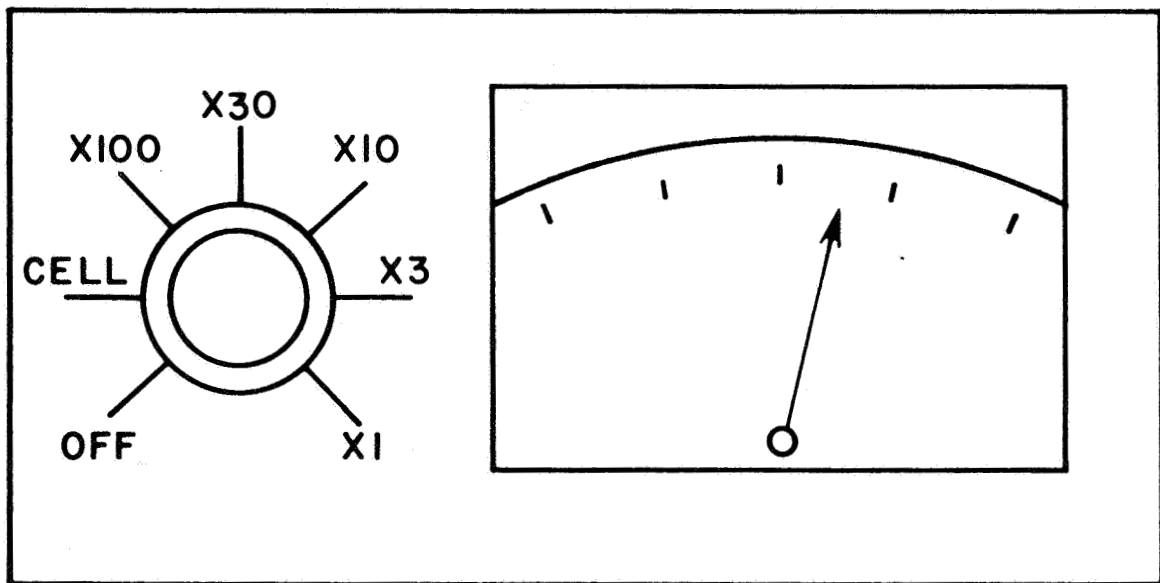Figure 1. Moisture Monitor Connections

Figure 2.   Moisture Monitor Scale

Method 150

Moisture Content
(Belt Furnace Sealing)

1. Purpose   The purpose of this test is to determine the moisture
content of gases enclosed in the device package.
This method is particularly applicable to belt furnace
operations. It utilizes the formation of visible water
vapor in an observation chamber under known
conditions which establishes moisture content.

2. Apparatus

2.1 Dew Point Monitor
Dew Pointer Type 7000
Alnor Instrument Company
(or equivalent)

3. Materials

3.1 0.25 inch I.D. Neoprene Tubing

3.2 6 mm Quartz Tubing

4. Procedure

4.1 Place a length of quartz tubing into the sealing area of
the furnace.

4.2 Connect the quartz tube to the dew point monitor inlet
with a short length of Neoprene Tubing.

NOTE: For dew points below -20°F, (422 PPM) the
connection should be via a brass ball-and-socket adapter
lubricated with silicone vacuum grease. Figure 1.

4.3 Connect the monitor to a 115 volt A-C receptacle.

4.4 Open the purging valve. Figure 2.

4.5 Pull out the operating valve.

1

4. 6   Turn the power switch "ON".

4. 7   Pump the gas to be tested through the instrument to flush
        out all the old gas (at least 20 strokes of the pump.)

4. 8   Close the purging valve.

4. 9   Pump a sample of gas into the monitor.

4. 10   Note the pressure ratio.

4. 11   Look into the observation window and press down on the
        operating valve.

4. 12   If a fog appears, it indicates the gas was cooled below
        the dew point. Make the subsequent trials (repeat steps
        4. 10 to 4. 12) at higher pressure ratios (lower pressures)
        until one reading is obtained where no fog appears. The
        last fogged reading is the "End Point".

4. 13   If no fog appears on the first trial, the gas was not cooled
        down to the dew point. Subsequent trials should be made
        at lower pressure ratios (higher pressures).

4. 14   Note the "End Point".

4. 15   Determine the "Q" value of the gas from Table I.

        NOTE: "Q" as applied, represents the cooling power for
        a given gas.

4. 16   Note the temperature.

4. 17   Calculate the dew point using the circular slide rule
        provided with the dew point monitor.

4. 18   Enter Table II with the gas dew point and determine moisture
        content in parts per million (by volume).

5.   Calibration

      Prior to each use the instrument must be adjusted to unity pressure
      ratio as follows:

2

5.1 Place operating valve in the out position.

5.2 Open purging valve.

5.3 Depress the gauge valve and turn the unity adjuster until the bottom of the miniscus is in line with the "1" mark.

5.4 Release the gauge valve.

6. Accuracy

Accuracy should be $\pm$ 20% at dew point below -40°F.

7. Test Frequency

This test should be performed periodically on belt type furnaces.

"Q" Values of Various Gases

Air	.285
Argon	.400
Carbon Dioxide	.225
Helium	.400
Hydrogen	.285
Nitrogen	.285
Oxygen	.285

Table I

Dew Point to p. p. m. Conversion Table

| D.P.	ppm	D.P.	ppm	D.P.	ppm	D.P.	ppm	D.P.	ppm	D.P	ppm
—130°F	0.1	— 91°F	3.28	—73°F	13.3	—56°F	44.6	—38°F	144	—21°F	400
—120	0.25	— 90	3.53	—72	14.3	—55	48.0	—37	153	—20	422
—110	0.63	— 89	3.84	—71	15.4	—54	51	—36	164	—19	448
—105	1.00	— 88	4.15	—70	16.6	—53	55	—35	174	—18	475
—104	1.08	— 87	4.50	—69	17.9	—52	59	—34	185	—17	500
—103	1.18	— 86	4.78	—68	19.2	—51	62	—33	196	—16	530
—102	1.29	— 85	5.3	—67	20.6	—50	67	—32	210	—15	560
—101	1.40	— 84	5.7	—66	22.1	—49	72	—31	222	—14	590
—100	1.53	— 83	6.2	—65	23.6	—48	76	—30	235	—13	630
— 99	1.66	— 82	6.6	—64	25.6	—47	82	—29	250	—12	660
— 98	1.81	— 81	7.2	—63	27.5	—46	87	—28	265	—11	700
— 97	1.96	— 80	7.8	—62	29.4	—45	92	—27	283	—10	740
— 96	2.15	— 79	8.4	—61	31.7	—44	98	—26	300	— 9	780
— 95	2.35	— 78	9.1	—60	34.0	—43	105	—25	317	— 8	820
— 94	2.54	— 77	9.8	—59	36.5	—42	113	—24	338	— 7	870
— 93	2.76	— 76	10.5	—58	39.0	—41	119	—23	358	— 6	920
— 92	3.00	— 75	11.4	—57	41.8	—40	128	—22	378	— 5	970
		— 74	12.3			—39	136			— 4	1020

Table II
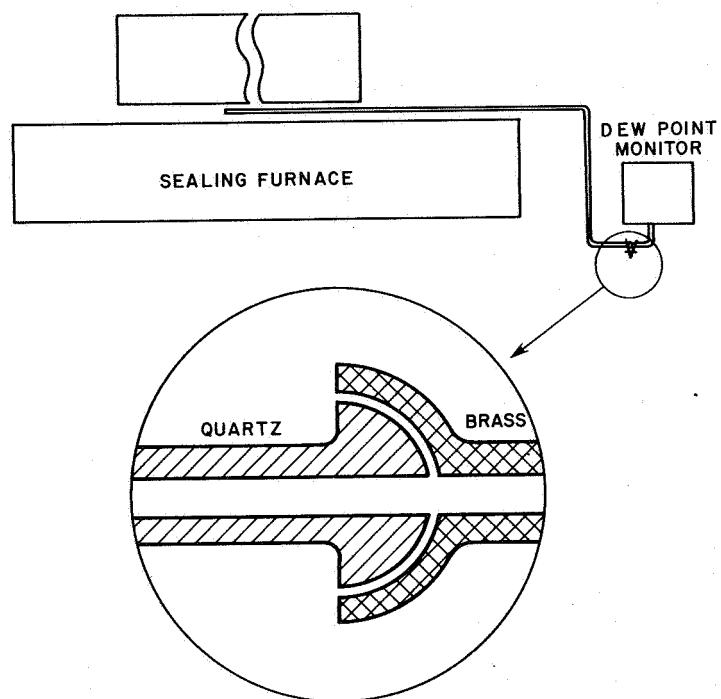
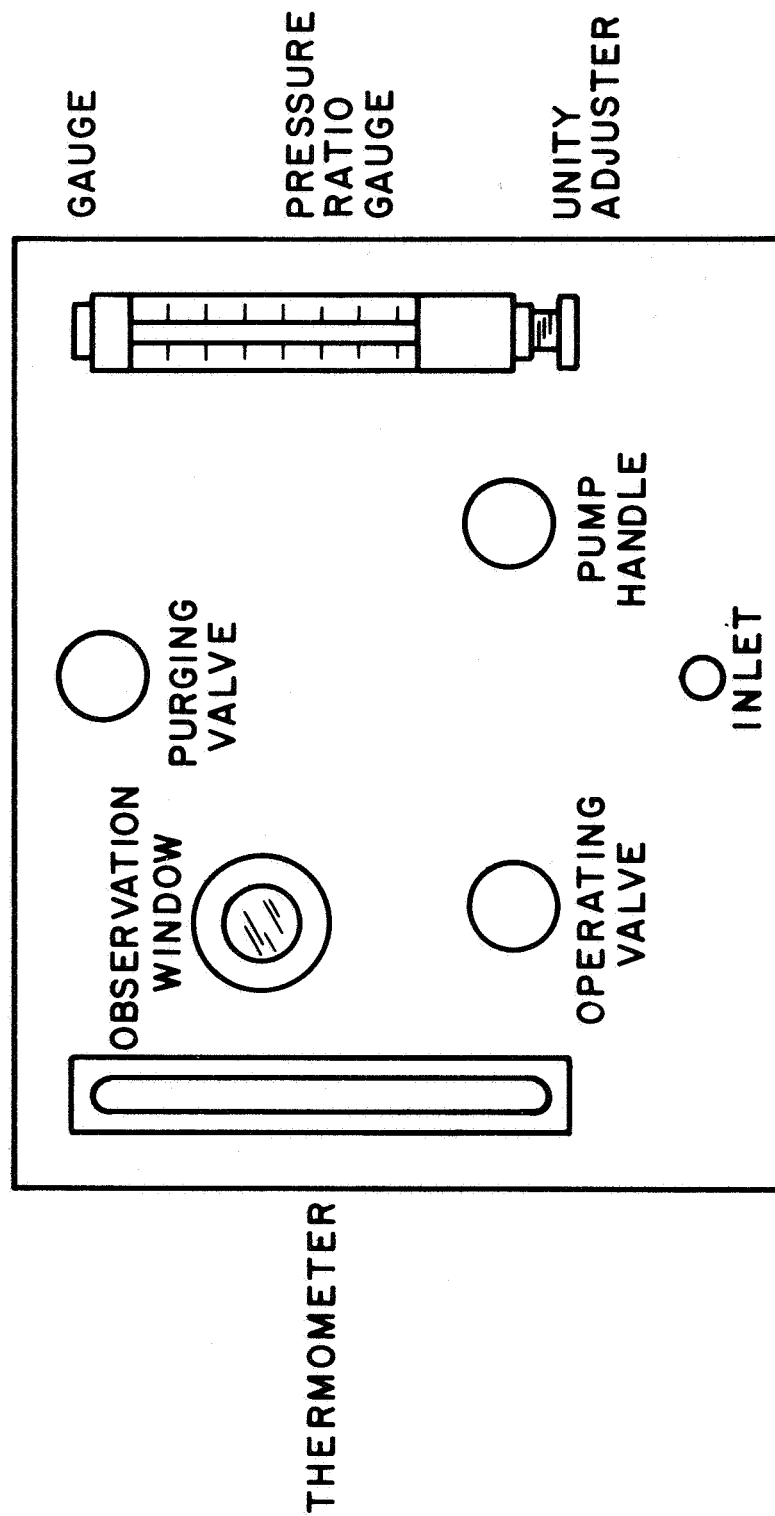Figure 1. Dew Point Monitor Setup

Figure 2. Dew Point Monitor Detail

Method 151

Hermaticity, Fine and Medium Leak
(Radiflo)

1. <u>Purpose</u> The purpose of this test is to detect fine and medium leaks (10^{-9} to 10^{-6} cc/sec) in the package of any device with an internal cavity. It utilizes the injection of radioactive gas into defective units and detection by a scintillation counter.

2. <u>Apparatus</u>

2.1 Radiflo Activation Unit
Consolidated Electrodynamics Corp., Model C2D5
(or equivalent)

2.2 Geiger-Mueller Counter
Consolidated Electrodynamics Corp.
(or equivalent)

2.3 Scintillation Counter
Consolidated Electrodynamics Corp.
(or equivalent)

2.4 Scintimonitor
Consolidated Electrodynamics Corp.
(or equivalent)

2.5 Survey Meter
Universal Atomic Division, Universal Transistor Products
  Corp., Model SM-160
(or equivalent)

3.   Materials

   3.1   Krypton-85

4.   Procedure

   4.1   Activation

       4.1.1   Presetting Activation Pressure and Activation Time

            4.1.1.1 Find the inspection level of the leak rate called for in the controlling documents $(1 \times 10^{-9}, 1 \times 10^{-8}, 1 \times 10^{-7}$, or $1 \times 10^{-6})$. Find the Activation Pressure and Activation Time corresponding to this leak rate in the manufacturer's operating manual.

            4.1.1.2 Record Activation Pressure and Activation Time in the appropriate columns of the Radiflo Operation Log.

            4.1.1.3 Go to the open portion of the plastic covered panel at the lower left of the machine. Preset the Activation Pressure by turning the knob under the Pressure Indicator until the needle points to the pressure value obtained in 4.1.1.1.

            4.1.1.4 Preset the Activation Time obtained by turning the Set knob, located in the lower left of the open portion of the plastic cover, until the correct value appears on the mileage-type meter.

            4.1.1.5 If the Activation Time required for a given load of devices is the same as for the load just processed, 4.1.1.4 may be omitted by simply pressing the Reset button.

       4.1.2   Loading the Test Units

            4.1.2.1 Load the devices into the wire basket.

4.1.2.2 Read Storage Activity Meter by holding Storage Monitor button depressed for at least 20 seconds and record value in Radiflo Operation Log. Read Storage Pressure Meter and record value in Radiflo Operation Log.

4.1.2.3 Push the Door button and lift hinged door.

4.1.2.4 Unlock lid of the Activation Tank by pulling the handle out.

4.1.2.5 Depress the two Open buttons to raise the lid of the Activation Tank.

4.1.2.6 Wipe the bottom of the lid with industrial tissue to remove any particles of dirt.

4.1.2.7 Insure that the 0-ring on top of the Activation Tank is free of dust.

NOTE: At the beginning of each day shift, the 0-ring shall be removed, wiped clean with industrial tissue, lightly lubricated with vacuum grease and reinserted. This cleaning operation shall be noted in the Radiflo Operation Log.

4.1.2.8 Lower the basket of devices into the Activation Tank.

4.1.2.9 Depress the two Close buttons to close the Activation Tank.

4.1.2.10 Push handle back to seal lid.

4.1.2.11 Shut hinged door.

4.1.2.12 Press Evacuate button to initiate the Radiflo cycles of:

(1) Evacuate
(2) Activate
(3) Store
(4) Wash

3

4.1.3   Unloading the Test Units

4.1.3.1 After the Radiflo has completed its cycles
        (indicated by the Stop and Door buttons
        lighting up) repeat 4.1.2.2 through
        4.1.2.5 of the Loading procedure.

4.1.3.2 Remove the basket of devices from the
        Activation Tank.

4.1.3.3 If more devices are to be activated, place
        them in the Activation Tank as soon as
        possible and repeat the activation process.

4.1.3.4 If no more devices are immediately available
        for activation, close the lid of the
        Activation Tank, seal the lid, and shut the
        hinged door.

4.1.3.5 It is imperative that devices are inspected
        in the Scintimonitor within two hours after
        removal from the Radiflo. Devices must
        be reactivated if they are not inspected
        within this interval.

4.1.3.6 DO NOT LEAVE LID OPEN AND UNSEALED.

4.2   Detection

For purpose of testing, the operator must translate the
cc/sec failure leak rate to counts/minute by referring to
the manufacturer's operating manual.

4.2.1   Turn Master switch to "ON" and allow equipment
         to warm for two minutes.

4.2.2   Turn H-V (High-Voltage) switch to "ON' .

4.2.3   Turn Function switch to zero. Adjust the center
         knob in the upper left of the console panel until
         the meter needle points to zero.

4.2.4   Turn Function switch to "CALIBRATE. " Turn the
         C/M (Counts/Minute) knob to 1K. Adjust the outer
         knob in the upper left of the console panel until the
         needle reads between the two vertical red lines on
         the upper scale of the meter.

4.2.5   Turn Function switch to H-V. Turn H-V setting knob on upper right of console panel until the meter reads the voltage that has been posted on the panel just below the knob.

4.2.6   Turn Seconds knob to 2.0 on the black scale.

4.2.7   Turn Function switch to C/M.

4.2.8   The background count can now be read from the meter and should be approximately 400 counts/minute. (Do not wear a wrist watch with luminous parts while testing).

4.2.9   Place one of the standard reject units which are maintained at the console into the test tube. Insert the tube into the Scintimonitor. A reject reading on the meter indicates that the equipment is operating properly and that the operator may proceed with the test.

4.2.10   Place enough devices into the test tube to fill it about half full. Insert the tube into the Scintimonitor.

4.2.11   Wait two seconds and observe the meter reading. If the counts/minute reading exceeds the allowable maximum as determined in 4.2 above, the test tube is known to contain one or more rejects. When this happens, the devices should be split into two groups and each group retested in the Scintimonitor. This process of dividing the group into smaller test samples should be continued until the reject(s) are isolated.

4.2.12   Place reject units in an evnelope. Write the device number, run number, operator badge number and the date on the envelope.

4.2.13   Safety Procedure.

        4.2.13.1   Place envelope of reject units into lead safety box.

        4.2.13.2   Store rejects in the Tank Room until the radiation has fallen to the background count of 400 counts/minute.

5. <u>Calibration</u>

    5.1 See Paragraph 4.2.8 and 4.2.9 for background count and sample check.

    5.2 For all other calibration and maintenance, refer to manufacturer's manual.

6. <u>Accuracy</u>

Accuracy obtainable is no less $\pm 50\%$ at all leak rates.

Example: Scintillation Count = 1×10^{-6} cc/sec. Actual rate will be between 5×10^{-6} and 5×10^{-5} cc/sec.

7. <u>Test Frequency</u>

All sealed units should be tested.

Method 152

Hermaticity, Gross Leak
(Bubble Test)

1.   Purpose   This method may be used to detect gross leaks
                      (on the order of 10^{-5} atmospheric cubic
                      centimeters/second) in device packages.

2.   Apparatus

     2.1   Hot Plate, Electric 6" x 6"
           Temco, Type 1900
           (or equivalent)

     2.2   Magnetic Immersion Board
           (any source)

     2.3   Pyrex Bowl
           (any source)

     2.4   Thermometer, 200°C
           (any source)

3.   Materials

     3.1   Mineral Oil, Clear

     3.2   Trichloroethylene, Electronic grade

4.   Procedure

     4.1   Before loading the devices on the immersion board ensure
           that they are free of any foreign matter and that they are at
           room ambinet temperature.

1

4.2   Load the devices on the immersion board so that the major axis is in the horizontal position.

4.3   Fill a Pyrex bowl of suitable size with clear mineral oil. Ensure that there is sufficient oil to cover the uppermost part of the devices to a minimum depth of one (1) inch.

4.4   Place the bowl on the hot plate and turn the temperature control to 125°C; monitor the temperature of the oil with a thermometer.

4.5   After the temperature stabilizes at $125°\,^{+5°C}_{-0°C}$, immerse the devices in the liquid and gently agitate until all trapped air is freed from the surface of the devices.

4.6   After the freeing of trapped air, leave the devices immersed for a minimum of one (1) minute. Observe the devices, particularly the seal areas, for leaks which will be indicated by a flow of bubbles escaping to the surface of the mineral oil.

4.7   Remove the devices from the immersion bath and wash in a beaker of TCE to remove all traces of the mineral oil.

4.8   Segregate defective units from the good units.

4.9   Thoroughly dry the units on the warm air dryer or under the heat lamp before performing any additional tests.

5.   Calibration

Not applicable.

6.   Accuracy

Not applicable.

7.   Test Frequency

All devices should be tested.

2

Method 153

Sealing, Defects in Glass
(Can Package)

1.   Purpose   The purpose of this method is to detect seal defects in the glass-to-metal seals of can-type packages.

2.   Apparatus

    2.1   Binocular Microscope, 30X, with illuminator (any source)

3.   Materials

None.

4.   Procedure

    4.1   Inspect header prior to sealing under microscope.

    4.2   Rotate device so seal area is observed at various angles.

    4.3   Note the following defects:

        4.3.1   Bubbles - A string of bubbles which connect one lead with another, Figure 1, or a pin with the eyelet, Figure 2.

        4.3.2   Void - Missing glass for the full length of the seal, either against the lead or completely in the glass. See Figure 3.

4.3.3 <u>Glass Climb</u> - Glass from seal flows an excessive distance, down lead or up pin.

4.3.4 <u>Cracks</u> - A fissure in the glass which connects one lead with another or a lead with the eyelet, similar to Paragraph 4.3.1

5. <u>Calibration</u>

Not applicable.

6. <u>Accuracy</u>

Not applicable.

7. <u>Test Frequency</u>

Each lot of headers should be sampled.
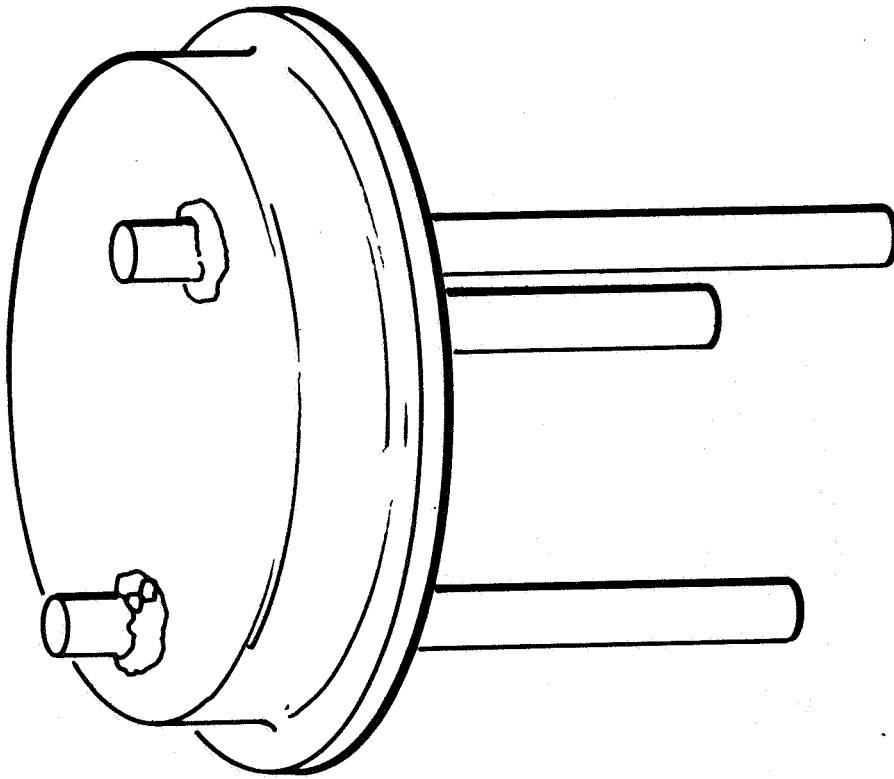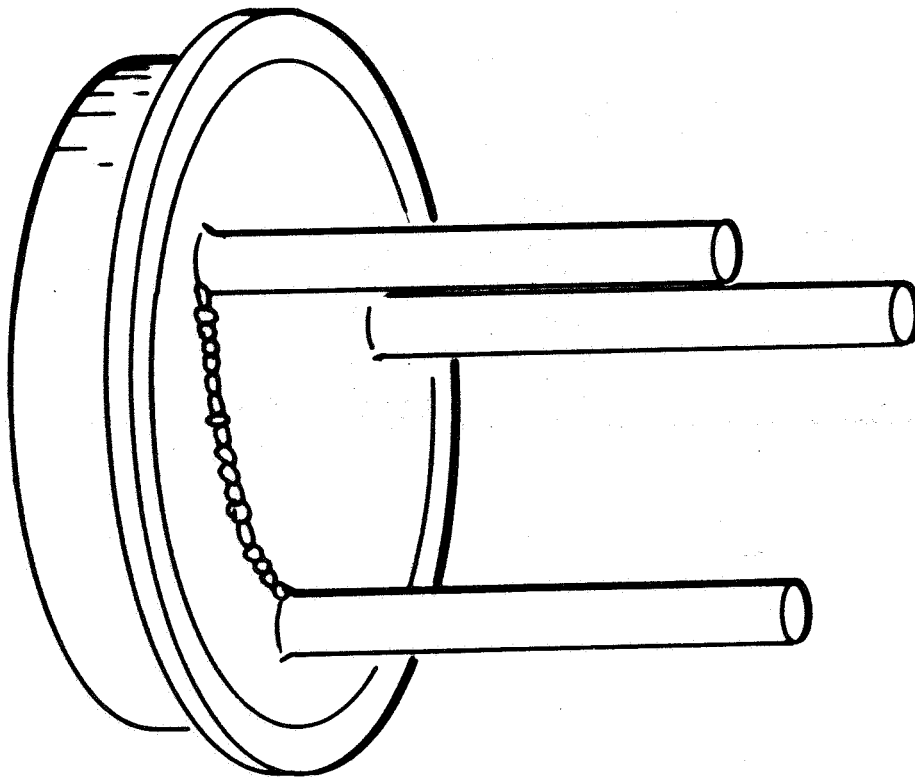
Figure 2.   Bubbles Connecting Lead with Eyelet
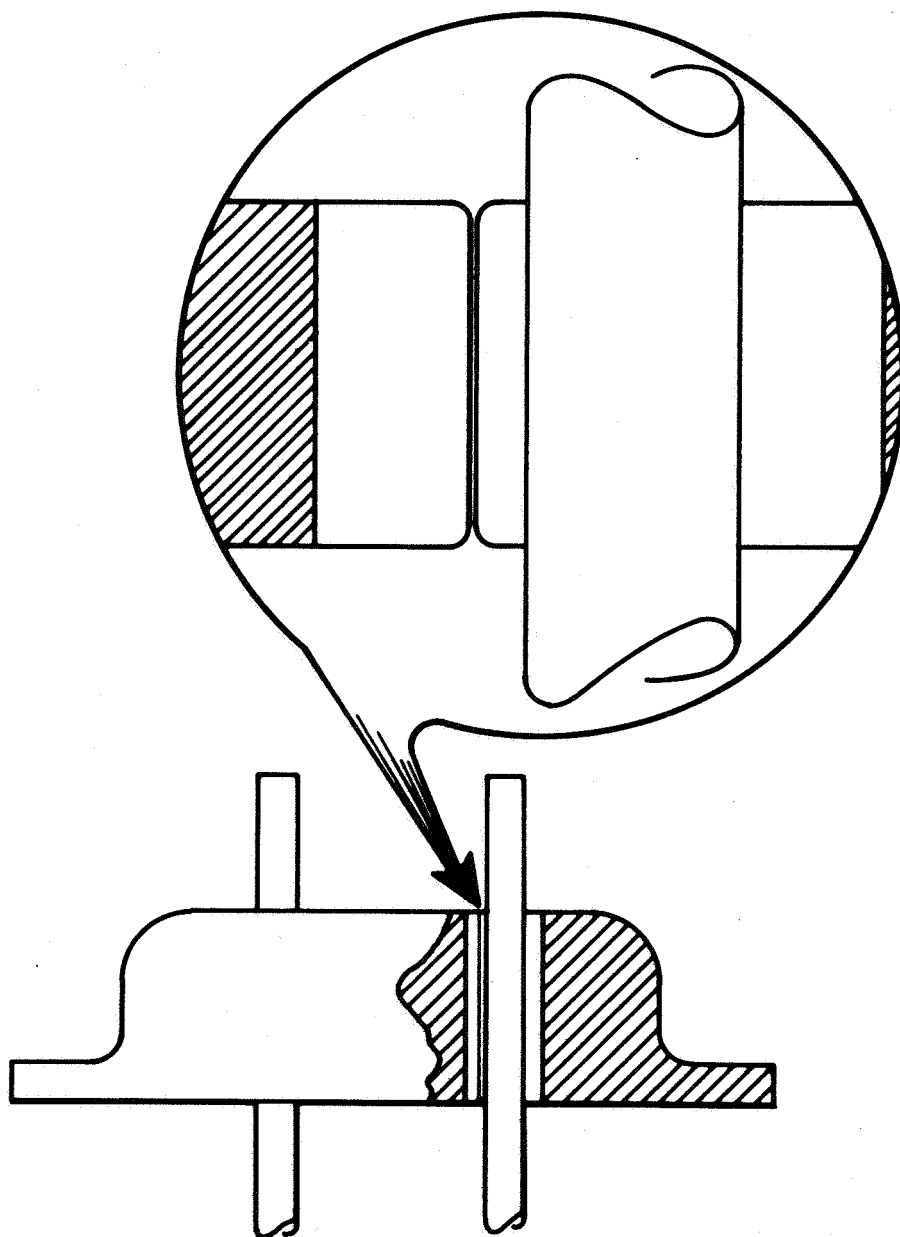

Figure 1.   Bubbles Connecting Leads

Figure 3.   Illustration of Void

Method 154

Sealing, Defects in Glass
(Flat Package)

1.   Purpose   The purpose of this method is to detect seal
defects in the glass seals of flat packages.

2.   Apparatus

2.1   Binocular Microscope, 15X, with illuminator
(any source)

3.   Materials

None.

4.   Procedure

4.1   Inspect sealed units under microscope.

4.2   Rotate device so seal area is observed at various angles.

4.3   Note the following defects:

4.3.1   Open Seal   -   Cap or base is tilted and glass
does not make a complete seal. See Figure 1.

4.3.2   Sprung Seal   -   Cap cannot make a complete seal
because frame leads are bent. See Figure 1.

1

4.3.3 <u>Insufficient Glass</u> - Lack of glass in a distinct area to the degree that the bottom of the hole is not visible. See Figure 2.

4.3.4 <u>Pin Hole</u> - A hole in the seal, without a visible bottom, less than one lead width in diameter. See Figure 3.

4.3.5 <u>Blow Hole</u> - Similar to Paragraph 4.3.4, but with surface residue. See Figure 3.

4.3.6 <u>Warped Seal</u> - An open seal due to warped ceramic. See Figure 4.

4.3.7 <u>Glass Climb</u> - Glass from seal flows out lead to an excessive distance.

4.3.8 <u>Excess Glass</u> - Package exceeds specified dimensions due to excess glass from seal.

5. <u>Calibration</u>

Not applicable.

6. <u>Accuracy</u>

Not applicable.

7. <u>Test Frequency</u>

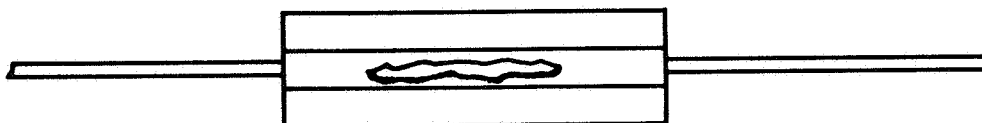All units should be tested after final sealing.
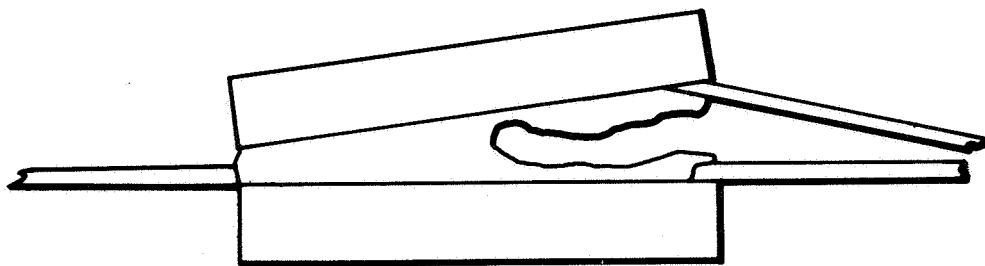
Figure 1.   Open or Sprung Seal
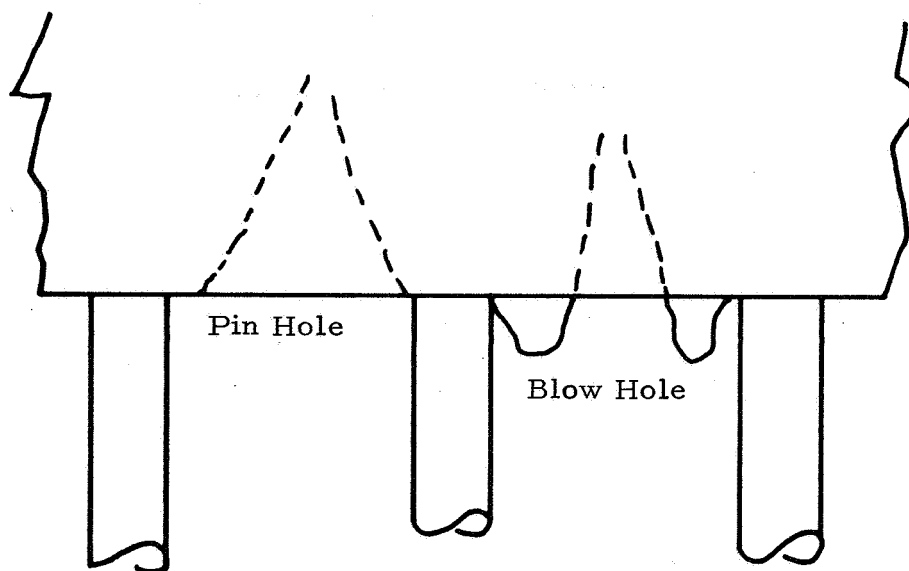

Figure 2.   Insufficient Glass

Pin Hole

Blow Hole

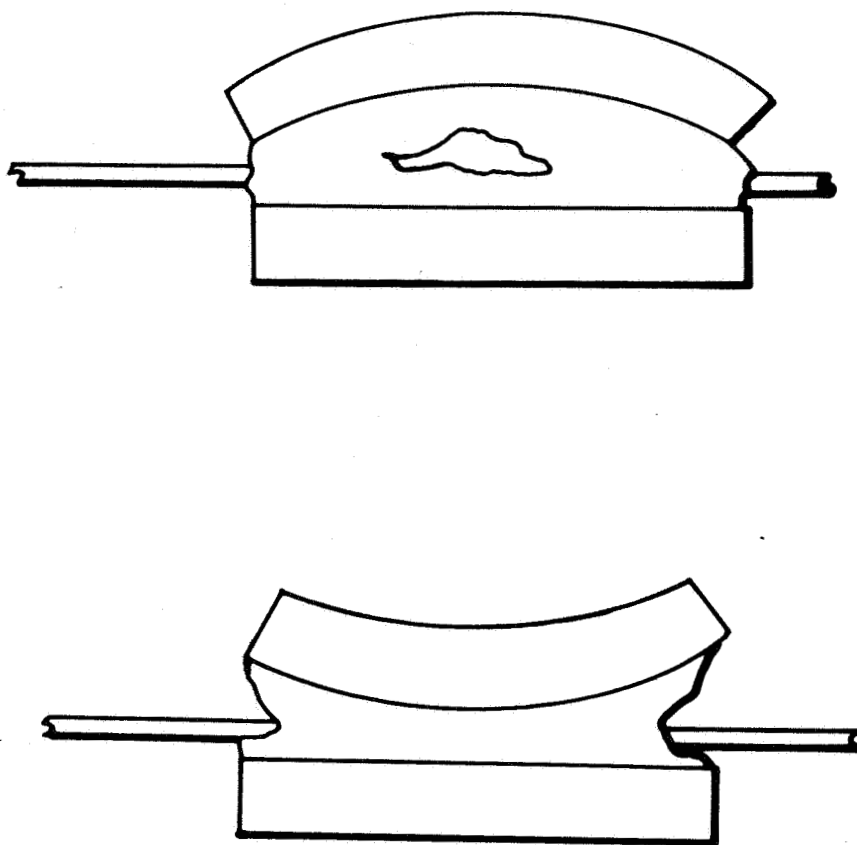Figure 3.   Holes in Glass

Figure 4. Warped Seal

Method 155

Stored Charge, Bipolar Transistor (Q_{bx})

1. <u>Purpose</u> The purpose of this test is to measure the stored charge of a device at specified conditions.

2. <u>Test Circuit</u>

See Figure 1.

3. <u>Procedure</u>

This procedure as depicted by Figure 1 fixes the input 'Q' and compares the variable 'Q' of the device in terms of storage time.

$$Q = \frac{CV}{I}$$

$$T_s = \frac{QC}{IC}$$

$$\frac{QC}{IC} = \frac{C_{(in)} V_{(in)}}{Ib}$$

Ts = Storage time
Q = Stored charge
C = Collector capacitance
Ic = Collector current
$C_{(in)}$ = Input capacitance

Where: $V_{(in)}$ = Input voltage

Ib = Base current

Therefore, since the storage of a device is a function of V_{CE} and collector capacitance, then with given conditions the stored charge may be obtained in Terms of Ts, using circuit in Figure 1. The specified 'Q' of the input, or comparison circuit , may be determined by changing the value of the input capacitance accordingly.

4.   <u>Summary</u>

The following details shall be specified.

(a)   Input capacitance and resistances.

(b)   Voltage and currents.

(c)   Pulse conditions.

5.   <u>Accuracy</u>

The accuracy of measurement will be dependent upon equipment used; (Q_{bx}) ±3% with optimum equipment.
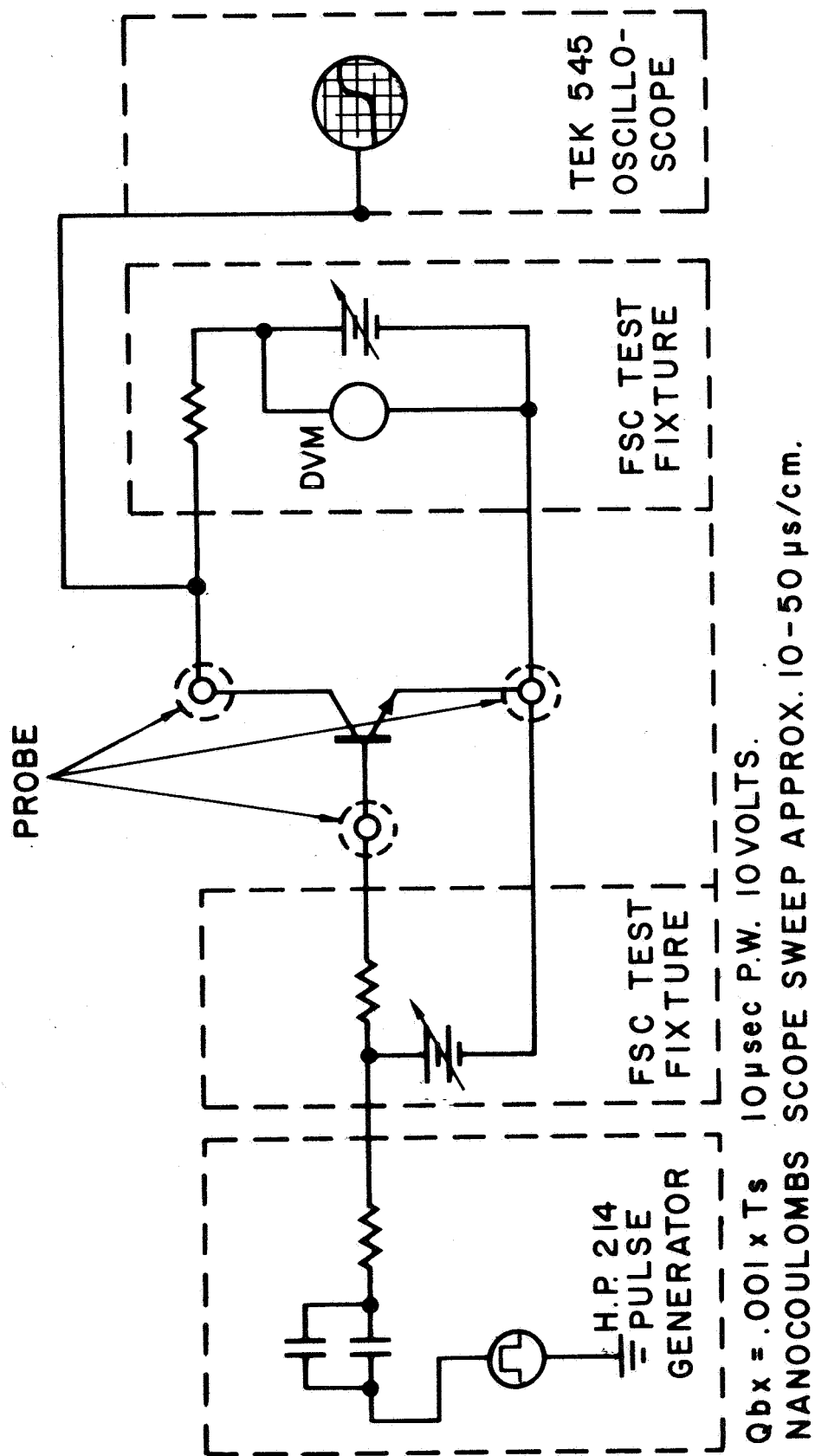
Figure 1. Q_{bx} Measurement Setup

$Q_{bx} = .001 \times T_s$ 10 µsec P.W. 10 VOLTS.

NANOCOULOMBS SCOPE SWEEP APPROX. 10−50 µs/cm.

Method 156

Breakdown Voltage (BV$_{DSS}$)
Drain to Source

1. <u>Purpose</u>   The purpose of this test is to determine if the breakdown voltage of the device under the specified conditions is greater than the specified minimum limit.

2. <u>Test Circuit</u>

See Figure 1.

3. <u>Procedure</u>

The resistor R_1 is a current-limiting resistor and should be of sufficiently high resistance to avoid excessive current flowing through the device and current meter. The voltage shall be increased, with the specified bias conditions applied, until the specified test current is reached. The device is acceptable if the voltage applied at the specified test current is greater than the minimum limit for BV$_{DS}$. If desirable, a suitable base current may be applied as the voltage is increased; however, the specified bias condition and test current must be applied when the voltage is measured. This method is intended for devices exhibiting negative resistance breakdown characteristics. In such cases, extreme care must be exercised to insure that the drain current and junction temperature of the device remain at a safe value.

4.   Summary

The following details shall be specified in the individual specification:

   (a)   Test current (See 3.)

   (b)   Duty cycle and pulse width, when required (See Note 1.)

   (c)   Bias condition as follows:

      A - Source to Gate   -   Short circuit.

5.   Accuracy

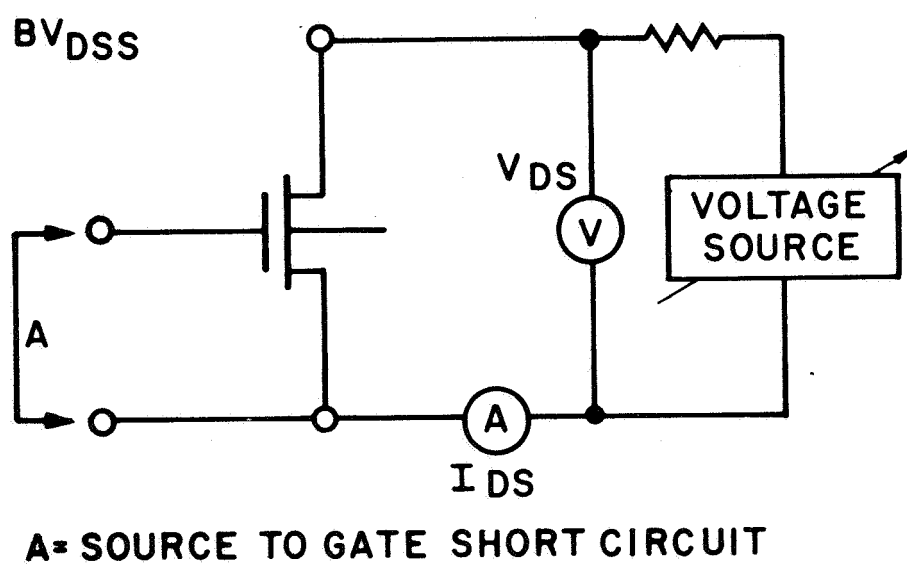The accuracy of measurement will be dependent upon equipment used; $(BV_{DSS}) \pm 1\%$.

BVDSS

VDS

VOLTAGE SOURCE

I DS

A⁼ SOURCE TO GATE SHORT CIRCUIT

Figure 1.   BV$_{DSS}$ Measurement Setup

Method 157

Breakdown Voltage, Source to Gate (BV_{GSS})

1. <u>Purpose</u>   The purpose of this test is to determine if the breakdown voltage of the device under the specified conditions is greater than the specified minimum limit.

2. <u>Test Circuit</u>

See Figure 1.

3. <u>Procedure</u>

The resistor R_1 is a current-limiting resistor and should be of sufficiently high resistance to avoid excessive current flowing through the device and current meter. The voltage shall be gradually increased, with the specified condition (A, B, C or D) applied, from zero until either the minimum limit for BVSGX or the specified test current is reached. The device is acceptable if the minimum limit for BV_{SGX} is reached before the test current reaches the specified value. If the specified test current is reached first, the device is rejected.

4. <u>Summary</u>

The following details shall be specified in the individual specification:

(a)   Test current (See 3.)

(b)   Bias condition:

A - Drain to Gate - Reverse bias. (Specify bias voltage).

B - Drain to Gate - Resistance return. (Specify resistance of R_2).

C - Drain to Gate - Short circuit.

D - Drain to Gate - Open circuit.

5.0 Accuracy

The accuracy of measurement will be dependent upon equipment used; $BV_{GSS} \pm 1\%$ with optimum equipment.
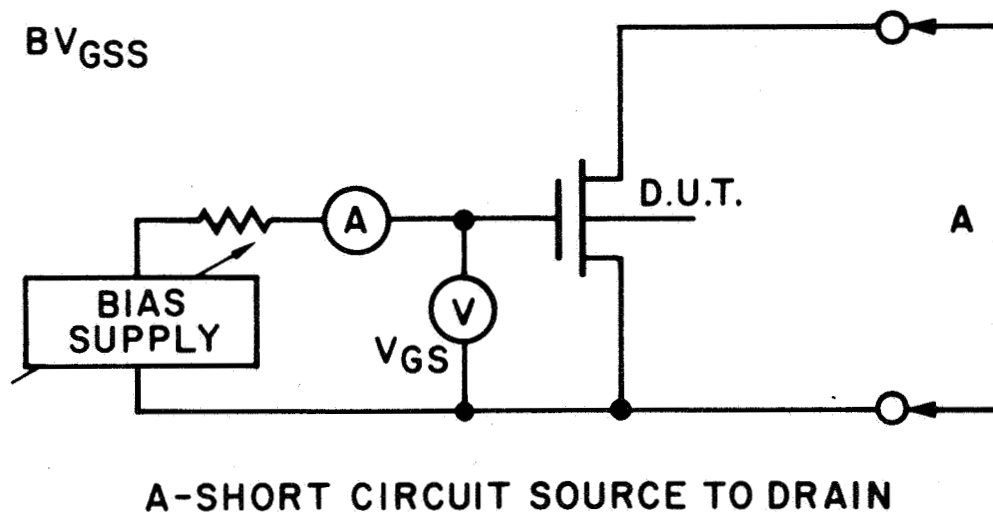
BV$_{GSS}$

A-SHORT CIRCUIT SOURCE TO DRAIN

Figure 1. BV$_{GSS}$ Measurement Setup

Method 158

Drain to Source Cutoff Current (I_{DSS})

1. <u>Purpose</u>   The purpose of this test is to measure the cutoff current of the device under the specified conditions.

2. <u>Test Circuit</u>

See Figure 1.

3. <u>Procedure</u>

The specified voltage shall be applied between the drain and source with the specified test condition (condition A, B, C, or D) applied to the base. The measurement of current shall be made at the specified ambient or case temperature.

4. <u>Summary</u>

The following details shall be specified in the individual specification:

(a)   Test voltage (see 3)

(b)   Test temperature if other than $25° \pm 3°C$ and whether case or ambient (see 3)

(c)   Bias condition:

A - Source to Gate - Reverse bias (specify bias voltage).

B - Source to Gate - Resistance return (specify resistance value of R_2) .

C - Source to Gate - Short circuit.

D - Source to Gate - Open circuit.

1

5.0 Accuracy

The accuracy of measurement will be dependent upon equipment used; $I_{DSS} \pm 2\%$ with optimum equipment.
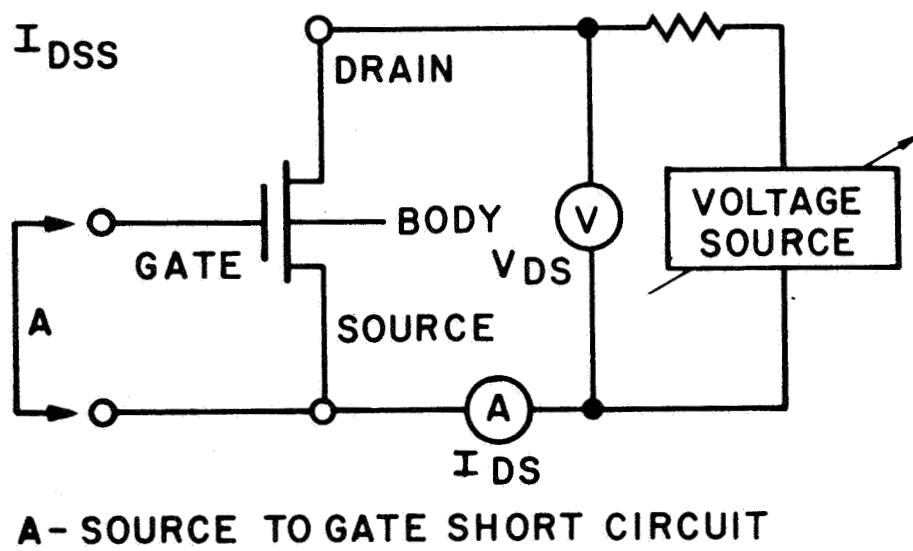
Figure 1. I_{DSS} Measurement Setup

Method 159

Source to Gate Cutoff Current (I_{GSS})

1.   <u>Purpose</u>   The purpose of this test is to measure the cutoff current of the device under the specified conditions.

2.   <u>Test Circuit</u>

See Figure 1.

3.   <u>Procedure</u>

The specified direct current voltages shall be applied between the emitter and the base with the specified bias condition (condition A, B, C, or D) applied to the collector. The measurement of current shall be made at the specified ambient or case temperature.

4.   <u>Summary</u>

The following details shall be specified in the individual specification:

4.1   Test voltage (See 3.).

4.2   Test temperature if other than $25° \pm 3°C$ and whether case or ambient (See 3.).

4.3   Bias condition (condition A, B, C, or D):

        A - Drain to Gate - Reverse bias (specify bias voltage).
        B - Drain to Gate - Resistance return (specify resistance of R_2).
        C - Drain to Gate - Short circuit.
        D - Drain to Gate - Open circuit.

5.0   <u>Accuracy</u>

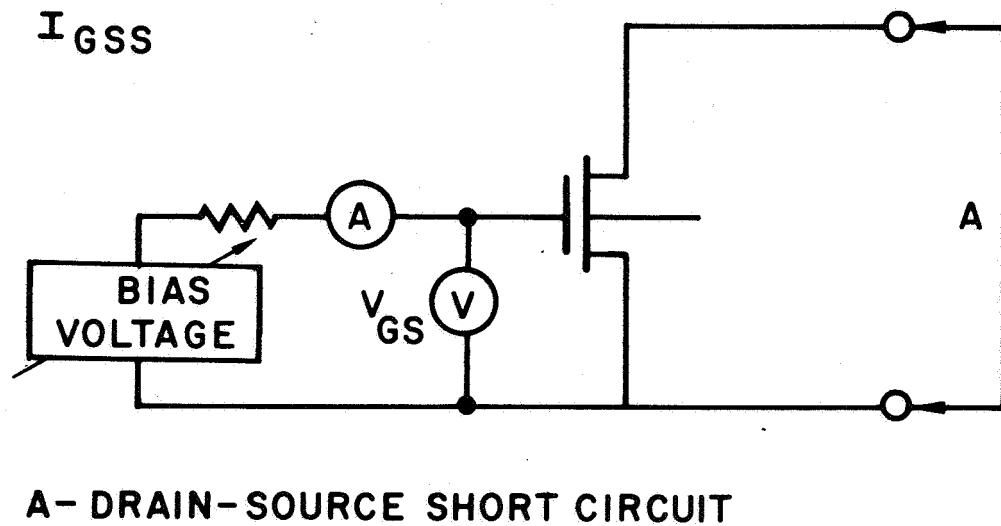The accuracy of measurement will be dependent upon equipment used; $I_{GSS} \pm 3\%$ with optimum equipment.

I_{GSS}

A- DRAIN-SOURCE SHORT CIRCUIT

Figure 1. I_{GSS} Measurement Setup

Method 160

Gate to Source Threshold Voltage (V_{GST})

1. <u>Purpose</u>   This method is designed to measure the voltage that will turn device on under specified conditions.

2. <u>Test Circuit</u>

See Figure 1.

3. <u>Procedure</u>

The gate voltage is increased until the specified drain current is obtained. The voltage read from source to gate at specified conditions. This will be the desired voltage.

4. <u>Summary</u>

The following details shall be specified in order to perform test.

(a)   Test voltages or currents

(b)   Parameters to be measured

5.0   <u>Accuracy</u>

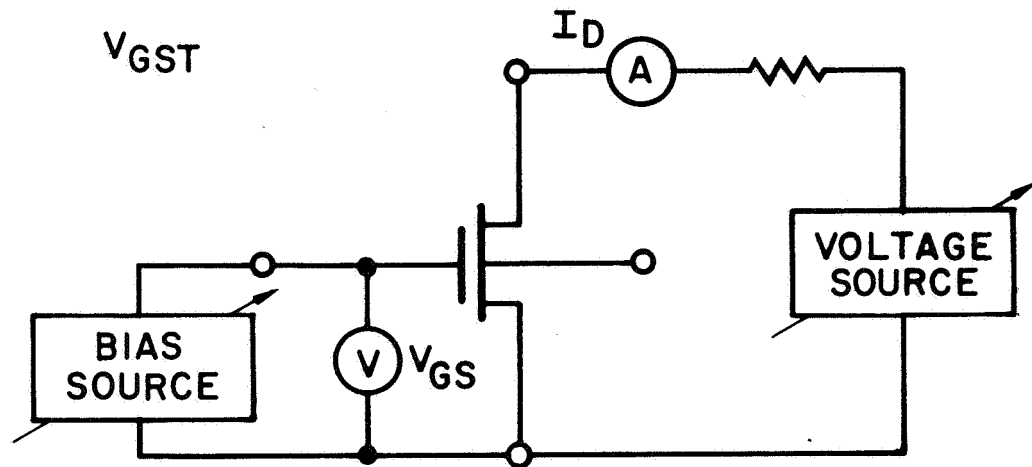The accuracy of measurement will be dependent upon equipment used; $V_{GST} \pm 1\%$ with optimum equipment.

1

Figure 1. V_{GST} Measurement Setup

Method 161

Gate Leakage Resistance (R_{GS})

1. Purpose   The purpose of this method is to measure the input resistance of the device under the specified conditions.

2. Test Circuit.

See Figure 1.

3. Procedure

The resistor R shall be made large. The ammeter shall be capable of reading currents to very low limits. The specified voltage shall be applied from source to gate. The leakage current will be read on ammeter therefore:

$$R_{GS} = \frac{V_{GS}}{I_{GS}}$$

4. Summary

The following details shall be specified.

(a)   Test voltage.

(b)   Test temperature.

(c)   Specify 'R'

5.0 Accuracy

The accuracy of measurement will be dependent upon equipment used; $R_{GS} \pm 1\%$ with optimum equipment.
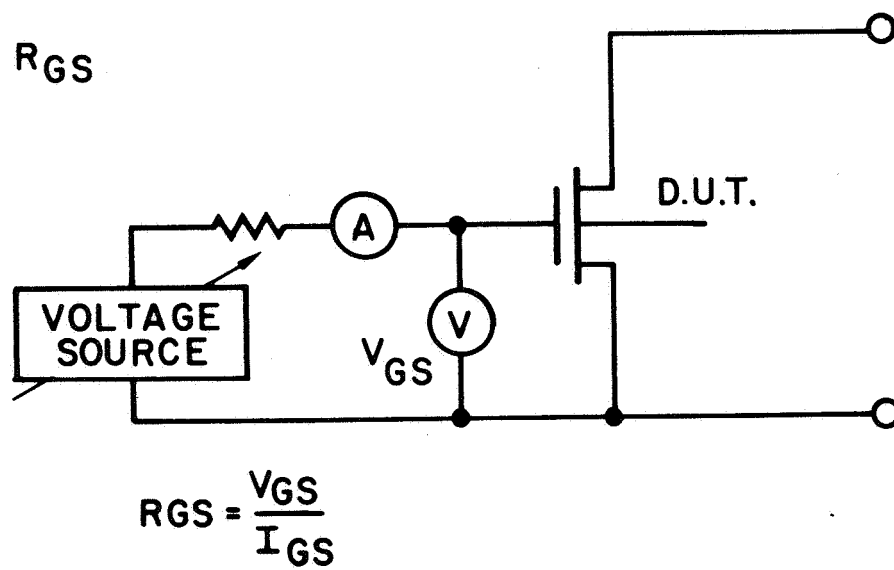
R_{GS}

Figure 1. R$_{GS}$ Measurement Setup

3

Method 162

Dynamic Drain-Source Resistance $(Rd_{(on)})$

1. **Purpose**   The purpose of this method is to measure the dynamic resistance from drain to source at specified conditions.

2. **Test Circuit**

See Figure 1.

3. **Procedure**

The specified D. C. drain to source voltage shall be applied. D. C. gate to source voltage should be applied according to specification. With specified D. C. biases and voltages, an A. C. signal of a given voltage r current is applied to source and drain. The measured A. C. voltage drop from drain to source, in conjunction with A. C. drain to source current will determine $rd_{(on)}$

$$R_{d\,(on)} = \frac{V_{A.\,C.}}{I_{A.\,C.}}$$

4. **Summary**

The following details shall be specified.

(a)   D. C. voltage or current

(b)   A. C. voltage or current

(c)   Frequency of A. C. signal

1

5.0   <u>Accuracy</u>

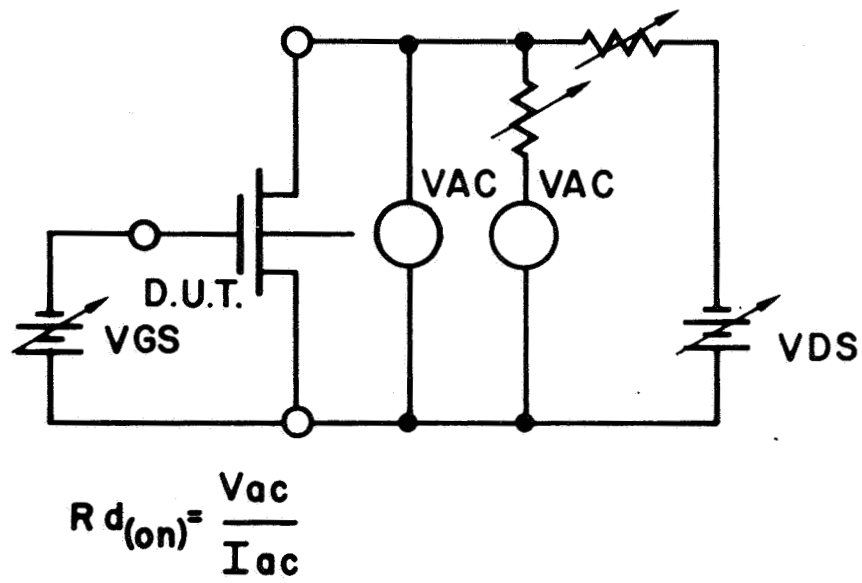The accuracy of measurement will be dependent upon equipment used; $Rd_{(on)}$ ± 2% with optimum equipment.

$$R\,d_{(on)} = \frac{V_{ac}}{I_{ac}}$$

Figure 1. $Rd_{(on)}$ Measurement Setup

3

Method 163

Static Transconductance (g_m)

1. Purpose   The purpose of this method is to measure the
                   static transconductance of the device under
                   specified conditions.

2. Test Circuit

    See Figure 1.

3. Procedure

    The resistor R, shall be made large. The resistor R_2 shall be
    chosen in combination with V_{DD} so that the specified collector
    current is achieved at a value of V_{DD} which is lower than BV_{DS}.
    The gate voltage shall be adjusted until V_{DS} and I_D achieve their
    specified values. The current I_D or I_S and the voltages V_{GS},
    V_{GD}, or V_{SG} shall then be measured. Using the values obtained
    through these measurements, the static transconductance shall
    be calculated as follows:

    Common Source   Common Drain   Common Gate

    $$g_{ms} = \frac{I_D}{V_{GS}} \qquad\qquad g_{md} = \frac{I_s}{V_{GD}} \qquad\qquad g_{mg} = \frac{I_D}{V_{SG}}$$

    If high current values are to be used in the measurement, suitable
    pulse techniques may be used to provide pulses of short duty
    cycle to minimize the rise in junction temperature.

4. Summary

    The following details shall be specified.

    (a)   Test voltage or current.
    (b)   Duty cycle and pulse width, if applicable.

1

5.0 Accuracy

The accuracy of measurement will be dependent upon equipment used; $g_m \pm 1\%$ with optimum equipment.
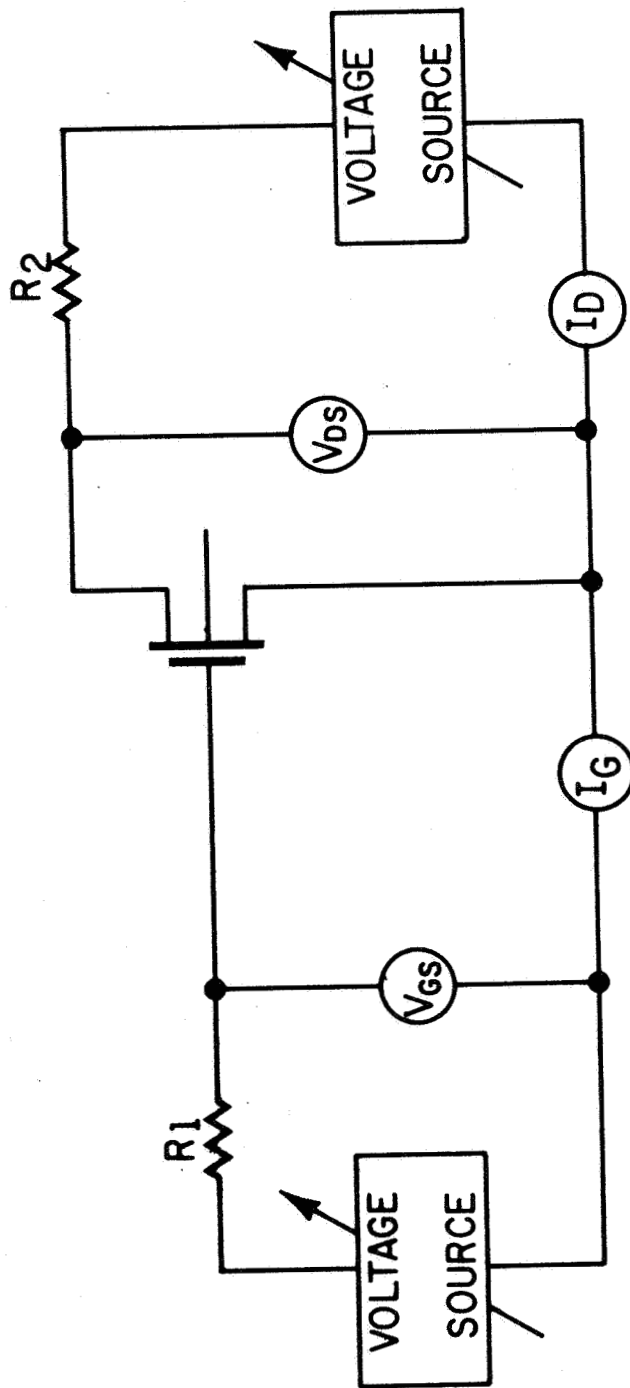
Figure 1. g_m Measurement Setup

Method 164

Direct Inter-terminal Capacitance (C_{GS}, C_{GD}, C_{DS})

1. Purpose   The purpose of this test is to measure the direct
inter-terminal capacitance between specified
terminals using specified electrical biases.

2. Test Circuit

A direct capacitance bridge or resonance Method may be used
to determine the value of the direct inter-terminal capacitance.
See Figures 1 through 3.

3. Procedure

The direct inter-terminal capacitance can be determined by
using Method A or Method B.

3.1 Method A   The specified voltage shall be applied between
specified terminals: an a.c. small signal shall be applied
to the terminals and the direct inter-terminal capacitance
shall be measured. The lead capacitance beyond 1/2 inch
from the body seat shall be effectively eliminated by
suitable means such as test socket shilding. The abbreviations
and symbols used are defined as follows:

C_{DG} (dir) ... Drain to Gate inter-terminal direct capacitance.

C_{SG} (dir) ... Drain to Gate inter-terminal direct capacitance.

C_{DS} (dir) ... Drain to Gate inter-terminal direct capacitance.

3.2 Method B   A suitable resonance method can be utilized
to measure the following two-terminal capacitances:

1

C_1 - Capacitance between drain terminal and ground, with gate and source terminals grounded.

C_2 - Capacitance between the gate terminal and ground, with drain and source terminals grounded.

C_3 - Capacitance between the drain and gate terminals strapped together and ground, with the source terminal grounded.

The direct inter-terminal capacitance can than be calculated from the following relationship:

$$C_{DG} = \frac{C_1 + C_2 - C_3}{2}$$

The direct inter-terminal capacitance for other configurations can be determined by suitable modifications of the above procedure. Such modifications shall be capable of demonstrating device conformance to the minimum requirements of the individual specification.
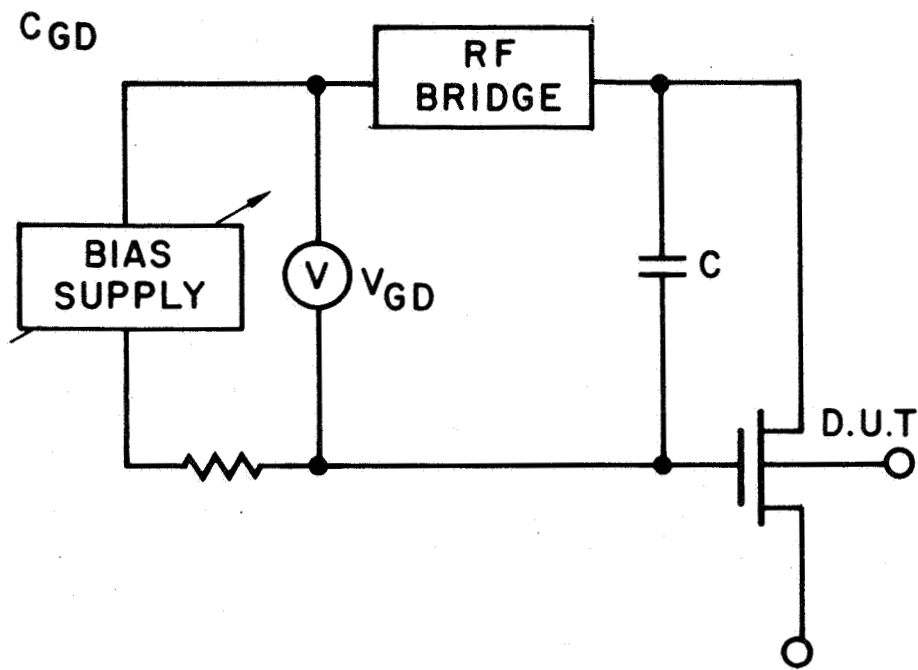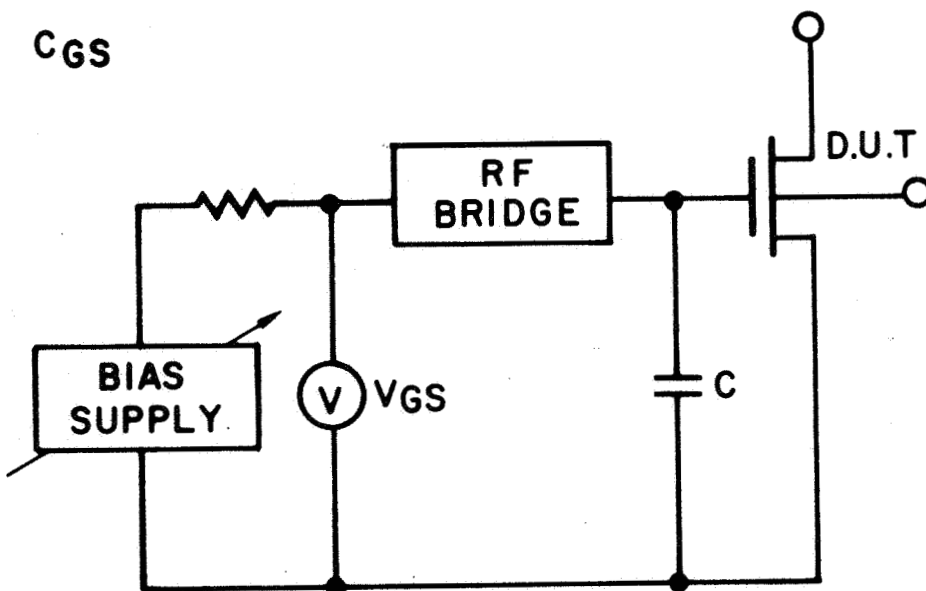
4.   Summary

The following details shall be specified on the individual specification:

(a)   Terminal arrangement

(b)   D. C. biasing conditions

(c)   Test voltage or current.

(d)   Measurement frequency.

5. 0   Accuracy

The accuracy of measurement will be dependent upon equipment used; $C_{XX} \pm 1\%$ with optimum equipment.

CGD

Figure 1. C$_{GD}$ Measurement Setup
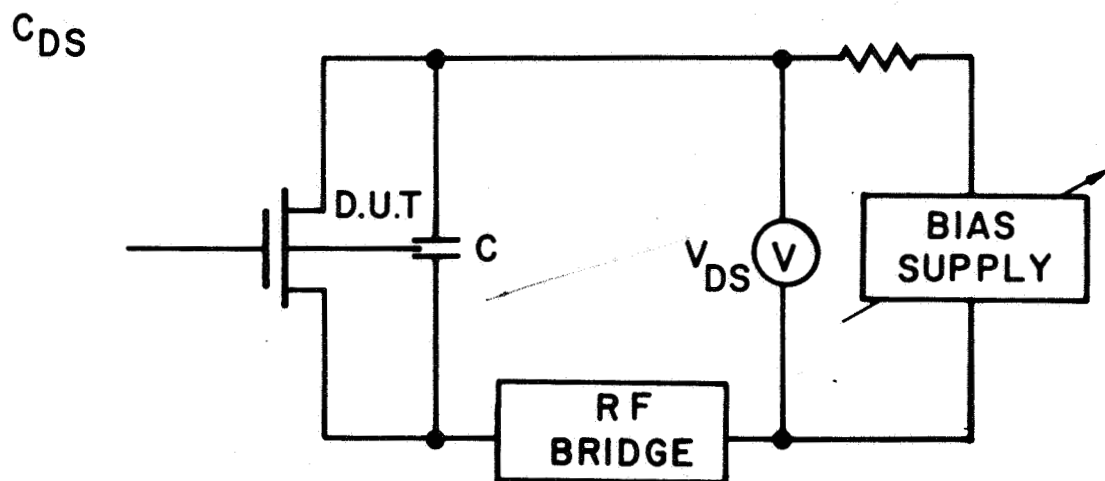
CGS

Figure 2. C$_{GS}$ Measurement Setup

C_{DS}

· Figure 3. C_{DS} Measurement Setup