JEDEC STANDARD

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

Gobco

JESD22-B112B

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JEDEC SOLID STATE TECHNOLOGY ASSOCIATION

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

(From JEDEC Board Ballot JCB-18-22, 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-B108A 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.

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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.

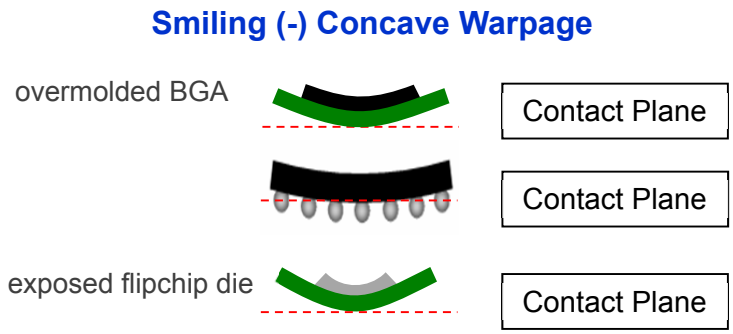

Figure 1a — Package concave warpage

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.

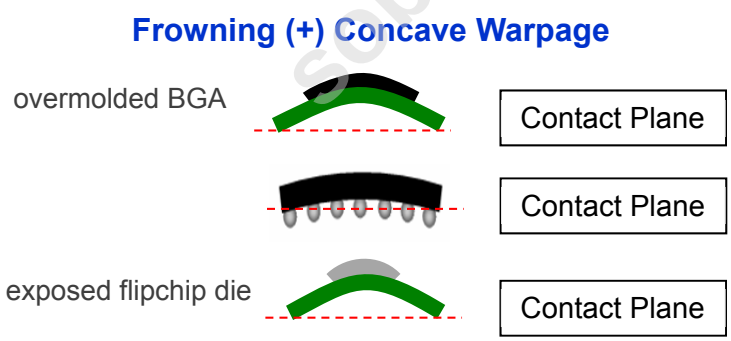

Figure 1b — Package convex warpage

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.

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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*

JEP-113, *Symbols and Labels for Moisture Sensitive Devices*

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

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

JESD22-B100, *Physical Dimensions*.

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

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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.

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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.

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