JEDEC STANDARD

Package Warpage Measurement of Surface-Mount Integrated Circuits at Elevated Temperature

JESD22-B112C

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PACKAGE WARPAGE MEASUREMENT OF SURFACE-MOUNT INTEGRATED CIRCUITS AT ELEVATED TEMPERATURE

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PACKAGE WARPAGE MEASUREMENT OF SURFACE-MOUNT INTEGRATED CIRCUITS AT ELEVATED TEMPERATURE

(From JEDEC Board Ballot JCB-23-41, formulated under the cognizance of the JC-14.1 Subcommittee on Reliability Test Methods for Packaged Devices.)

1 Scope

The purpose of this test method is to measure the deviation from uniform flatness of an integrated circuit package body for the range of thermal conditions experienced during the surface-mount soldering operation.

2 Background

When integrated circuit packages are subjected to the high-temperature solder reflow operation associated with circuit board assembly, deformation and deviation from an ideal state of uniform planar flatness, i.e., warpage, often results. The package warpage during board assembly can cause the package terminals to have open or short circuit connections after the reflow soldering operation. Certain package types, such as ball grid arrays (BGAs), have been found to be more susceptible to component warpage. Intrinsic package warpage is largely driven by coefficient of thermal expansion mismatch between the various packaging material constituents, but can also be affected by absorbed moisture. Package warpage is temperature dependent, and the final warpage state is a function of the entire temperature history or reflow profile.

JESD22-B108B measures device terminal coplanarity only at room temperature and cannot be used to predict warpage at elevated temperatures. The worst-case warpage may be at room temperature, maximum reflow temperature, or any temperature in-between; consequently, package warpage must be characterized during the entire reflow soldering thermal cycle. Critical engineering evaluations of the package and printed circuit board warpage should be conducted in the laboratory under simulated reflow conditions. For many packages, warpage can change with continued reflow cycles so this measurement should be made and reported for the first reflow cycle.

3 Terms and Definitions

concave warpage: Negative (-) warpage resulting in the package corners being farther from the contact plane than the center of the bottom surface of the package substrate. This is figuratively referred as a smiling face occurrence. See Figure 1a.

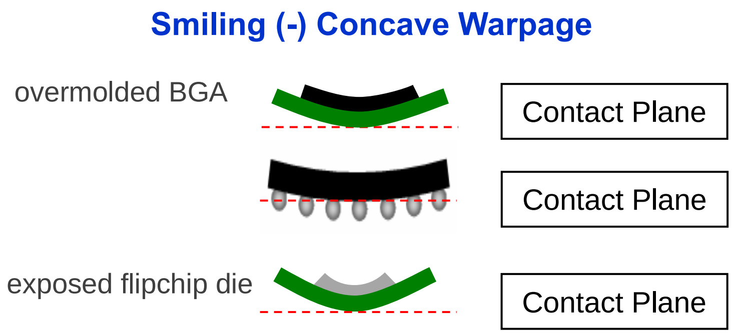


Figure 1a — Package Concave Warpage

contact plane: A plane parallel to the reference plane passing through the lowest contact point on the package substrate.

convex warpage: Positive (+) warpage resulting in the package corners being closer to the contact plane than the center of the bottom surface of the package substrate. This is figuratively referred as a frowning face occurrence. See Figure 1b.

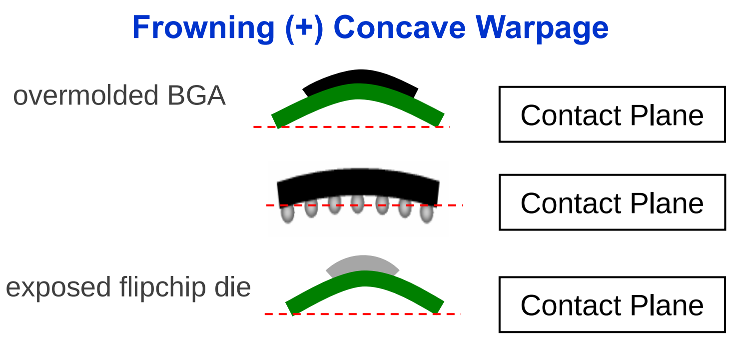


Figure 1b — Package Convex Warpage

complex warpage: Various warpage shapes that are not represented by the convex or concave warpage such as ‘M’ shaped warpage, ‘W’ shaped warpage, or twist warpage

deviation from planarity: The difference in height between the highest point and the lowest point on the package substrate bottom surface measured with respect to the reference plane.

digital image correlation: A 3D imaging technique utilizing multiple triangulated cameras and computerized image matching.

fringe projection: The projection of structured light on the sample utilizing image processing to determine package surface displacement.

3 Terms and Definitions (cont'd)

laser reflectometry: Use of a confocal microscope to determine focal plane and thereby measure the displacement of a surface.

package warpage: The maximum distance between the contact plane and the bottom package surface within the measurement area.

peak reflow temperature: The maximum package reflow temperature as specified in J-STD-020 depending on package dimensions and whether the product is intended for eutectic Sn-Pb or Pb-free reflow soldering temperature.

rated moisture sensitivity level (MSL): The moisture sensitivity level as determined by J-STD-020.

reference plane; regression plane: A least-squares fit of all the bottom-side or top-side measurement points on a package.

shadow moiré: Referring to an optical noncontact method to measure warpage using a moiré fringe pattern resulting from the geometric interference between a flat reference grating and the projected shadow of the grating on a warped test object.

4 Reference Documents (informative)

JEITA ED-7306, *Measurement methods of package warpage at elevated temperature and the maximum permissible warpage*

J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices.*

J-STD-033, *Standard for, Handling Packing, Shipping, and Use of Moisture/Reflow Sensitive Surface-Mount Devices.*

JESD22-A113, *Preconditioning of Nonhermetic Solid State Surface Mount Devices Prior to Reliability Testing.*

JESD22-B100, *Physical Dimensions*.

JESD22-B108, *Coplanarity Test for Surface-Mount Semiconductor Devices*.

5 Measurement Instrument Requirements

5.1 General Metrology Considerations

Warpage metrologies such as Shadow Moiré, 3D Digital Image Correlation, Fringe projection (structured light phase modulation), and various forms of line scanning and/or high-resolution focusing based tools have been successfully applied and validated under ambient test conditions. A few of these tools have been successfully adapted and commercialized to support in-situ package warpage measurements at elevated temperatures. This specification focuses on general measurement issues and presents some tool specific considerations. Temperature uniformity across the sample, rate of the temperature ramp, and moisture absorbed in the measurement sample are all important variables.

The tool used for elevated temperature warpage metrology should be verified using a concave or convex warpage standard that is invariant to temperature changes across the temperature range of interest, as outlined in clause 6. Measurement accuracy should be verified at temperature extremes such as through the use of a concave or convex ground glass manufactured from ultra-low-expansion material such as Zerodur® optical ceramic with a coefficient of linear expansion between 20˚C and 300˚C of 0.05 ± 0.10 x 10-6/°C. Periodic repeatability measurements should be conducted at elevated temperature using the high temperature warpage standard.

Reproducibility of test data should be initially evaluated with respect to any operator-to-operator, day-to-day, or other extrinsic factors which may potentially influence tool performance. Once successfully validated, the tool should be routinely calibrated and monitored on a periodic basis. Sample preparation, temperature profiling, and sample temperature distribution guidelines should be followed according to clause 7 of this document.

5.2 Thermal Shadow Moiré Apparatus

5.2.1 Camera to capture shadow moiré pattern

5.2.2 Ronchi ruled grating made from low CTE glass, specifically defined lined pitch grating through which light passes to cast a shadow moiré pattern onto the sample. Typically 40 to 200 lines/cm.

5.2.3 Light source to project white light through the grating and to cast a shadow of the reference grating (i.e. Ronchi grating) on the sample. The observer sees the shadow on sample and the superimposed reference grating. Moiré pattern is formed by interaction between the shadow grating and the reference grating.

5.2.4 Electromechanical Z stepping sample stage for phase shifting and acquiring fringe pattern at different heights.

5.2.5 Computer controlled display system for fringe pattern display, storage, retrieval, printing and analysis.

5.2.6 Sample Holder used to hold and align the sample and to prevent it from moving during measurement.

5.2.7 NIST traceable calibration block using step height changes may be required for some instruments.

5.2.8 A curved glass standard made of ultra low expansion glass of known bend radius is also recommended for tool validation at elevated temperature.

5.2.9 Thermal chamber used to heat the samples for in situ warpage measurements, convection heating is preferred due to it similarity to actual solder reflow ovens. IR heating will produce temperature gradients across the device under test and may require the heating and cooling rates to be reduced in order to obtain accurate results.

5.2.10 Thermocouples attached to the sample or attached to a second identical reference sample used for measuring elevated temperature response. Temperature gradients across the sample may product erroneous results. Temperature uniformity should be verified on the reference sample or a test run.

5.2 Thermal Shadow Moiré Apparatus (cont'd)

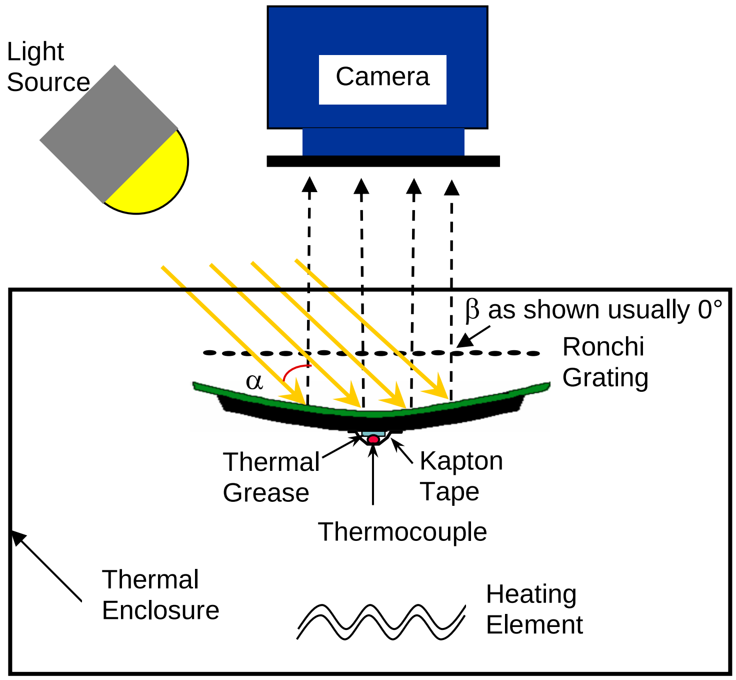


Figure 2 — Shadow Moiré Apparatus

Thermal Shadow moiré measurements are conducted by placing the Ronchi ruled grating and the sample of interest into a thermally insulated enclosure, see Figure 2. A heat source is then used to ramp the temperature of the sample under test.

A shadow of the reference grating is cast onto the surface of the specimen below by projecting a beam of white light at a specified angle through the grating. Moiré fringe patterns are produced as a result of the geometric interference pattern created between the reference grating and the shadow grating.

The Ronchi grating line spacing and overall planarity of the glass substrate are generally invariant to changes in temperature.

5.2.11 An accurately calibrated fringe constant is required to convert a whole field shadow moiré fringe pattern into a 3D surface map of package warpage. The shadow moiré fringe count is related to out-of-plane deformation (warpage) using the fringe constant calibration formula (1).

$$W = \frac{Np}{\tan\alpha + \tan\beta} \qquad (1)$$

where:
N = Fringe order
p = grating pitch
α = angle of illumination
β = angle of observation
W = out of plane (normal) displacement or warpage

5.2 Thermal Shadow Moiré Apparatus (cont'd)

In typical shadow moiré systems the imaging plane is directly over the object such that the observation angle $\beta=0°$ and the light source illumination angle $\alpha \geq 45°$.

Phase shifting is routinely implemented as a means of converting whole field fringe patterns into continuous 3D plots of surface topography, see Figure 3. A precise computer controlled stepper motor is utilized to displace the sample stage with respect to the glass grating and in doing so generates a series of discrete phase shifted fringe patterns. Typically four such patterns are acquired although numerous schemes exist that utilize 3 or more phase shifted patterns.

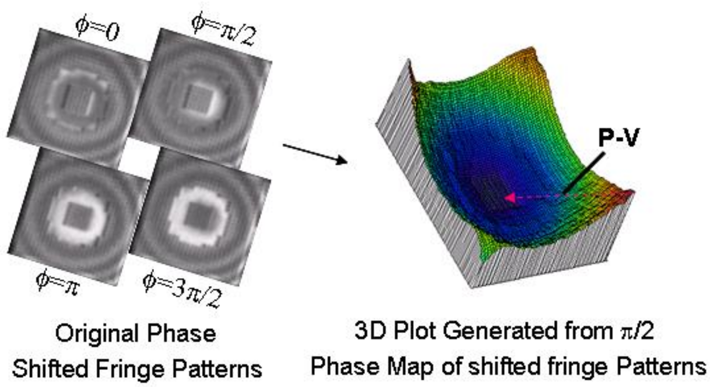


Figure 3 — Package Substrate Phase-shifted Fringe Pattern Sequence and Resulting 3D Surface Profile.

The Ronchi rule grating line frequency is typically in the range of 40 to 200 lines/cm and the physical gap required between the grating and sample is typically on the order of several millimeters. The physical gap between the grating and the sample is adjusted to optimize fringe contrast of the generated fringe pattern. Following equation (1), finer pitch gratings yield increased measurement sensitivity but require a smaller gap between the grating and sample in order to achieve good contrast. With a given grating frequency (pitch), the closer sample is placed to the reference grating, the better the fringe visibility; however, caution should be used that the samples do not touch the reference grating during testing. In general, the finest possible grating pitch should be used in order to maximize the fundamental sensitivity of the instrument.

The fringe pattern should generate a minimum of 2 circular or irregular concentric fringes when the sample is symmetrically oriented and nominally running parallel with respect to the plane of the Ronchi grating. If geometric considerations or the height of other assembled electronic devices restrict the proximity of the grating to the package surface, a coarser grating must then be considered that will necessarily permit a greater grating to sample gap.

Fringe analysis is applied to solve for the phase angle at each pixel location across a region of interest. Phase is then converted to displacement through use of the sensitivity relationship given by equation 1. The phase shifting technique has the added benefit of enhancing the overall system sensitivity since the ability to track small pixel to pixel intensity variations translates into fractional fringe resolution. Critical factors that ultimately limit phase shifting assisted resolution are fringe contrast, spatial noise, surface artifacts, CCD camera A/D bit resolution, and mechanical phase stepping accuracy and calibration.

5.3 Three-Dimensional DIC

Three-dimensional digital image correlation is a triangulation technique employing two or more calibrated cameras. Correspondence between object points is established by means of image matching techniques, which can achieve sub-pixel accuracies. The typical measurement setup for three-dimensional DIC consists of two cameras that are rigidly mounted on a bar to eliminate relative motion of the cameras as shown in Figure 4a. The triangulation angle between the cameras is typically kept in the range of 10-30 degrees. Depth sensitivity is increased by larger triangulation angles and shorter stand-off distances as shown in Figure 4b. The two cameras are normally hardware synchronized.

The calibration procedure involves taking successive images of the calibration target within the field of view (figure). Images should include rotating the target, tilting the target, and moving the target throughout the whole field of view. Target specifications include that the target should not deform throughout the calibration, and the distances between the dots should be known. In essence, calibration sets a distance scale for the camera system.

For this purpose, a random pattern on the object is employed to provide high information content for reliable matching. The pattern can either be naturally occurring, or permanently applied to the object using spray paint, etching, or a number of other techniques. Permanent application of the pattern to the object has the advantage that correspondence can be established throughout a time series of images, which permits measurements of deformations and strain.

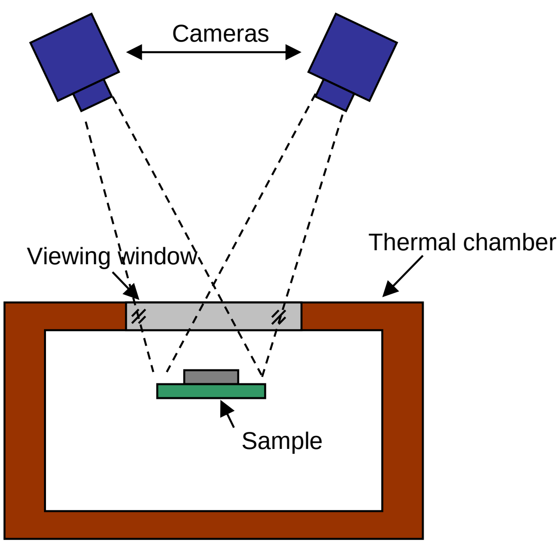


Figure 4a — Digital Image Correlation Setup

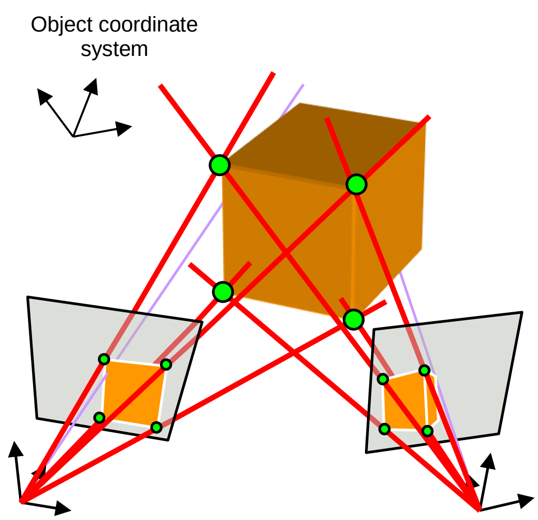


Figure 4b — Triangulation Setup

5.4 Laser Reflection Method (Confocal Displacement Metrology)

Confocal displacement metrology finds the position of best optical focus for a sample. When the lens accurately focuses the laser beam on the sample, the reflected beam converges precisely at the pinhole over the light-receiving element. At this lens position, the light-receiving element receives the maximum light intensity. As the lens moves closer to or further from the target, however, the reflected beam is diffused and does not converge at the pinhole over the light-receiving element. As a result, the quantity of light passing through the pinhole to the light-receiving element decreases greatly. Figure 5b shows the relationship between the lens position and the quantity of light-received. A detection signal is generated only when the lens is precisely positioned for maximum light reception (peak light quantity). The sensor then calculates the lens position and outputs a measured value. Since this measurement is at a point, translation stages are integrated to scan over entire sample surfaces. A sufficiently large number of measurement points are selected to construct whole shape of sample as shown in Figure 5a and Figure 5b.

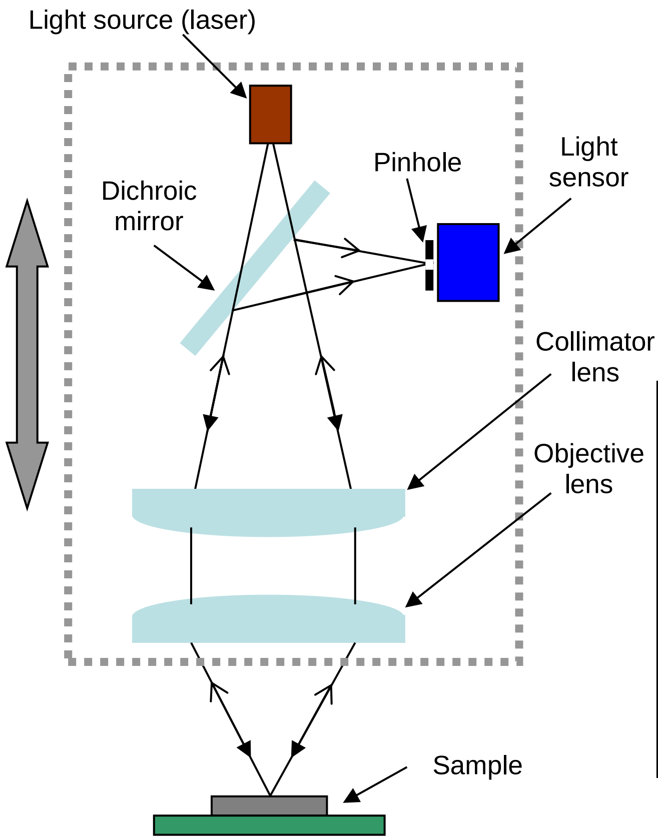


Figure 5a — Laser Reflection Setup

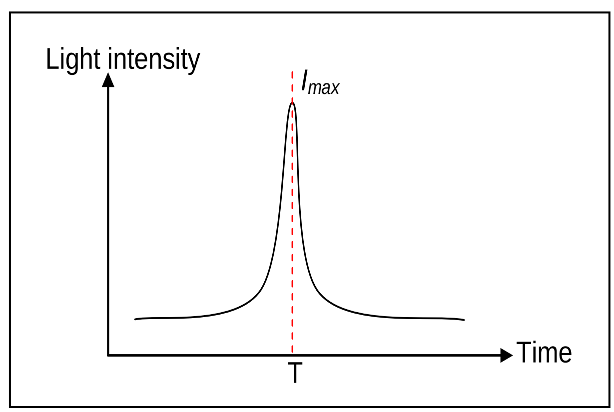


Figure 5b — Laser Intensity at the Sensor

5.5 Fringe Projection or Projection Moiré

This technique uses computer generated variable parallel stripes projected on the sample, and a CCD cameral to capture the stripe image. The structured light is directly projected onto the sample as shown in Figure 6. The stripe density is variable and controlled by the acquisition software without operator interaction. In the case of a plane, horizontal sample surface, the resulting pattern on the sample consists of parallel, equidistant dark and bright stripes of light. Each surface warpage results in a modification of the light pattern. Any arbitrary warpage will generate a complicated stripe structure, which is analyzed by the software to be represented as an ordinary 3D z(x,y) topography of the sample surface. Measurements can be made on BGA packages with the solder balls still attached. Software based reconstruction of 3D topography enables z-deformation calculation between different temperatures by image subtraction.

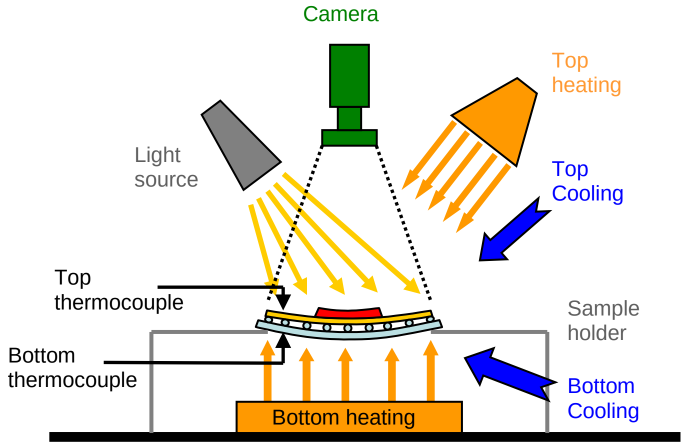


Figure 6 — Structured Light Phase Modulation Apparatus

5.6 Glass Datum Plane Method

This technique uses a measuring glass to hold the sample as shown in Figure 7. The surface of the measuring glass is virtually established as a datum plane or a horizontal reference level, on which the surface of the sample is supposed to be set for easy and precise reference. The laser sensor or camera placed under the glass datum plane to capture the position change of each terminal of the sample at different temperatures. The glass datum plane method can detect and measure the coplanarity or warpage of the target work piece as the deviation or distance from its surface at each point in numerical values. The same technique described in 5.4 can be implemented for this method. The benefit of this method is to measure the devices at the same orientation as how to attach the devices at system boards.

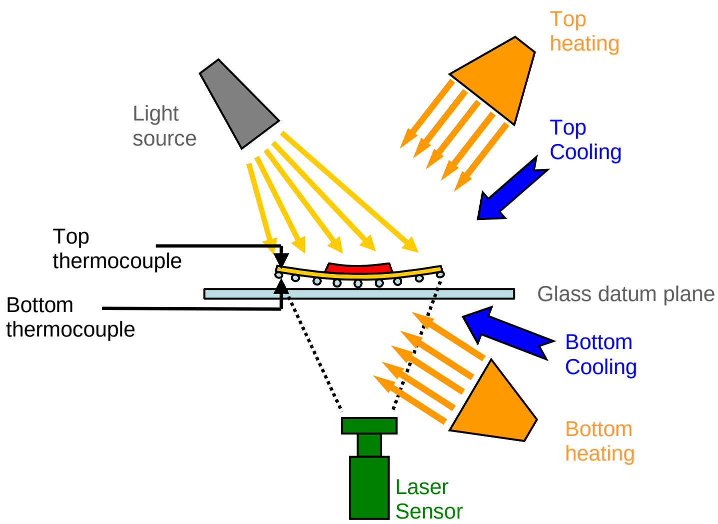


Figure 7 — Glass Datum Plane Method

6 Calibration Requirements

6.1 A calibration routine using a concave or convex warpage standard that is guided by the machine software should be utilized to initialize the instrument at room temperature before a series of measurements are made on any package style.

6.2 Measurement accuracy and tool repeatability at elevated temperature may be independently validated through the use of an ultra-low-expansion glass warpage standard which exhibits no measurable changes in warpage with increased temperature. The radius of curvature or warpage of the spherical glass standard should be independently established using a laser interferometer of higher overall accuracy.

6.3 Calibration procedure for measurement on the top surface of the package. In some BGA package variants it is difficult to use some of these techniques to measure package Warpage as package surface features interrupt these measurement techniques. In the case where package Warpage is measured on the top side it shall be verified on a package of similar construction that equivalent Warpage is observed. Variation in Warpage measurement of 10% or less shall be considered equivalent.

7 Test Procedures

For area array packages, warpage measurements should be viewed on the substrate side to effectively collect data for the entire planar region of the package footprint. Test samples may be assembled without solder balls attached in order to avoid possible measurement errors caused by light scattering from the solder balls. A simulated solder ball attachment process is recommended to subject the devices to the thermal process used to attach the solder balls. For any process to remove the solder balls, care should be taken not to disturb the structural integrity of the package that will ultimately affect the final warpage characteristic of the component. Verification of the technique used to remove the solder balls must be conducted. For many packages, warpage can change with continued reflow cycles so this measurement should be made and reported for the first reflow cycle.

For lead frame based packages, either the top or bottom for the package body surface can be measured. All measurements should maintain the (+/-) warpage convention as shown in Figure 1.

7.1 **Sample Size:** A minimum of 3 samples shall be measured to determine variation within an assembly lot. It is recommended that at least 2 samples be measured in each of the moisture soaked and dry (after bake as per J-STD-020) states if the warpage is affected by package moisture absorption. The minimum moisture soaked condition shall be the rated moisture sensitivity level per J-STD-020. More samples may be required for other purposes such as setting room temperature coplanarity limits.

NOTE This test is primarily intended for characterization of a package. If any changes to materials are made then the package should be re-characterized. If this test method is used for monitoring, then the package warpage may be measured in only the dry state.

7.2 Painting of the measurement surface may be required for enhancing light reflectivity and to achieve rated instrument accuracy.

7.3 **Thermocouple Placement:** Accurate temperature measurement of the sample body temperature is required during the thermal exposure in the chamber of 5.2.9 and will require that proper thermocouple type and attachment procedures are followed. It is recommended that a thermocouple of gauge 30 or finer is used and that the thermocouple is attached to the center of the package body using either a thermally conductive epoxy or attached using high temperature polyimide tape. When polyimide tape is used, it is recommended that a thermal paste should be applied between the thermocouple bead and the surface of the test sample to reduce the thermal contact resistance, thereby producing a more accurate and consistent body temperature measurement. Alternatively the thermocouple may be placed on a nearby adjacent package, this may be more practical for packages less than 1 cm^2 in area.

7 Test procedures (cont'd)

7.4 **Temperature Ramp Rate:** The temperature ramp rate during both heating and cooling will influence the measured warpage. Ideally, a temperature ramp rate that can closely match the thermal profile response as seen during board assembly should be used. However, if equipment limitations prevent the achievement of assembly matched ramp rates, the equipment should be configured to achieve as fast a ramp rate as possible without introducing significant temperature differences between the top and bottom of the package body. The temperature profiles in J-STD 020 are useful targets, if achievable. Temperature profiles should be shown in the full report.

NOTE Excessively long profiles or large temperature gradients may also introduce cracking and/or delamination of the packages as a result of moisture and/or reflow damage which may then result in erroneous warpage measurements. Excessively rapid ramp rates may induce temperature gradients across the sample that will alter the Warpage of the sample.

7.5 **Data Filtering:** Warpage measurement techniques may gather millions of individual data points and may apply smoothing or filtering functions to remove local variations such as residual solder from solder ball removal. The data filtering method, if employed, should be identified in the full report.

8 Parameters to be Measured

8.1 Total warpage magnitude (or peak-to-valley between the test surface and reference datum across the x-y spatial dimensions of the component) as a function of body temperature up to the peak reflow temperature. The measurement area should only encompass the soldering area as show in figure 7a for a full array and figure 7b for a partial array. Calculate the reference plane from the least squares fit of all data points in the measurement area. The contact plane is parallel to the reference plane at the lowest point on the package.

8.2 Magnitude of the package warpage assigning a positive warpage magnitude as convex in shape and negative as concave, e.g., positive magnitude assigned for packages with the corners warped down towards the contact plane "frowning", refer to Figure 1 and see Annex A. Warpage is measured for the all positions on the package in the measurement area as shown in figure 7. The data may be presented in microns or mils and the units of measure shall be clearly noted. Warpage can be measured in two ways: in 3D contour plots or diagonal line scans. The max warpage will be the difference in height between the lowest point and the highest point for the same temperature.

8.3 A plot showing total warpage magnitude versus temperature with the (+) and (-) conventions assigned. See Annex A.1 for an example of a unit with significant warpage over temperature and hysteresis. See Annex A.2 for device with minimal hysteresis.

8 Parameters to be measured (cont'd)

8.4 3-D contour plots of package shape as a function of peak reflow temperature. Such plots should be carefully reviewed in conjunction with peak-to-valley data order to determine whether reported peak-to-valley readings are reliable and not skewed by any image processing artifacts such as sharp edge discontinuities or surface irregularities of the test sample. See Annex A.2 for a sample with both hysteresis and moisture sensitivity. This detailed information is useful for engineering improvement activities and is not required for successful reflow soldering. See Annex A.3 for a package with minimal hysteresis and moisture sensitivity.

8.5 Diagonal line scans showing total warpage magnitude across the diagonal of the component, see Annex A.2. Similar to contour plots, this information is optional for normal reflow soldering.

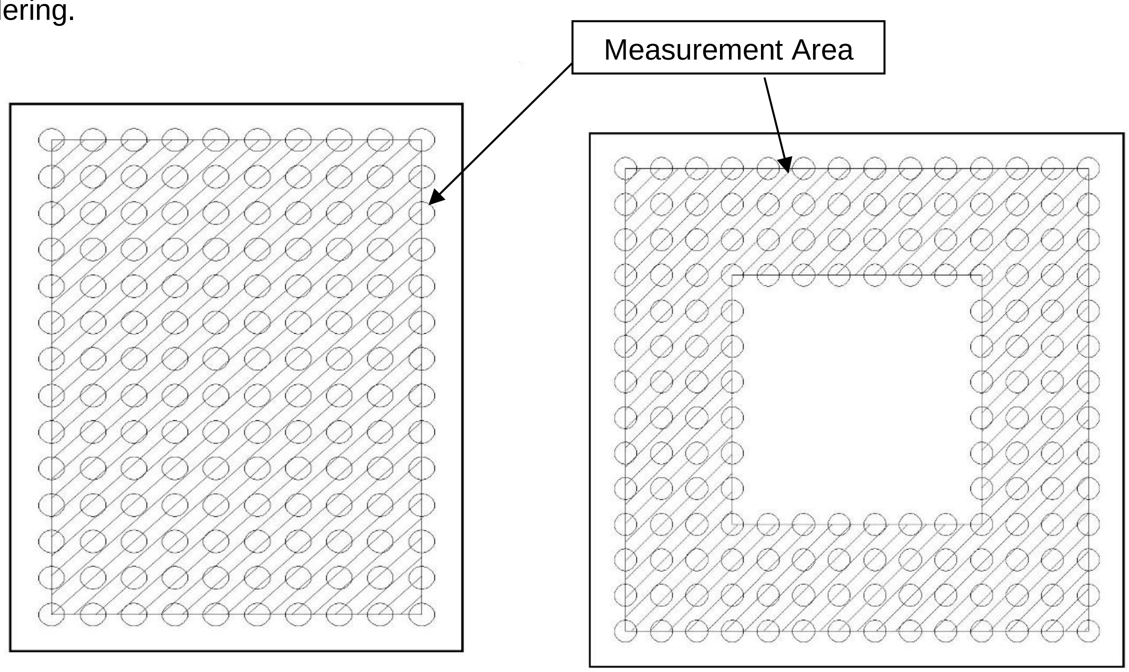


Figure 8a — Full Array Measurement Area

Figure 8b — Partial Array Measurement Area

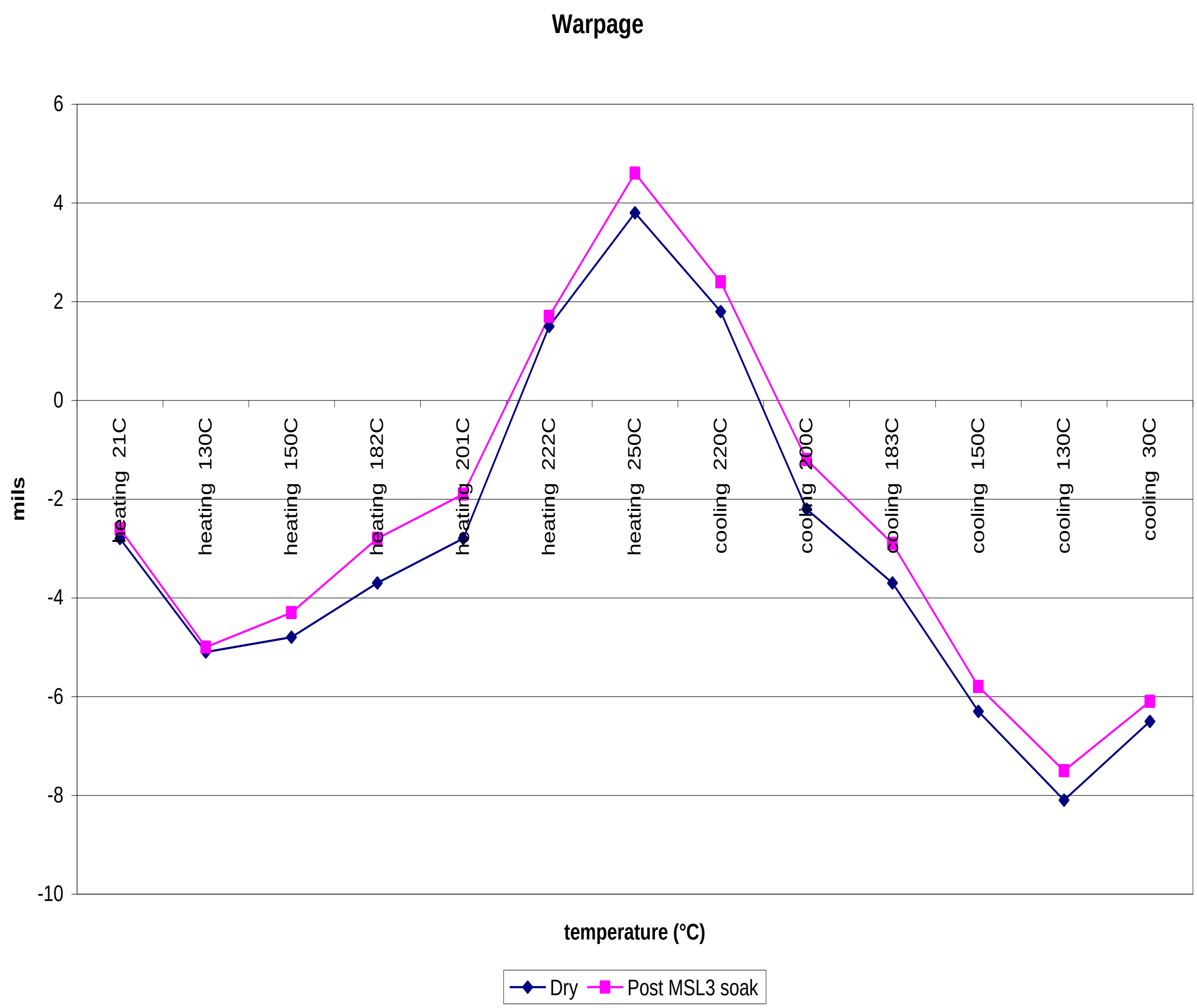
Annex A (informative) Sample Warpage Data Report

Warpage of device at various temperatures of simulated surface mount reflow (Dry and Post moisture soak)

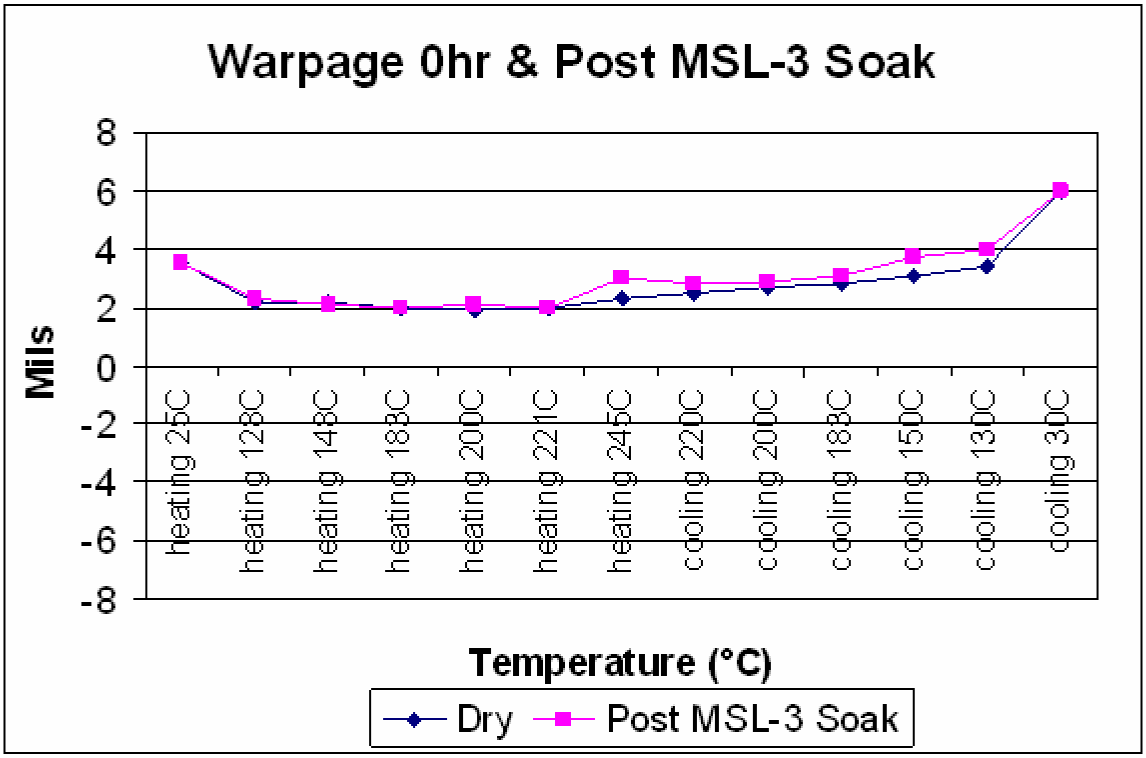
Device: Sample1 serialization

Package information: dimensions, BOM, etc.

A.1 Plot of Warpage vs Temperature – Device with Hysteresis

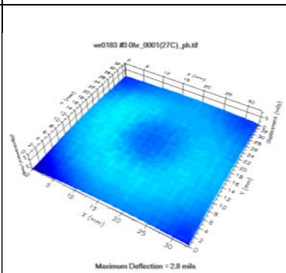
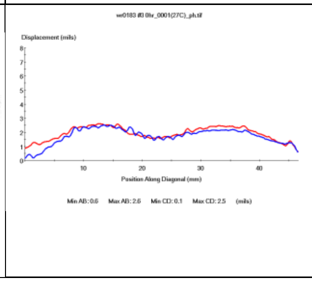
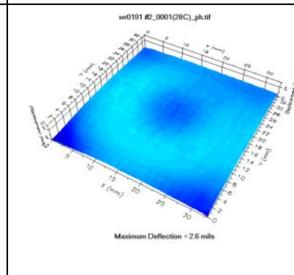
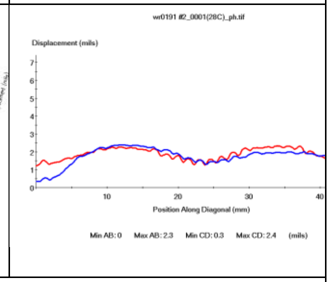
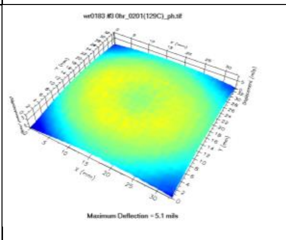
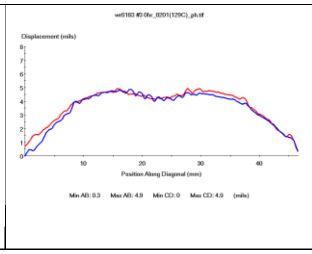
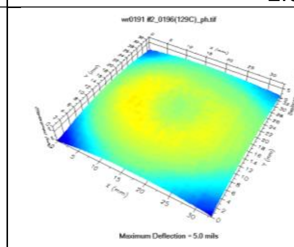
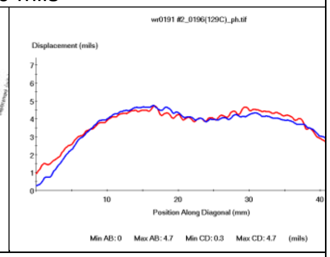
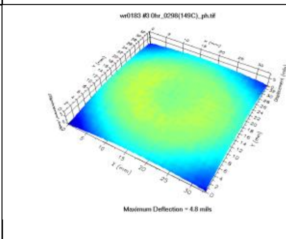
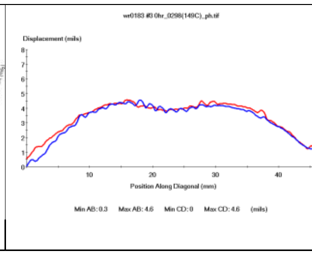
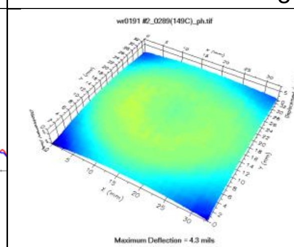
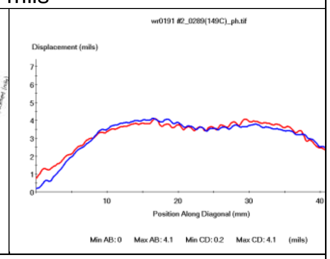
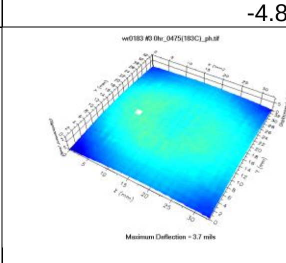
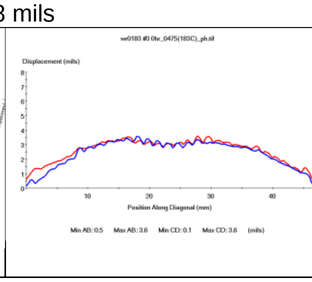
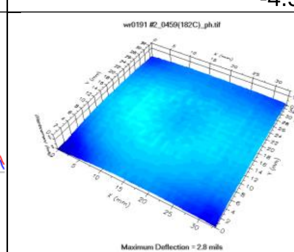
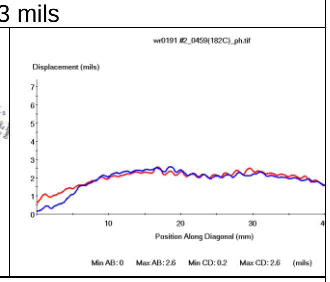
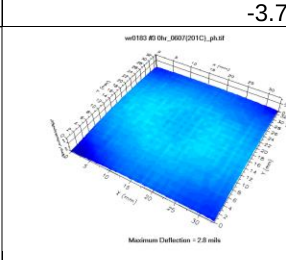
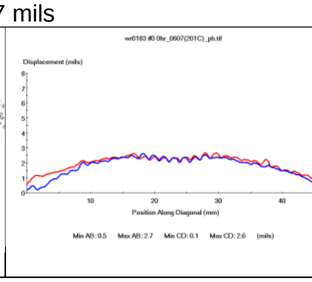
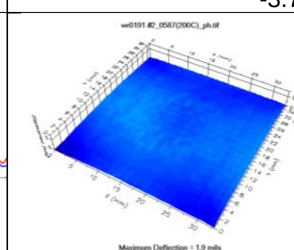
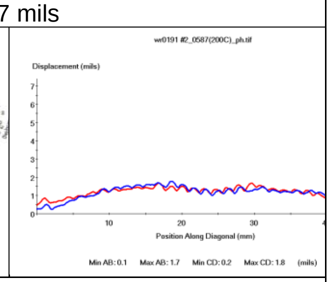


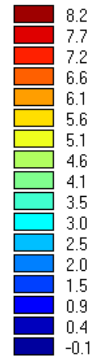
A.2 Plot of Warpage vs Temperature – Device with Minimal Hysteresis

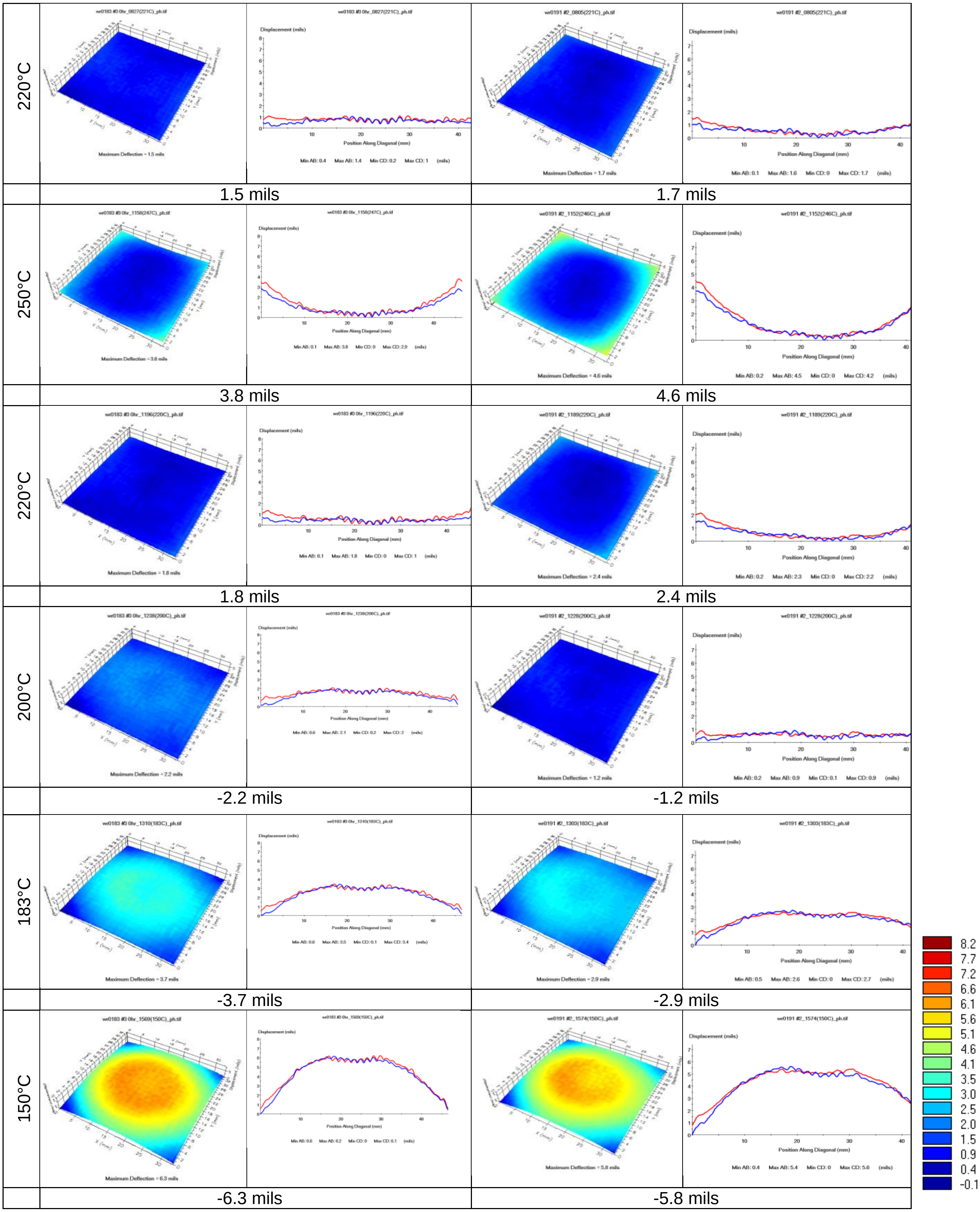


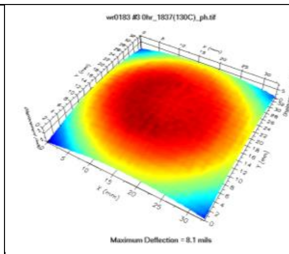
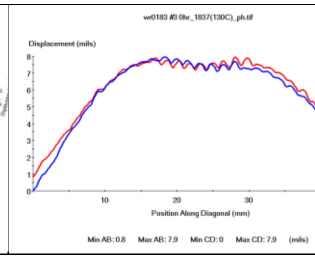
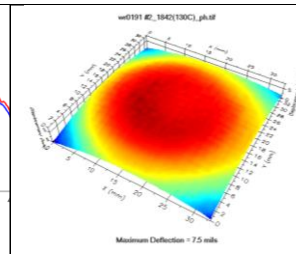
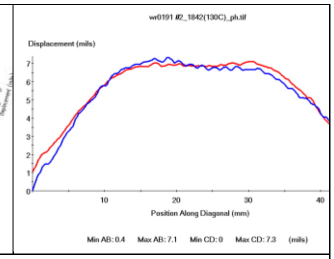
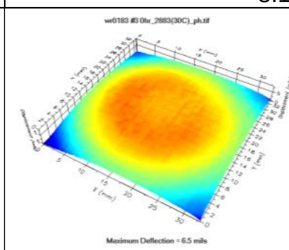
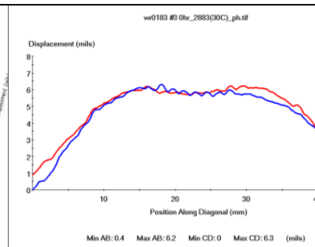
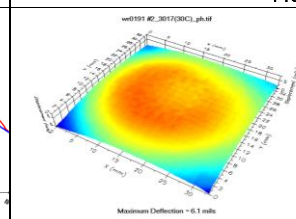
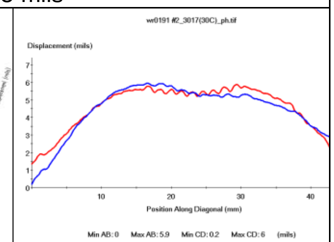
A.3 Graphical Representation of Measured Warpage at Temperature

Samples in "dead bug" position, in mils. Device with moisture sensitivity and hysteresis.

	Post Bake		Post MSL soak	
	3D contour plots	Diagonal line scans Corner to Corner	3D contour plots	Diagonal line scans Corner to Corner
30 °C				
	-2.8 mils		-2.6 mils	
130°C				
	-5.1 mils		-5 mils	
150°C				
	-4.8 mils		-4.3 mils	
183°C				
	-3.7 mils		-3.7 mils	
201°C				
	-2.8 mils		-1.9 mils	

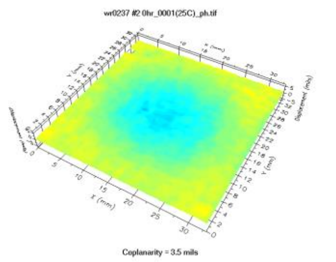
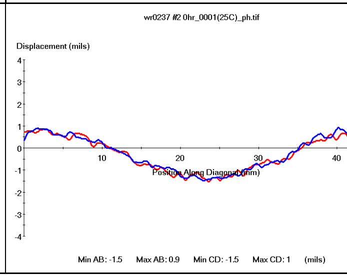
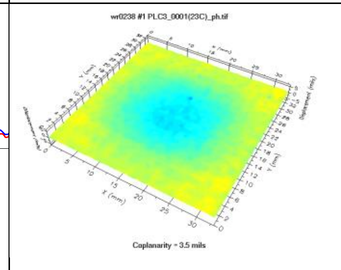
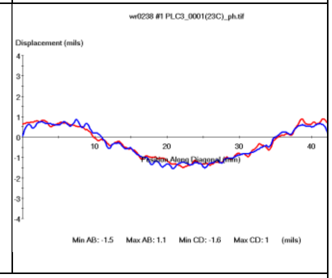
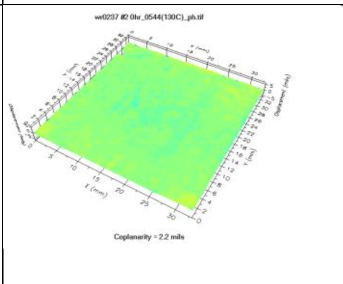
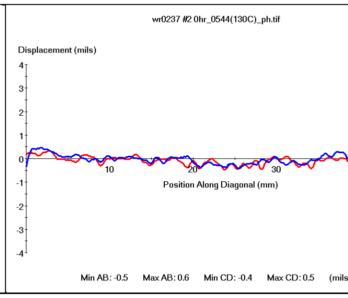
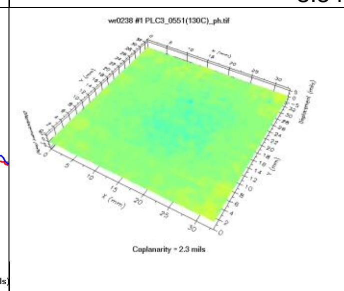
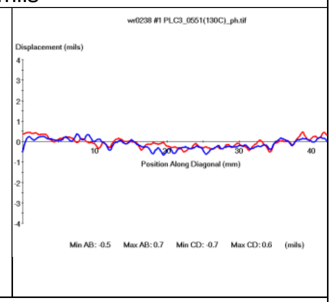
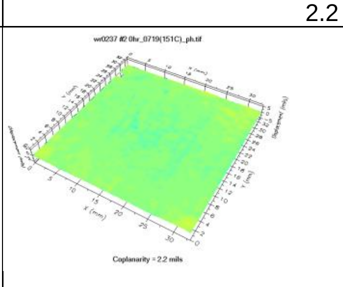
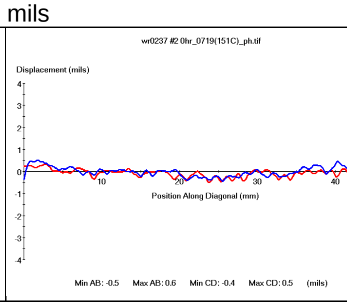
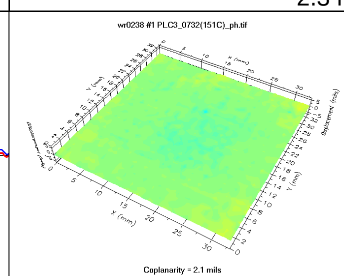
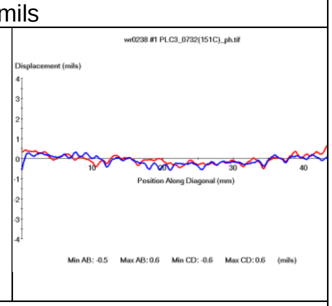
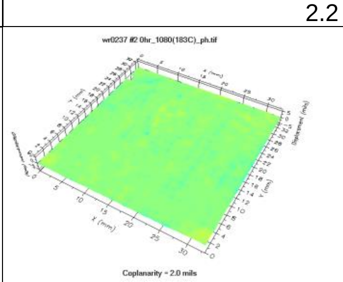
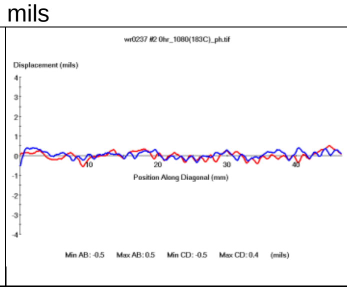
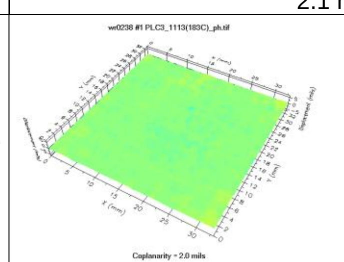
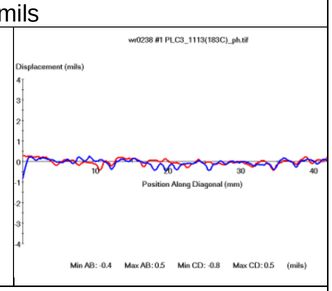


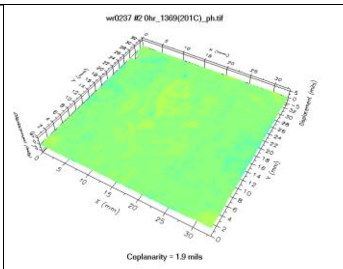
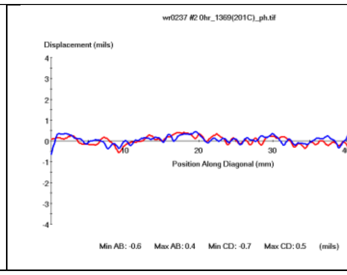
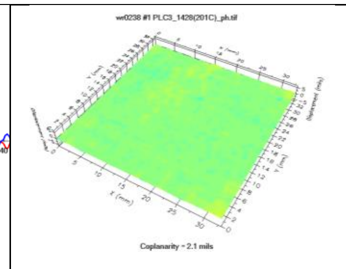
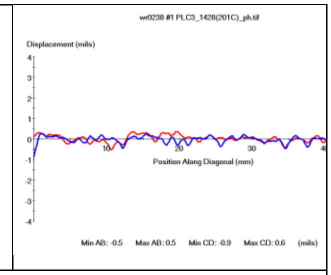
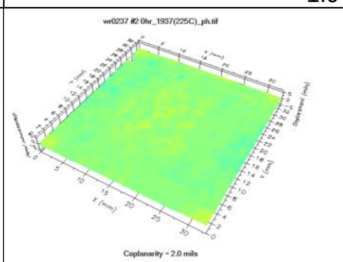
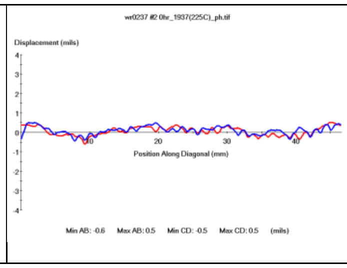
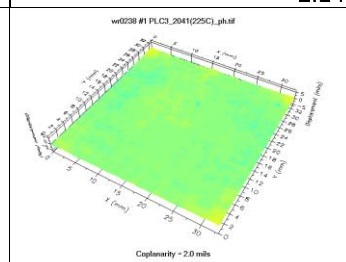
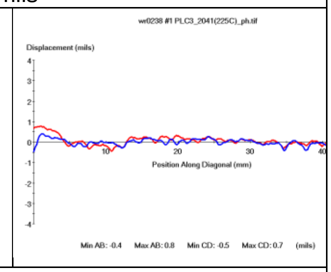
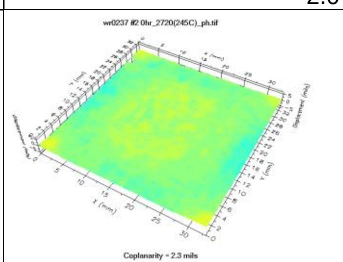
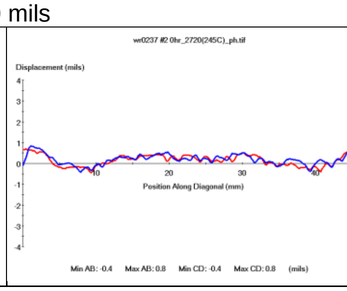
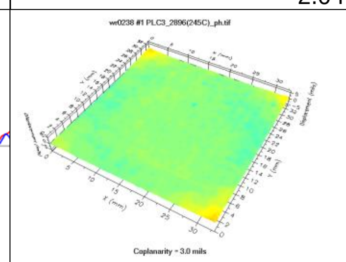
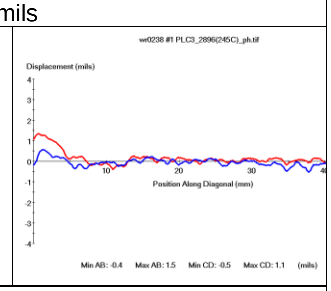
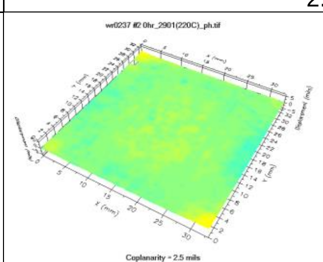
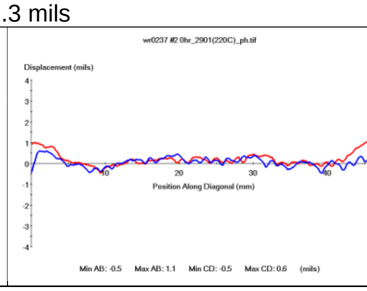
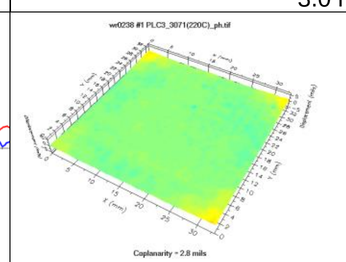
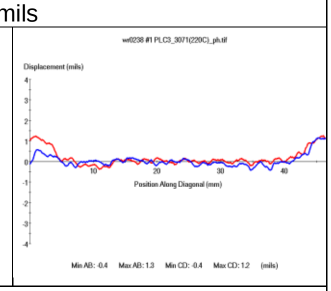
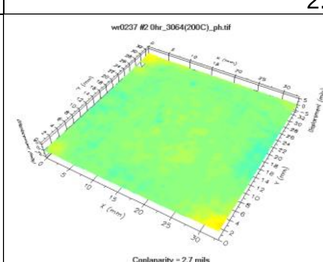
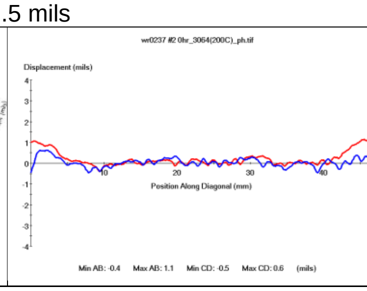
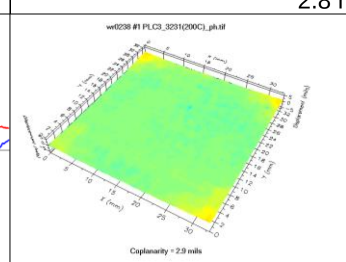
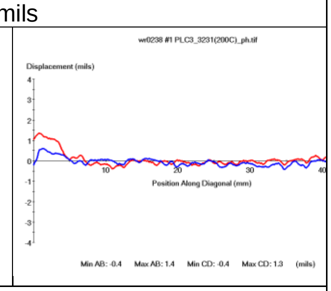

220°C
1.5 mils
1.7 mils
250°C
3.8 mils
4.6 mils
220°C
1.8 mils
2.4 mils
200°C
-2.2 mils
-1.2 mils
183°C
-3.7 mils
-2.9 mils
150°C
-6.3 mils
-5.8 mils
8.2
7.7
7.2
6.6
6.1
5.6
5.1
4.6
4.1
3.5
3.0
2.5
2.0
1.5
0.9
0.4
-0.1

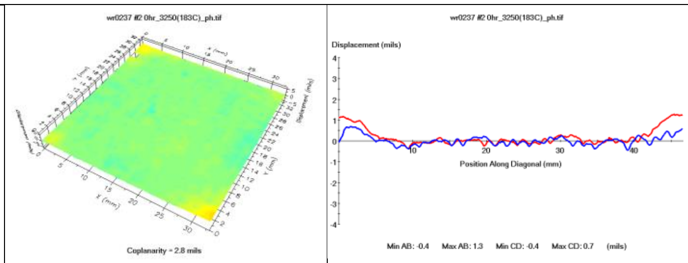
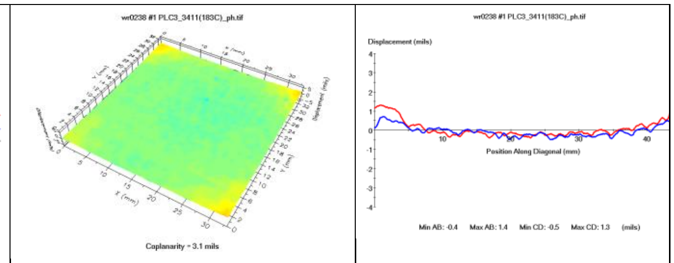
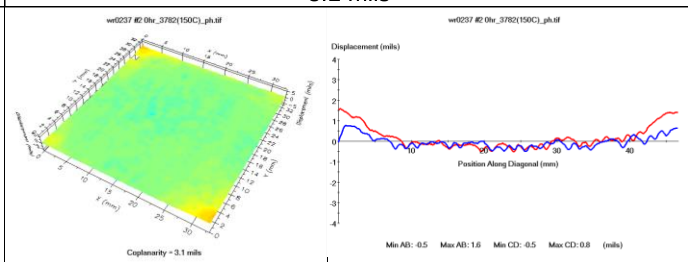
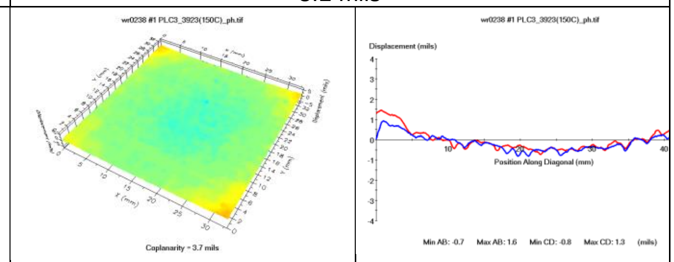
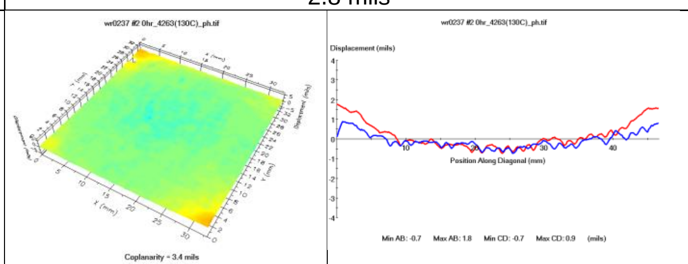
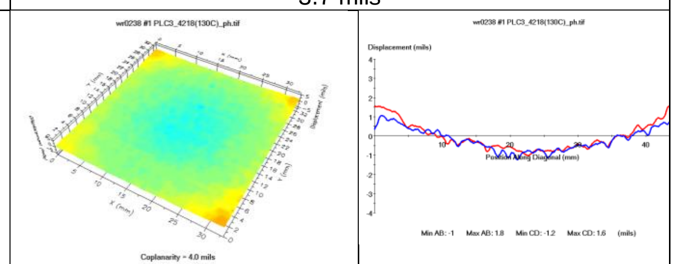
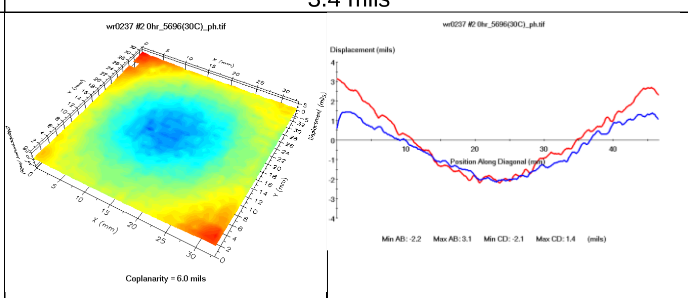
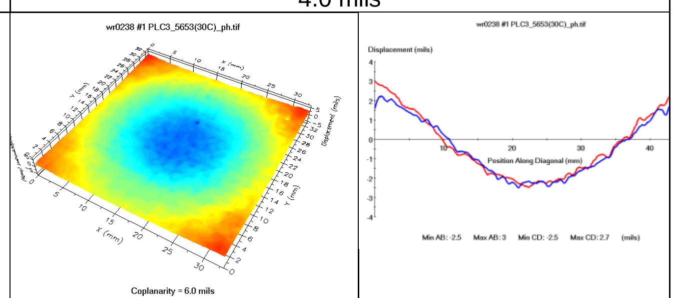
<table>
<tr><td>130°C</td><td>
</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td></td><td colspan="2">-8.1 mils</td><td colspan="2">-7.5 mils</td></tr>
<tr><td>30°C</td><td>
</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td></td><td colspan="2">-6.5 mils</td><td colspan="2">-6.1 mils</td></tr>
</table>

A.4 Graphical Representation of Measured Warpage ot Temperature

Samples in “dead bug” position, in mils. Device with minimal moisture sensitivity and hysteresis.

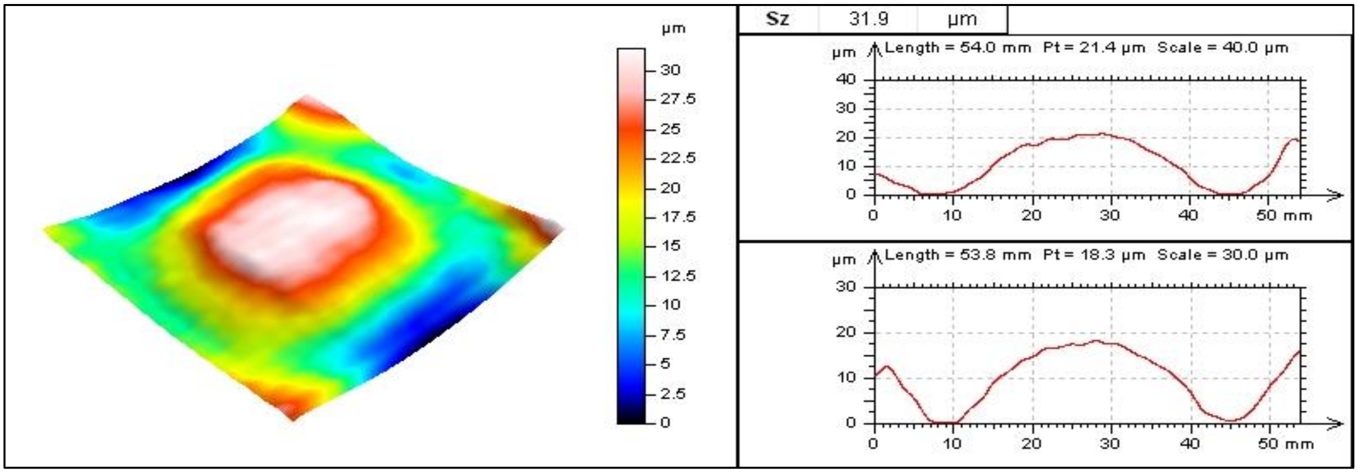
	Post Bake		Post MSL soak	
	3D contour plots	Diagonal line scans Corner to Corner	3D contour plots	Diagonal line scans Corner to Corner
30 °C				
	3.5 mils		3.5 mils	
130°C				
	2.2 mils		2.3 mils	
150°C				
	2.2 mils		2.1 mils	
183°C				
	2.0 mils		2.0 mils	

201°C				
	1.9 mils		2.1 mils	
220°C				
	2.0 mils		2.0 mils	
245°C				
	2.3 mils		3.0 mils	
220°C				
	2.5 mils		2.8 mils	
200°C				
	2.7 mils		2.9 mils	

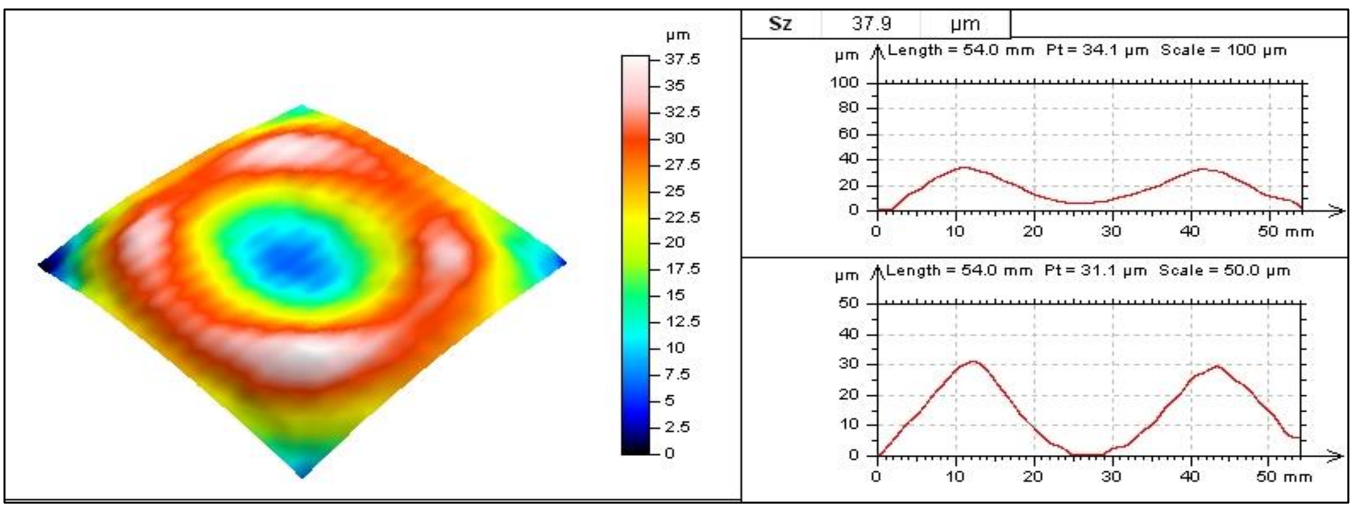
183°C		
	3.1 mils	3.1 mils
150°C		
	2.8 mils	3.7 mils
130°C		
	3.4 mils	4.0 mils
30°C		
	6.0 mils	6.0 mils

A.5 Further Examples of Concave Warpage and Convex Warpage

Graphical representation of measured Warpage –'M' Shaped Warpage @ 183 ºC Sample is in 'dead bug' position, in µm



Graphical representation of measured Warpage –'W' Shaped Warpage @ 75 ^{0}C Sample is in dead bug' position, in µm



Annex B (informative) Differences between Revisions

This annex briefly describes most of the changes made to entries that appear in this standard, JESD22-B112C, compared to prior revisions. If the change to a concept involves any words added or deleted (excluding deletion of accidentally repeated words), it is included in the list below. Some punctuation changes are not included.

B.1 Differences between JESD22-B112C and JESD22-B112B (August 2018)

Clause	Description of Change
Various	Replace "components" with "devices" in accordance to JEDEC terms and definitions. a) and b) figure titles placed on separate lines to accommodate the automatic TOC tool.
2	Harmonize to current reference to JESD22-B108B (revision B).
4	Remove JEP113 reference and insert J-STD-033 as current standard.
4	Update JESD22-A113 to current title.

B.2 Differences between JESD22-B112B and JESD22-B112A (October 2009)

Clause	Description of Change
3	Convex and concave referring to frowning or smiling face decorative terms.
3	Complex warpage definition and convex/concave figure 1a and 1b update.
5.6	Glass Datum Plane Method.
8	Figure 8a and 8b – correction on numbering.
A.5	Illustrations of complex warpage – 'W' and 'M' shapes.

B.3 Differences between JESD22-B112A and JESD22-B112 (May 2005)

Clause	Description of Change
Cover	Changed title from: High Temperature Package Warpage Measurement Methodology.
2	Background replaces introduction. Adds caution that absorbed moisture can affect warpage.
3	Terms and Definitions – a. BGA dropped, already in JEDEC dictionary. b. Digital Image Correlation and laser reflectometry methods added. c. Reference or regression plane concept is added, figures modified to show both reference plane and reference plane. d. Seating plane dropped, already in JEDEC dictionary.
5	Measurement Instrument Requirements added for Digital Image Correlation, Fringe Projection, and Laser reflectometry.
6	Calibration procedure added for top side package measurements.
7	Test Procedures – Caution to ensure packages are measured dry and soaked to rated MSL. Acknowledges more samples may be required to set room temperature Coplanarity limits.
7.3	Thermocouple Placement – Allows for placement of a thermocouple on an adjacent identical package.
7.5	Data filtering – since so much data is gathered, any filtering method used should be disclosed.
8	Parameters to be measured – How to calculate reference if reference plane is specified. Defines maximum warpage.
8	Added Figure 7a and Figure 7b to clearly show measurement area.

Standard Improvement Form

JEDEC JESD22-B112C

The purpose of this form is to provide the Technical Committees of JEDEC with input from the industry regarding usage of the subject standard. Individuals or companies are invited to submit comments to JEDEC. All comments will be collected and dispersed to the appropriate committee(s).

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1. I recommend changes to the following:
   - [ ] Requirement, clause number ____________
   - [ ] Test method number ____________ Clause number ____________

   The referenced clause number has proven to be:
   - [ ] Unclear [ ] Too Rigid [ ] In Error
   - [ ] Other ________________________________

2. Recommendations for correction:

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3. Other suggestions for document improvement:

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