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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.22.2	
Subject	
Substrate Curvature: Silicon Wafers with Deposited Dielectrics	
Date	Revision
7/95	
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.

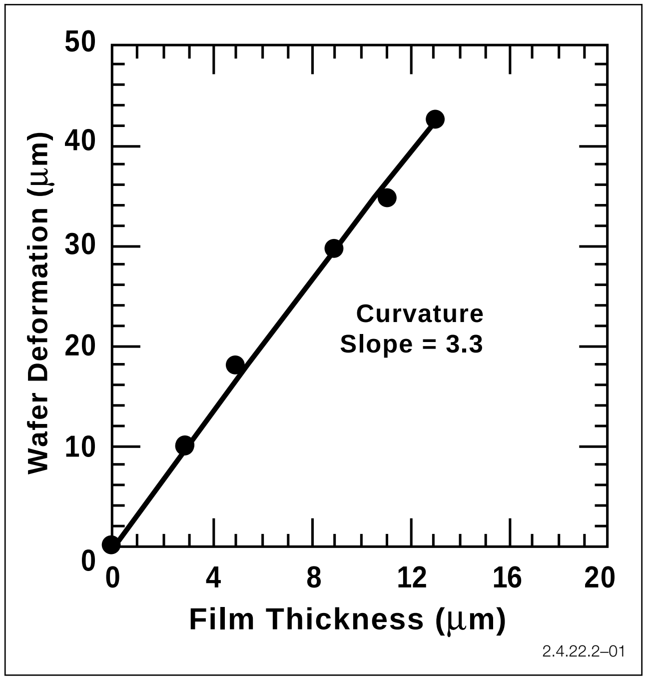

Figure 1

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.

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.