ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

2215 Sanders Road
Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number **2.4.22**	
Subject **Bow and Twist (Percentage)**	
Date **6/99**	Revision **C**
Originating Task Group **Rigid Printed Board Test Methods Task Group (7-11d)**	

1 Scope This test method covers three procedures used to determine the bow and twist percentage of individual rigid printed boards, rigid portions of rigid-flex printed boards, and/or multiple printed panels. Measurements on non-rectangular samples pose a unique testing problem and may necessitate careful evaluation of the requirements imposed by the users of this test method. This test method does not describe the special considerations necessary when testing the bow and twist of printed board assemblies (i.e., component placement & weight, edge supports & connectors, etc.).

The first two procedures describe production (Go/No-Go) methods that generally characterize the bow and twist as being no more than a specific value. The other procedure is a referee method used to precisely determine the twist.

1.1 Definitions Bow and twist are defined in IPC-T-50. The definitions are repeated in this test method for convenience.

1.1.1 Bow (Sheet, Panel, or Printed Board) The deviation from flatness of a board characterized by a roughly cylindrical or spherical curvature such that, if the product is rectangular, its four corners are in the same plane (see Figure 1).

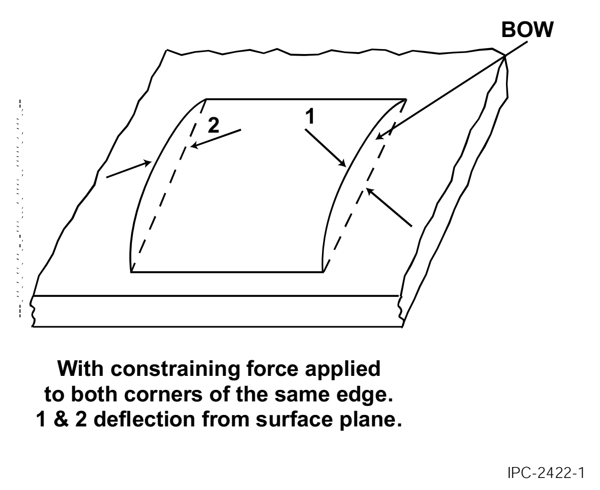

Figure 1 Box

1.1.2 Twist The deformation of a rectangular sheet, panel, or printed board that occurs parallel to a diagonal across its surface, such that one of the corners of the sheet is not in the plane that contains the other three corners (see Figure 2).

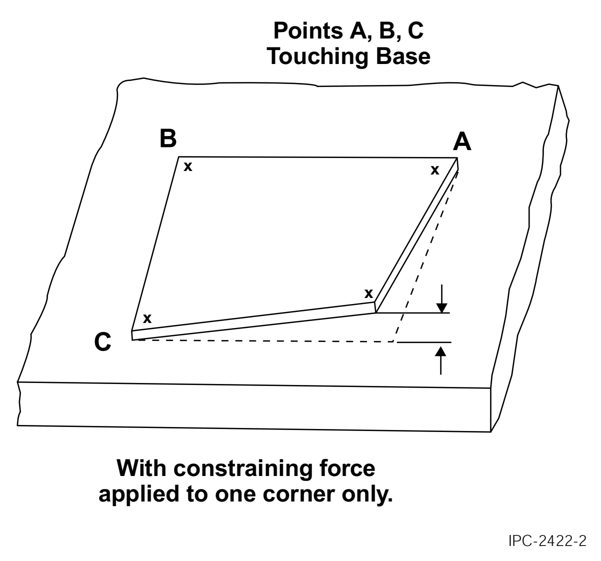

Figure 2 Twist

2 Applicable Documents

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-TM-650 Test Methods

3 Test Specimens The test specimens shall be in the form of either printed boards or multiple printed panels (single-sided, double-sided, multilayer, or rigid-flex boards).

3.1 For non-rectangular test specimens, the most convenient way to measure bow and twist is approximating a rectangle over the test specimen. To accomplish this, an imaginary rectangle that totally encloses the sample must be superimposed over the test specimen. The dimensions of this superimposed rectangle should be the smallest that will fully enclose the specimen. Although this technique will give an approximation of bow and twist, the actual noted values will be less than the actual bow and twist of the sample.

4 Equipment/Apparatus

4.1 Precision surface plate

4.2 Thickness measurement shims (feeler or pin gauges)

4.3 Leveling jacks

4.4 Standard metrology height dial indicator gauge

4.5 Gauge blocks

4.6 Linear measuring devices of suitable accuracy

4.7 Micrometer of suitable accuracy for thickness measurement

5 Procedure Unless otherwise specified, testing shall be performed at standard laboratory conditions (see IPC-TM-650, Section 1.3).

5.1 Production Testing (Bow)

5.1.1 Place the sample on the surface plate. While applying sufficient pressure to flatten the test sample, measure the length and width of the sample and record it as length (L) & width (W) (see Figure 3).

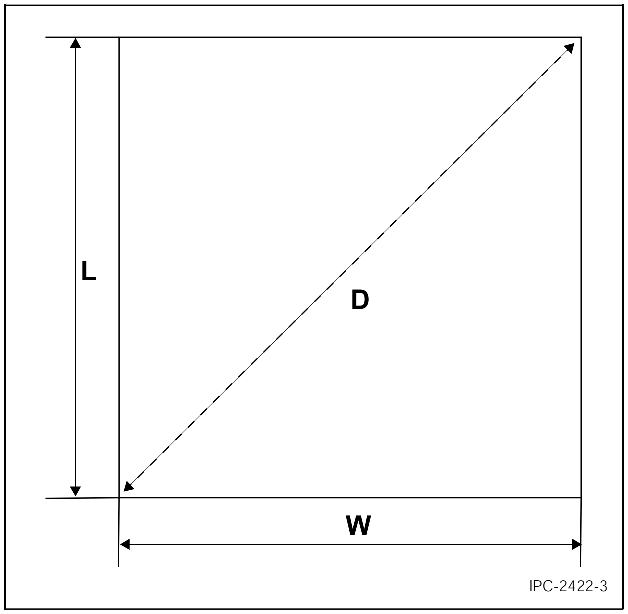

Figure 3 External Measurements

5.1.2 Calculate the size of the feeler/pin gauge (Go/No-Go) to be used for maximum bow percentage using the following formula:

$$R_L = \frac{L\,(B)}{100} \qquad Rw = \frac{W\,(B)}{100}$$

Where:

R_L = Go/No-Go feeler/pin gauge size for sample length
R_W = Go/No-Go feeler/pin gauge size for sample width
L = Length measurement as determined above
W = Width measurement as determined above
B = Maximum allowable bow percentage

5.1.3 Place the sample to be measured on the surface plate with the convex of the sample facing upwards. For each edge, apply sufficient pressure on both corners of the same sample edge to ensure contact with the surface (see Figure 4).

5.1.4 Attempt to slide the feeler/pin gauge of thickness R_L under the length side(s) of the sample and R_W under the width side(s) of the sample. If the Go/No-Go feeler/pin gauge will slide between the sample and the surface plate, the bow in that direction exceeds the allowable percentage used in the calculation above. Repeat this procedure until all sides of the sample have been measured.

5.1.5 If a determination of actual percentage of bow is desired, repeat 5.1.1 through 5.1.4 using a feeler/pin gauge that will easily fit between the side of the sample and the surface plate. Continue to increase the feeler/pin gauge size until the largest feeler/pin gauge that will fit between the sample and the surface plate for both the length (x2) and width (x2) is obtained. Measure this feeler/pin gauge with the micrometer and record as R_L or R_W.

Calculate the percentage for bow as follows:

$$B_L = \frac{R_L}{L} \text{ X } 100 \qquad B_w = \frac{Rw}{W} \text{ X } 100$$

Where:

B_L = Percentage bow in the length direction
B_W = Percentage bow in the width direction
R_L = Measured maximum feeler/pin gauge size across sample length
R_W = Measured maximum feeler/pin gauge size across sample width
L = Length measurement as determined above
W = Width measurement as determined above

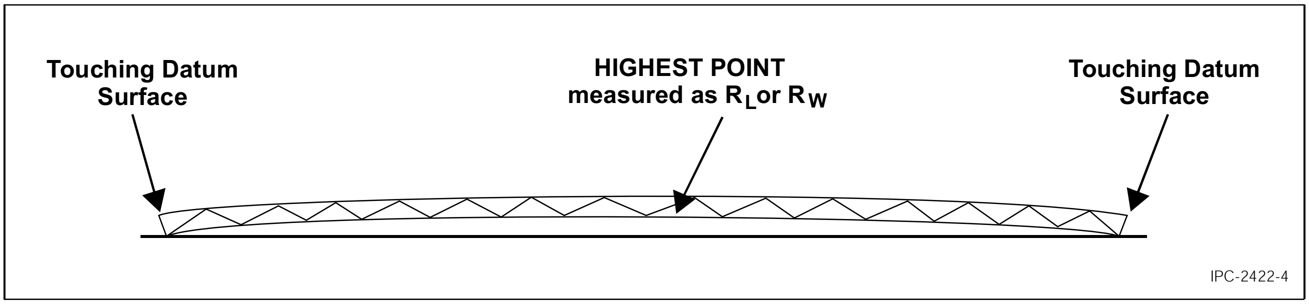

Figure 4 **Bow Measurement**

5.2 Production Testing (Twist)

5.2.1 Place the sample on the surface plate. While applying sufficient pressure to flatten the test sample, take the diagonal measurement across the sample and record it as D (see Figure 3).

5.2.2 Calculate the size of the feeler/pin gauge (Go/No-Go) to be used for maximum twist percentage using the following formula:

$$R = \frac{2\ (D)\ (T)}{100}$$

Where:

R = Go/No-Go feeler/pin gauge size

D = Diagonal measurement across the sample as determined above

T = Maximum allowable twist percentage

Note: This formula includes a factor of two because, by constraining one corner of the sample on a surface plate, the vertical deflection of twist is approximately doubled.

5.2.3 Place the sample to be measured on the surface plate with any three corners of the sample touching the surface. Apply sufficient pressure (if necessary) to only one corner of the sample to ensure three of the four corners are in contact with the surface plate. It may be necessary to turn the sample over to accomplish this (see Figure 5).

5.2.4 If it is not possible to get three corners of the sample to touch the surface plate by restraining only one corner, this production test is not applicable and the referee test described in 5.3 shall be used.

5.2.5 Attempt to slide the feeler/pin gauge of thickness R under the corner not touching the surface plate. If the Go/No-Go feeler/pin gauge will slide under the corner not touching the surface plate without lifting any of the other three corners of the sample from the surface plate, the twist in that direction exceeds the allowable percentage used in the calculation above. Repeat this procedure until all corners of the sample that can be measured using this technique have been measured.

5.2.6 If a determination of actual percentage of twist is desired, repeat 5.2.1 through 5.2.5 using a feeler/pin gauge that will easily fit under the corner that is not touching the surface plate. Continue to increase the feeler/pin gauge size until the largest feeler/pin gauge size that does not lift any of the three touching corners from the surface plate is obtained. Measure this feeler/pin gauge with the micrometer and record as R.

5.2.7 Calculate the percentage of twist as follows:

$$\text{Percentage Twist} = \frac{R}{2\ (D)} \text{ X } 100$$

Where:

R = Go/No-Go feeler/pin gauge size

D = Diagonal measurement across the sample as determined above

Note: This formula includes a factor of two because, by constraining one corner of the sample, the vertical deflection of twist is approximately doubled.

5.3 Referee Method (Twist)

5.3.1 Place the sample to be measured on the datum surface with the two lower opposite corners touching the datum surface or on a raised parallel surface of equal height from the datum surface (see Figure 6).

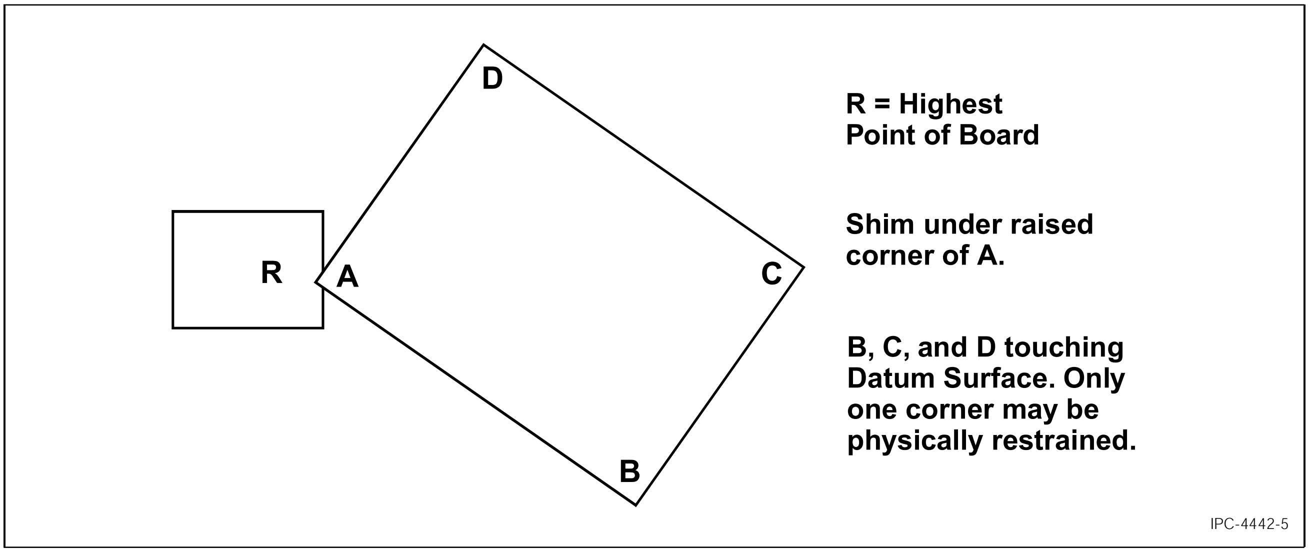

Figure 5 **Measurement of Twist**

5.3.2 Support the other two corners with leveling jacks or some other appropriate devices, ensuring the two raised corners are of equal height from the datum surface. This may be checked by using the dial indicator (see Figure 7).

5.3.3 Using the dial indicator, measure the highest raised portion on the board and record the reading as R1 (see Figure 8).

5.3.4 Without disturbing the sample, take a reading with the dial indicator on one of the corners contacting the surface (R2) and record the reading (see Figure 8).

5.3.5 Take the diagonal measurement of the sample and record the reading.

5.3.6 Calculation Deduct the measured R2 from the measurement R1. This difference is denoted as twist. Divide the measured deviation by the recorded length and multiply by 100. The result of this calculation is the percentage of twist.

$$\text{Percentage Twist} = \frac{R1 - R2}{L} \text{ X } 100$$

6 ***Notes*** None

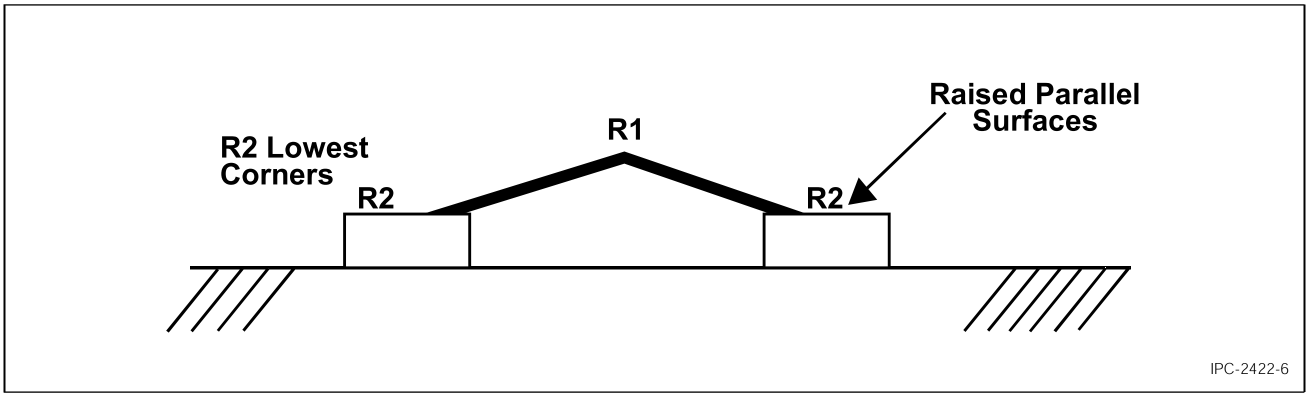

Figure 6 **Sample Placement**

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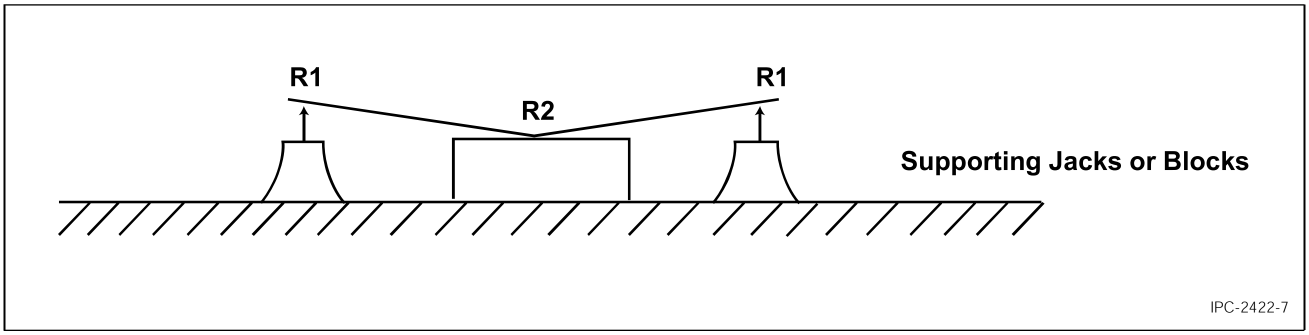

Figure 7 Corners Supports

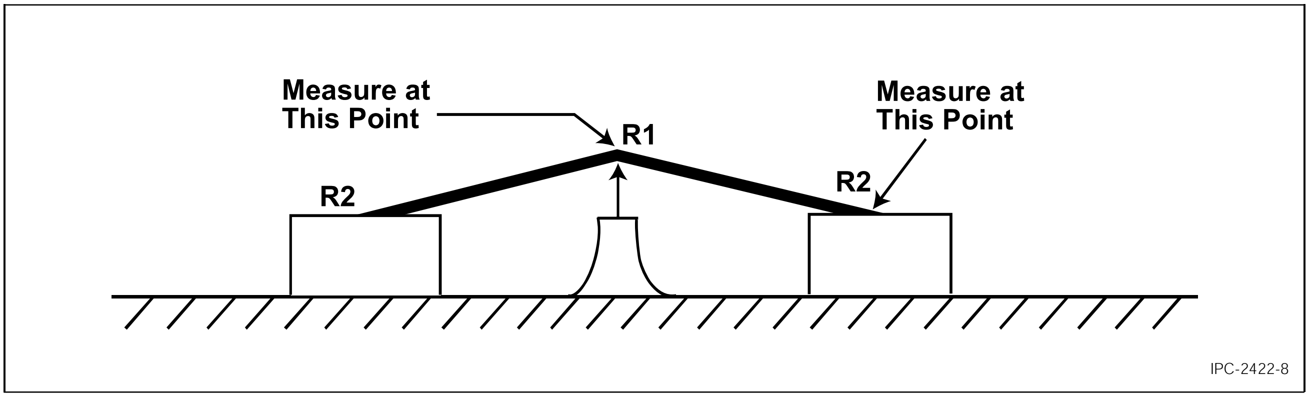

Figure 8 Highest Point Measurement

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TEST METHODS MANUAL

Number **2.4.22.1**	
Subject **Bow and Twist—Laminate**	
Date **5/93**	Revision **C**
Originating Task Group	

1.0 Scope This method covers the measurement of bow and twist by maximum vertical displacement of an unrestrained panel of either cut to size panels or finished rigid printed boards including single- and double-sided, multilayer, and the rigid segments of rigid flex printed circuits. This test method is only applicable to laminates greater than or equal to 0.5 mm [0.020 in] in thickness. This test method can also be used after etching or after thermal stress with requirements as agreed between user and vendor.

2.0 Applicable Documents

None

3.0 Test Specimen The test specimen for incoming inspection shall be 300 x 300 mm ± 2 mm [12 x 12 in ± 0.08 in] in size. For smaller panel sizes and finished printed wiring boards, use actual size. A minimum of three specimens is required per sample, when evaluating pressed laminate sheets.

4.0 Apparatus

4.1 Sample Shear

4.2 Granite Surface Plate or Equivalent

4.3 Feeler Gauges or Equivalent

4.4 Micrometer

5.0 Test Procedure

5.1 Preparation of the Test Specimen

5.1.1 For laminate sheet, the test specimens are to be cut in such a fashion as to minimize mechanical flexing.

5.1.2 For cut to size panels or printed wiring boards, use actual size.

5.1.3 Mark the specimen for traceability. No mechanical or chemical pre-cleaning is permitted on the specimens.

5.2 Measurement of Bow and Twist

5.2.1 Place the test panels on the surface plate such that the maximum vertical displacement is observed. The panel should be turned over in establishing the maximum vertical displacement. The maximum vertical displacement may be a corner or a side of the test specimen as illustrated in Figures 1 and 2.

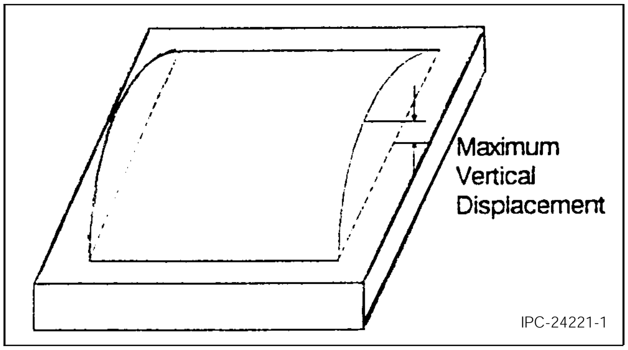

Figure 1

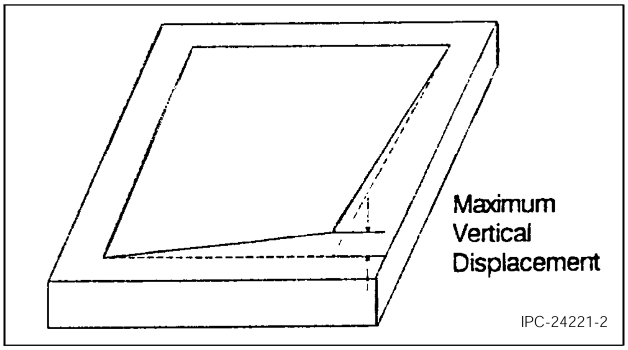

Figure 2

5.2.2 Measure the maximum vertical displacement by inserting the feeler gauges between the surface plate and the bottom surface of the laminate.

5.2.3 Verify the thickness measurement by measuring the total thickness of the feeler gauges with the micrometer.

5.2.4 Record the maximum vertical displacement in 0.25 mm [0.01 in]. One value is recorded per test specimen. This is the bow and twist of the test specimen.

5.3 Calculation of Results

5.3.1 Average Bow and Twist Results

Bow and Twist =

$$\frac{\text{Sum of the Measured Maximum Vertical Displacements in mm [in]}}{\text{Number of Test Specimens}}$$

5.3.2 Maximum Bow and Twist Results The maximum vertical displacement in mm [in] obtained for each lot of material.

6.0 *Notes*

6.1 This is the referee method; other methods of measurement are allowable, if agreed upon between user and vendor.

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TEST METHODS MANUAL

Number
2.4.22.2

Subject
Substrate Curvature: Silicon Wafers with Deposited Dielectrics

Date
7/95

Revision

Originating Task Group
Deposited Dielectric Task Group (C-13a)

1.0 Scope This test method establishes a procedure for determining the flatness of silicon wafers coated with deposited organic films.

2.0 Applicable Documents

ASTM D 618 Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing

3.0 Test Specimen The test specimens are 125 mm diameter silicon wafers 625 ± 15 µm in thickness. The surface of the wafers must be clean, and at least one side of the wafers must be polished. A minimum of 9 wafers are required.

4.0 Apparatus or Material

4.1 Radius Of Curvature Measurement Device Flexus Thin Film Stress Measuring Apparatus (TFSMA) Model 2-300 or equivalent.

4.2 Wafer Thickness Measurement Device Micrometer capable of measuring accurately to 5 µm. A thickness gauge including weights can also be purchased from Flexus that can be used with the TFSMA to measure thickness.

4.3 Film Thickness Measurement Device Nanospec Model 210, Tencor AlphaStep, or equivalent film thickness measurement device capable of measuring accurately to 0.1 µm.

5.0 Procedure

5.1 Radius Of Curvature Of Uncoated Wafers

5.1.1 Label each wafer with a unique identification.

5.1.2 Measure the thickness of the uncoated silicon wafers.

5.1.3 Measure the radius of curvature of the uncoated wafers following the manufacturers recommended procedure.

5.2 Coat Wafers

5.2.1 Use a minimum of three film thicknesses for each polymer or processing condition investigated. The film thicknesses should span as large a range as possible, e.g., 5, 10 and 15 µm. Coat at least three wafers for each film thickness for a minimum of nine wafers.

5.2.2 Coat the polymer solution onto the back (unpolished side) of the silicon wafers using manufacturer s recommended deposition technique (e.g., spin coating). Process the coating according to the manufacturer s recommended procedures. The final film thickness must not vary by more than 2% across the substrate surface.

5.3 Radius of Curvature Of Coated Wafers

5.3.1 The coated wafers should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for exactly 24 hours prior to testing. Many polymers exhibit stress relaxation or a decrease in stress associated with moisture absorption, therefore it is essential that the coated wafers are equilibrated under identical conditions. Refer to ASTM D 618.

5.3.2 Measure the radius of curvature of the coated wafers following the equipment manufacturer's recommended procedure. Correct placement of the wafers in the device is essential to compensate for nonuniform wafers, therefore the wafer must be placed in the same position for each measurement. At this point the coating thickness is unknown; however, some value may be required by the curvature measurement device. Use whatever number is convenient for now, the data will be edited later.

5.3.3 Repeat step 5.3.1 four (4) times for each wafer. The reason for the repeated measurements is to generate an average to compensate for errors in placing the wafer in the curvature measurement device at the exact position in which it was originally measured during step 5.1.3.

5.4 Film Thickness Measurements Measure the film thickness on each coated wafer to an accuracy of 0.1 µm or better using the film thickness measurement device. The thickness should be measured at several different locations to compensate for nonuniform coatings.

5.7 Calculations

5.7.1 Calculate the average effective radius of curvature and the standard deviation for each wafer from the 4 measurements made on each wafer in step 5.3.2 using the following equation:

$$R = \frac{(R_1\ R_2)}{(R_1 - R_2)}$$

where R1 and R2 are the radius of curvature of the uncoated and coated wafers respectively. The standard deviation is calculated as follows and reported to two significant figures:

$$S_x = \sqrt{\frac{N\sum_{i=1}^{N} X_i^2 - \left(\sum_{i=1}^{N} X_i\right)^2}{N(N-1)}}$$

where X_i is the value of a single observation (i = 1 through N), N is the number of observations and s_x is the estimated standard deviation.

5.7.3 Calculate the average effective radius of curvature for each film thickness using the averages from step 5.7.1 of all three wafers at the same film thickness. Do not include in the calculation the data from any wafer for which the standard deviation from 5.7.1 is greater than 10%.

5.7.4 Convert the average effective radius of curvature for each film thickness from step 5.7.3 into the wafer deformation, h, using the following equation

$$h = R_A - \sqrt{R_A^2 - \frac{L^2}{4}}$$

where L is the diameter of the wafer and R_A is the average effective radius of curvature obtained in 5.7.3.

5.7.5 Curvature Slope The wafer deformation values for each film thickness from step 5.7.4 are plotted as wafer deformation (y-axis) versus film thickness (x-axis). An equation of the form y = mx (i.e. a straight line with intercept at x = 0, y = 0) is fit to the data (unweighted) and the slope of the line can be used to compare different materials or processes when coated on identical substrates. A typical plot is illustrated in Figure 1.

6.0 *Notes*

6.1 The Flexus determines the radius of curvature by shining a He-Ne laser beam through a beam splitter. The two beams are reflected off the surface of the wafer into detectors. The radius of curvature, R, is calculated from the angle of reflection and the distance between the two beams. If measurements are made on the coated side of the wafer, the laser beam is refracted twice, once upon entering the polymer layer and again upon exiting the polymer layer. As the polymer layer increases in thickness, the refracted laser beam can no longer be correctly detected by the detector, resulting in erroneous values for the radius of curvature. In practice, the upper limit on thickness for polyimides was found to be approximately 10-12 µm. To avoid this complication, the polymer films are deposited on the back of the wafers and the measurements are made on the front (polished side) of the wafer. This extends the useful thickness range to 50 µm.

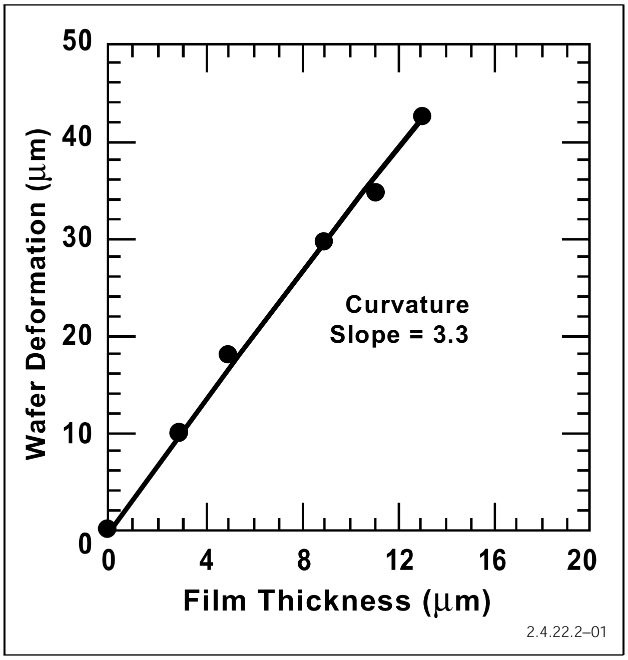

Figure 1

6.2 The radius of curvature will depend on the thickness of the wafer. Wafers of comparable thickness (625 ± 15 µm) must be used when making comparisons of different materials.

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IPC-TM-650
TEST METHODS MANUAL

Number **2.4.23**	
Subject **Soldering Resistance of Laminate Materials**	
Date **3/79**	Revision
Originating Task Group **N/A**	

1 Scope This test method is used to determine the resistance of laminate materials (both unclad and etched surfaces) to the thermal abuse of a solder dip. Resistance to softening, loss of surface resin, scorching, delamination, blistering and measling are considered in the evaluation.

2 Applicable Documents

IPC-TM-650 Test Methods Manual
2.4.1

Adhesion, Tape Testing

2.4.12

Solderability, Edge Dip Method

MIL-F-14256 Flux

3 Test Specimen Each specimen must be 3.18 cm x 3.18 cm thickness. A separate specimen is required for the unclad, etched, fluxed, and unfluxed tests. Three samples are required from each sheet.

4 Equipment/Apparatus

4.1 An electrically heated, thermostatically controlled pot of sufficient size to accommodate the specimen and containing no less than 2.25 kg of Sn60 or Sn63

4.2 A device, as shown in Figure 1, or some other similar device may be used, if:

- The rate of immersion, dwell time, and withdrawal are within the test limits described in the procedure
- The specimen and solder surface remain perpendicular within 5°
- Wobble, vibrations, and other extraneous movements are eliminated

4.3 Warnow 2-710 black acid resisting ink, or equivalent

4.4 NAZ-DAR ER-111 black epoxy ink, or equivalent

4.5 A convection drying oven capable of attaining at least 149°C

5 Procedure

5.1 Etched and Unetched Specimen

5.1.1 Expose:

- One specimen having a surface upon which no metal cladding was ever applied
- One specimen on which the metal cladding has been removed by standard etching processes
- One specimen with metal cladding remaining to the Solderability Edge Dip Method in IPC-TM-650, Method 2.4.12

5.1.2 Examine the specimens for evidence of discoloration or surface contaminants, loss of surface resin, softness, delamination, interlaminar blistering, or measles. The specimen having metal cladding must also be examined for blistering or delamination of the metal foil from the laminate material.

5.2 Plastic Surface Tape Test

5.2.1 Screen print one of the test inks to the surfaces of an unclad specimen and an etched specimen.

5.2.2 Treat test inks as follows:

1. Warnow 2-710: Cure for a minimum of 30 minutes in air or oven. The dry film must be hard and dull in finish.
2. NAZ-DAR ER-111: Cure for a minimum of 8 minutes at 135°C. The cured ink must have a hard glossy finish.

5.2.3 After the specimens have cured properly, perform the plating adhesion test on the inked surfaces, as defined in IPC-TM-650, Method 2.4.1. Use type I class A tape.

5.2.4 Carefully examine specimens for the items discussed in 5.1.2.

5.2.5 Examine for evidence of mold release agents, indicated by particles of ink adhering to the tape, or by the absence of ink from the laminate surface, or both.

5.3 Fluxed and Unfluxed Specimens