JEITA

Standard of Japan Electronics and Information Technology Industries Association

JEITA ED-7306

Measurement methods of package warpage at elevated temperature and the maximum permissible warpage

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Measurement methods of package warpage at elevated temperature and the maximum permissible warpage

Foreword

This standard was prepared by the Subcommittee on Integrated Circuit packages, Technical Standardization Committee on Semiconductor Device Packages (TSC), Japan Electronics and Information Technology Industries Association.

The increased reflow temperatures associated with lead-free reflow processes are prone to cause larger warpages of packages and PWB, which have resulted in the detrimental effect on the yield of the board level assembly. Under such circumstances, the Subcommittee started deliberations to standardize the measurement method of package warpage at elevated temperature on Jun. 2005. After the deliberations and agreements on the measurement methods and the criteria of the maximum permissible package warpage, this standard was approved by TSC in Mar. 2007.

1. Scope

This standard stipulates the package warpage criteria and the package warpage measurement methods at elevated temperature for BGA, FBGA, and FLGA

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

JEITA EDR-7315	Design guide for semiconductor packages, Ball Grid Array Package (BGA)
JEITA EDR-7316	Design guide for semiconductor packages, Fine-pitch Ball Grid Array and Fine-pitch Land Grid Array (FBGA/FLGA)
JEITA ED-4701/300	Environmental and endurance test methods for semiconductor devices TEST METHOD 301B Resistance to soldering heat for surface mounting devices (SMD)
JEITA ED-7304	Measuring method for Package Dimensions of Ball Grid Array

3. Terms and definitions

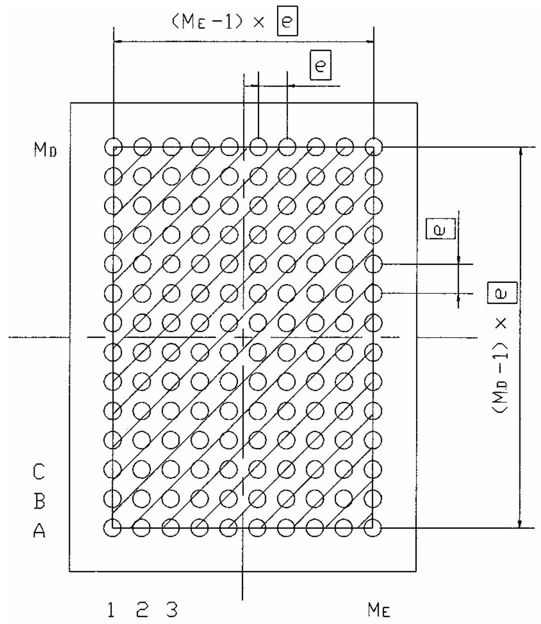
For the purposes of this document, the following terms and definitions apply.

3.1 Measuring zone

The area to be measured to determine the package warpage.

a) For the packages whose standoff height is more than 0.1 mm, such as BGA and FBGA, the measuring zone is the area where terminals are located. This area is bordered by the lines connecting the centers of the outermost neighboring solder balls (See **Fig. 1** and **Fig. 2**). If there are thermal balls at the package center, their area is also considered as a part of measuring zones.

b) For the packages whose standoff height is 0.1 mm or less, such as FLGA, the measuring area is the substrate surface except certain edge margin (See **Fig. 3**, dimension L). The width of this margin L depends on the capability of each measuring instrument (0.2 mm recommended).



NOTE: The hatched area indicates the measuring zone.

Fig. 1 Measuring zone of BGA and FBGA in full grid layout

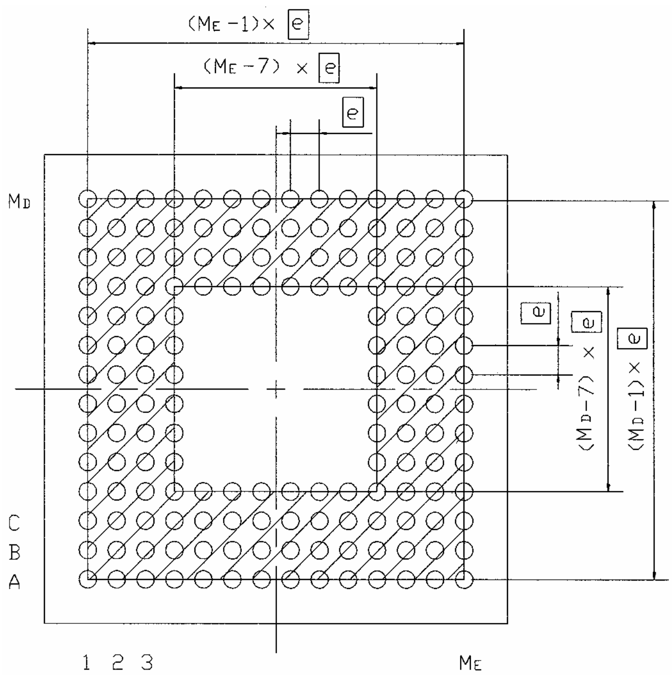
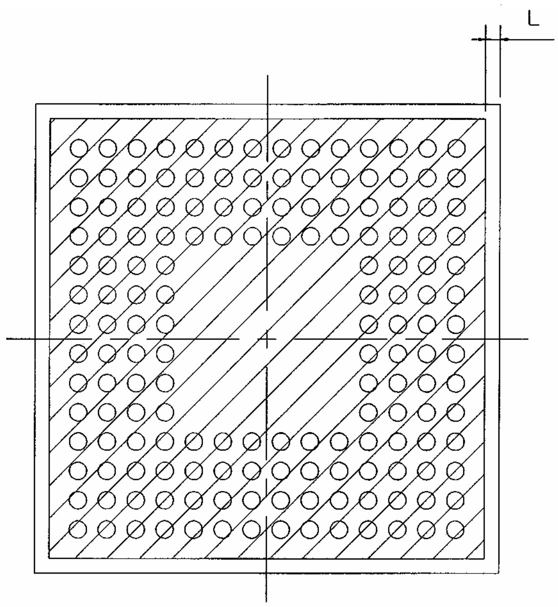


Fig. 2 Measuring zone of BGA and FBGA perimeter layout with 4 rows and 4 columns



NOTE: The edge margin L indicates the exempt area from measurement to avoid measurement noise depending on the instrument capability. Recommended edge margin L=0.2 mm.

Fig. 3 Measuring zone of FLGA perimeter layout with 4 rows and 4 columns

3.2 Convex warpage

Arched top surface (not interconnect side) of package being mounted on PWB. The sign of the convex warpage is defined as plus.

3.3 Concave warpage

Inward-curving top surface (not interconnect side) of package being mounted on PWB. The sign of the concave warpage is defined as minus.

3.4 Package warpage sign

Plus or minus sign of package warpage determined by the sign of the sum of the largest positive displacement and the largest negative displacement of the package profile on both measurement zone diagonals. These diagonals are regarded as base lines connecting the outermost opposite corners of the measuring zone. The sign of the package warpage is defined as the sign of:

$$(AB_{MAX}+AB_{MIN}+CD_{MAX}+CD_{MIN}).$$

AB_{MAX} is the largest positive displacement and AB_{MIN} is the largest negative displacement of the package profile on the diagonal AB; (The sign of AB_{MAX} is plus and AB_{MIN} is zero in **Fig. 4**.)

CD_{MAX} is the largest positive displacement and CD_{MIN} is the largest negative displacement of the package profile on the diagonal CD; (The sign of CD_{MAX} is plus and that of CD_{MIN} is minus in **Fig. 4**.)

The concave or convex impression of the package warpage can differ from the above defined sign, in critical case.

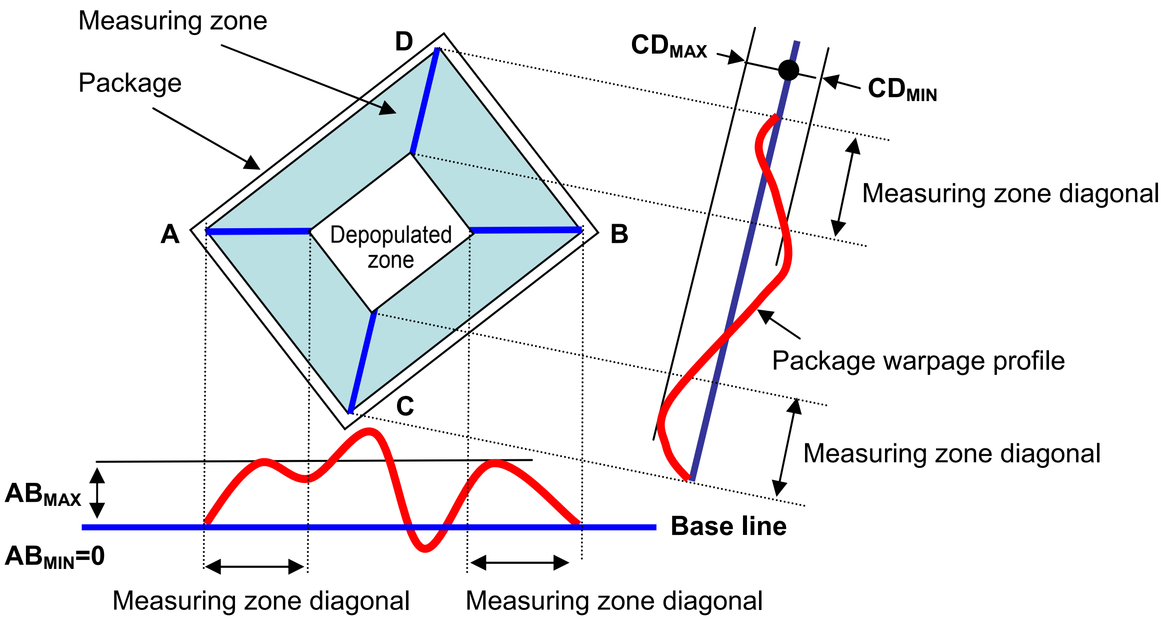


Fig. 4 Calculation of the sign of package warpage

3.5 Package warpage

The difference of the largest positive and the largest negative displacements of the package warpage in the measuring zone with respect to the reference plane, preceded by package warpage sign. This reference plane is derived using the least square method with the measuring zone data. For example, the absolute value of the package warpage $|C|$ is obtained by the sum of the absolute value of the largest positive displacement $|A|$ and that of the largest negative displacement $|B|$. This is in respect to the reference plane which is derived by using the least square method, as shown in **Fig. 5**. Package warpage sign precedes $|C|$.

$$|C| = |A| + |B|$$

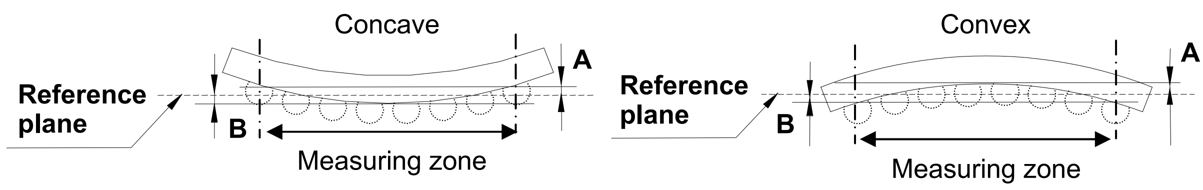


Fig. 5 Package warpage

4. Sample

4.1 Sample size

At least three samples are required for each measurement condition.

4.2 Solder ball removal

If the measurement method of the package warpage requires the elimination of the solder balls from a package, it is recommended to use mechanical removal rather than hot reflow. If the samples are prepared without solder balls for the convenience of the measurement, the package shall be subjected to the thermal history of the solder ball attachment process.

4.3 Pretreatment conditions

The bake and moisture soak conditions shall conform to the moisture sensitivity level specified in **TEST METHOD 301B**, **JEITA ED-4701/300**. The peak temperature of the package warpage measurement shall meet the specification of the product.

4.4 Maximum time after pretreatment until measurement

It is recommended to measure the warpage no longer than 5 hours after the pretreatment.

4.5 Repetition of the reflow cycles for the sample

The same sample shall not be subjected to the repetition of the reflow cycles. The sample can be subjected to more than one cycle of reflow for remeasurement, only if reproducibility of test data was verified prior to the test.

5. Measurement

5.1 General description

The package warpage is measured by “shadow moiré method” or “laser reflection method”.

Samples are subjected to heating and cooling while measuring the package warpage at the temperatures specified in **5.2**. The measurement points shall not be on the crown of solder balls but on the substrate surface of the package. Only when the behavior of the top surface of the package (mostly marking surface) is verified to coincide with that of the substrate surface, the measurement on the top surface is allowed.

5.2 Temperature profile and the temperatures for measurements

5.2.1 The temperature profile for the warpage measurement does not necessarily simulate that for production. Higher priorities are placed on

- maintaining the temperature constant during the measurement,
- never exposing the samples more than necessary duration at high temperature. Samples shall be proceeded to the next measurement as soon as possible,
- avoiding a temperature surge to prevent the overshoot, and
- minimizing the temperature difference between the top and bottom surfaces.

5.2.2 The temperatures for measurements are

- room temperature,
- melting point,
- peak temperature,
- solidification point, and
- room temperature after cool down.

The melting point and the solidification point are 220°C for Sn-3.0Ag-0.5Cu solder as a reference. Other solder composites may take different temperatures. The peak temperature basically conforms to the package classifications specified in **TEST METHOD 301B**, **JEITA ED-4701/300**, but to be exact, it shall follow the supplier's recommended max temperature.

5.2.3 It is recommended that a thermocouple of gauge 30 (ϕ0.25 mm) or flat tip type be used.

5.2.4 The thermocouple is attached on the center of the package body using either thermally conductive epoxy or heat-resistant polyimide tape. When polyimide tape is used, thermally conductive sheet shall be applied between the thermocouple bead and the package surface to enhance thermal conductivity as a thermal interface material.

5.2.5 When a measuring instrument is being set up, the temperature of the molded side of the package facing a heater is also measured. The temperature difference from the substrate surface shall preferably be less than 10°C by adjusting the heating mechanism and the temperature profile.

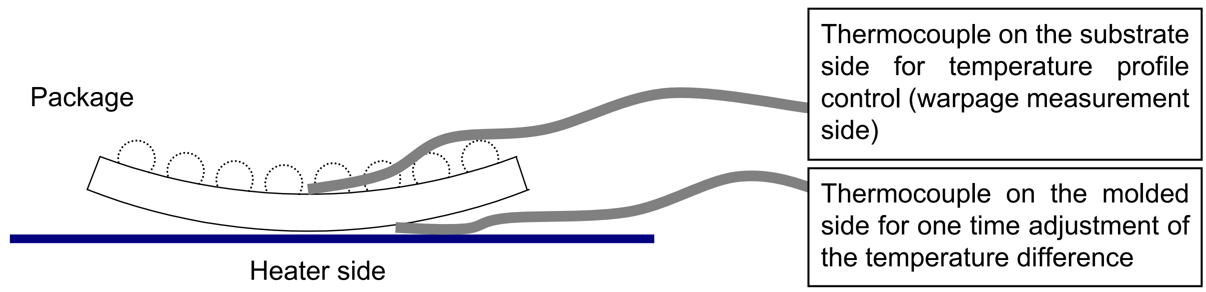


Fig. 6 Thermocouple placement

5.3 Measurement method

5.3.1 Shadow moiré method

Solder balls shall be removed prior to the measurement on the substrate surface. Measurements are conducted by placing the grating (low CTE glass with transparent and opaque stripes) parallel to the sample. Then, the projection of light beam at an angle of approximately 45° through the grating produces the stripe pattern on the sample. Observation of the stripe pattern through the grating results in the moiré fringe pattern (geometric interference pattern). Image processing and the analysis of the patterns provide the displacement from planarity over the substrate surface. The instrument is capable of setting the measuring zone and measuring the warpage at elevated temperatures including the peak temperature.

5.3.2 Laser reflection method

Solder balls shall be removed when the solder ball pitch is not large enough for laser beam to measure the warpage on the substrate surface. Samples are placed on the measurement table. The displacement from the flatness is measured by the laser displacement sensor. The warpage is generally measured by scanning the laser beam over the terminal lands or between balls throughout the measuring zone. The grid pitch of the measurement points is preferably less than the solder ball pitch. The instrument is capable of setting the measuring zone and measuring the warpage at elevated temperatures including the peak temperature.

5.3.3 Data analysis (Data table, Diagonal scan graph, 3D plot graph)

The magnitude of the warpage is obtained from the data table of the measurements or 3D plot graph (warpage distribution diagram over the measuring zone). Then the sign of the warpage (warpage direction) is determined from the diagonal scan graph and precedes the value.

6. Maximum permissible package warpage at elevated temperature

The criteria of the maximum permissible package warpages for BGA and FBGA are specified in **Table 1**, and those for FLGA are specified in **Table 2**.

Table 1 Maximum permissible package warpages for BGA and FBGA

Unit: mm

Solder ball pitch	0.4	0.5	0.65	0.8		1.0	1.27
Condition of ball height	0.20	0.25	0.33	0.35	0.40	0.50	0.60
Maximum permissible package warpage (Absolute value)	0.10	0.11	0.14	0.17	0.17	0.22	0.25

Table 2 Maximum permissible package warpages for FLGA

Unit: mm

Land pitch	0.4	0.5	0.65	0.8
Condition of thickness of molten solder paste	0.08	0.10	0.11	0.13
Maximum permissible package warpage (Absolute value)	0.08	0.10	0.11	0.13

7. Recommended datasheet for the package warpage

7.1 Measurement temperatures for data sheet

Typical measurement temperatures for datasheet are room temperature, melting point, peak temperature, solidification point, and room temperature after cooling.

7.2 Datasheet

Datasheet is composed of

- temperature dependency of the package warpage (See **Fig. 7**),
- surface topography at each temperature in 3D plots (optional). (If the sign of warpage is opposite, explanation is required; See **Fig. 8**),
- diagonal profile of the package at each temperature (optional). (If the sign of warpage is opposite, explanation is required; See **Fig. 8**),
- explanatory figure of the sign of the package warpage (optional), and
- temperature profile for measurement.

7.3 Example of datasheets

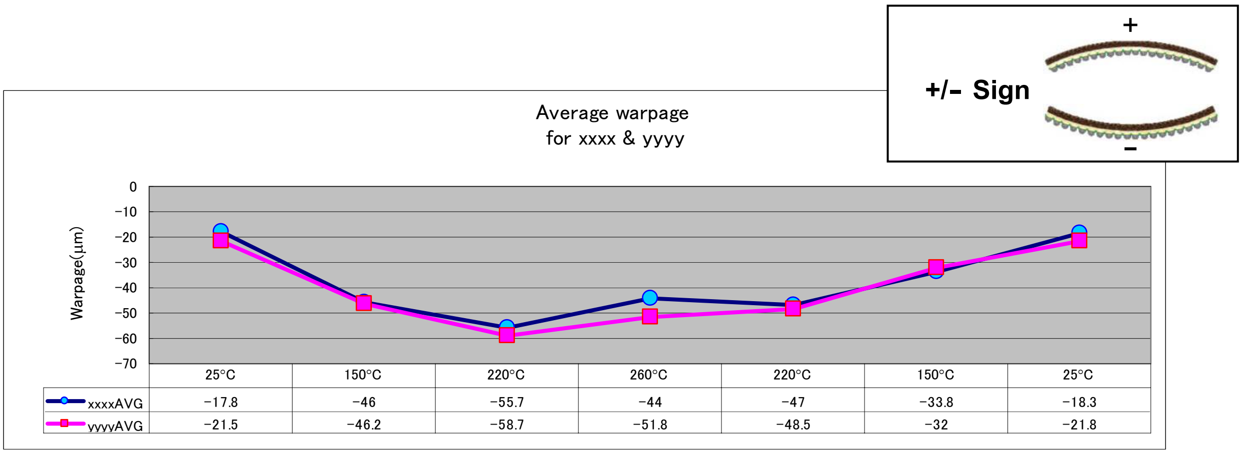
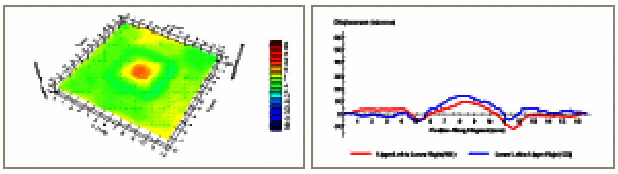
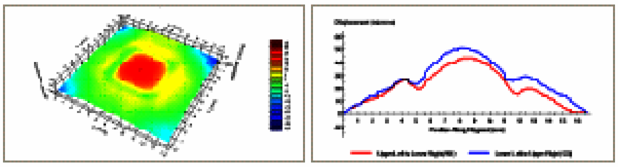


Fig. 7 Temperature dependency of the package warpage

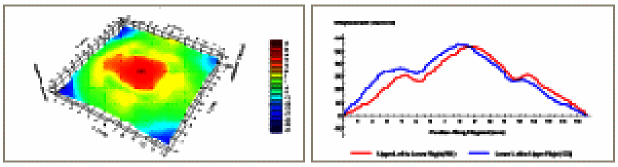
Room temperature



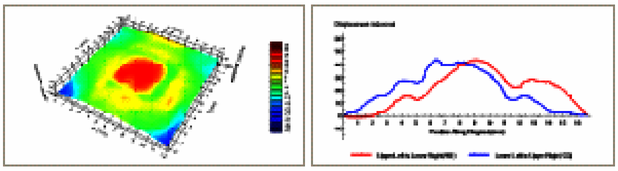
(150°C)
(Preheat temperature)
(For reference)



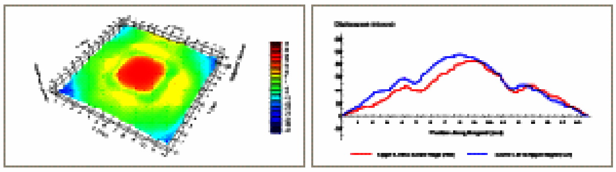
220°C
Melting point



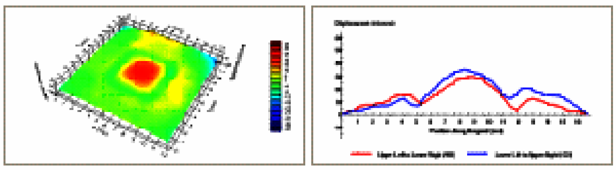
260°C
Peak temperature



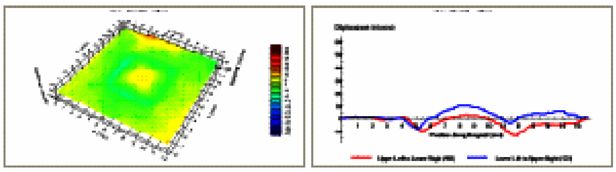
220°C
Solidification point



(150°C)
(Tg of PWB)
(For reference)



Room temperature



NOTE: The signs in the 3D plots and in the diagonal profile are opposite from the package warpage sign due to the dead bug position in the measurement.

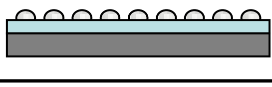


Fig. 8 Recommended datasheet

Explanation

This part of the document is not a specification but is intended for the explanation of the specification and related issues.

1. Purpose of the establishment

In an environment marked by the higher-speed and miniaturizing trend of the electronic products, BGA packages have been used in most of the electronic products thanks to the advantages of higher pin count and compact body size features. Along with high volume usage of the BGA packages, analysis data of soldering failures have accumulated and the package warpage at elevated temperature has been gaining attention as a cause of these failures. This phenomenon is that the package warps during the rising temperature of the reflow process and solder joints fail in an open or short mode, even if the package meets the coplanarity requirement at room temperature.

Migration to thinner package body, finer pitch balls, and lead-free material has increased package warpage during the reflow process and raised problems of open solder joints or solder bridges between balls. It is known that the more a package is moisturized, the more the package warps. The Subcommittee reached an agreement that the semiconductor suppliers shall specify the maximum permissible package warpages at elevated temperature. It is similar to the package delamination specification at reflow stress. This specification aimed at agreement of the common terms, unification of measurement methods, and establishment of the criteria.

2. History of deliberation

In a past TSC had focused on the standardization of the dimensions of packages. The recent expansion of the mission to the field of the package reliability has triggered the standardization activity on the package warpage at elevated temperature, which has been requested by customers.

The standardization task force on the measurement method of the package warpage at elevated temperature was formed on Jun. 23, 2005. The activity plan was to establish the standard of the package warpage measurement by Apr. 2006 as phase 1 and the criteria of warpage by Dec. 2006 as phase 2. The deliberation started from listing the factors that may affect the measurement methods and gathering experimental data from the task force members. After the evaluation of the seriousness of the factors, the specification was drafted. On the way of deliberation, the task force was informed the publication of “High temperature package warpage measurement methodology”, **JESD22B112**, on Aug. 2005. The task force discussed the measurement method based on this specification with the basic policy of maintaining international harmonization.

3. Brief contents of deliberations

3.1 Measurement methods of the package warpage at elevated temperature

The task force reached an agreement on the following facts after reviewing the experimental data from member companies:

- The absorption of moisture increases the magnitude of the warpage.
- There is stronger correlation of the magnitude of the warpage with the temperature rather than the temperature profile including duration of heat stress or temperature ramp rate. Also if the temperature profile in the measurement simulates the reflow temperature profile forcibly, high temperature ramp rate may cause temperature overshoot or larger temperature difference between the top and bottom sides of the package, which makes the measurement inconsistent. Therefore, the approximation of the temperature profile to the reflow condition is not a high priority.
- The warpage data of remeasurement are usually consistent, but some reports claimed poor reproducibility in remeasurement. Therefore, the repetition of the measurement cycles to the same sample is not recommended.
- Warpage data measured by the shadow moiré method agreed with those measured by the laser reflection method as far as the measuring zone was the same.
- It was confirmed that zero to five hours in waiting time after pretreatment until measurement did not show any difference in measurements.

Based on these agreements in facts, the measurement methods and conditions of package warpage at elevated temperature were specified.

3.2 Maximum permissible package warpage at elevated temperature

This specification was initially drafted as a standard of the measurement method of the package warpage, and their criteria were planned to be specified in each package design guide. However, the Subcommittee decided to specify the maximum permissible package warpage of BGA, FBGA, and FLGA in this specification. It is because the comprehensive specification provides the overall explanations for the budget allocation of the maximum relative displacement and well-aligned criteria by ball pitch.

For stackable packages, the premise of the budget allocation, 80 % of the maximum relative displacement to package and 20 % to PWB, is not valid; therefore, they are out of the scope in this specification.

The task force drafted the specification based on the theoretical approach to the mechanisms of open solder joints and solder bridges, as well as the experimental approach to those through soldering the artificially warped package. Maximum permissible package warpage of BGA is given 80 % of the maximum relative displacement that does not cause open solder joints or solder bridges. The other 20 % of the displacement is reserved for a tolerance of the PWB warpage and the fluctuation of the paste thickness.

On the other hand, the maximum permissible package warpage of FLGA is defined to be 100 % of the maximum relative displacement. It is defined to be the height of the molten solder paste, which does not cause open-solder joints. Any tolerance is reserved for the warpage of PWB because the maximum permissible warpage is already very close to the coplanarity requirements. It implies how difficult mounting FLGA is. There are some means to generate some extra tolerance to allow some PWB warpage, such as thick pre-coated terminals to reserve some collapse height of FLGA during reflow.

This specification does not refer to such an extent.

3.3 Open solder joints after BGA board level assembly

Take BGA as an example, since it indicates larger warpage at elevated temperature. The behaviors of the package warpage and the solder paste during the reflow process are described as follows:

(1) It is premised that the package is flat with acceptable coplanarity at room temperature and PWB is ideally flat in all conditions.

(2) The package warps larger in association with rising temperature. Just below melting point, some crowns of the solder balls may even separate from the surface of the solder paste at the package corners, where the warpage is larger.

(3) As temperature rises further and exceeds the melting point of solder, the solder balls and paste melt and collapse.

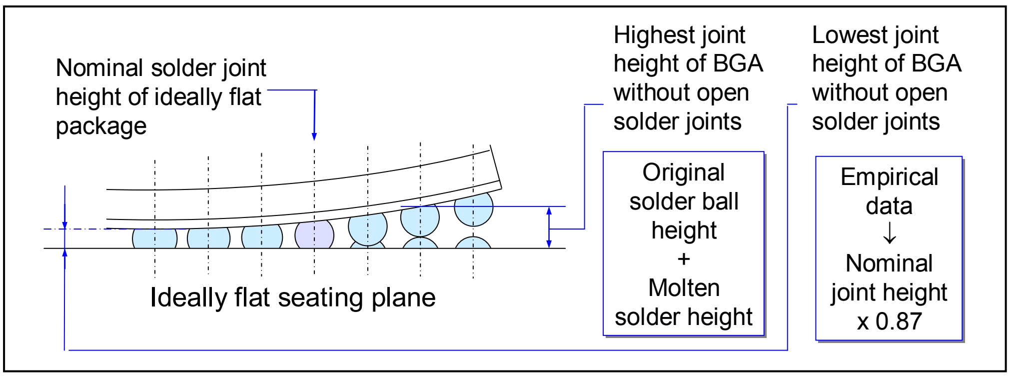
(4) Even if the crowns of some solder balls were apart from the solder paste just below the melting point, the collapse of the balls produces good solder connection with the activated solder paste.

(5) Acceptable solder joints are formed after reflow.

(6) In case package warps more than the criteria, the crowns of these balls does not touch the paste when the balls collapse. It causes the open solder joints.

Under the consideration of mechanisms from **(1)** to **(6)**, if the sum of package warpage at elevated temperature and the lowest standoff height is smaller than the sum of the original solder-ball height and the thickness of the molten solder paste, good solder connection can be expected after the board assembly, and vice versa. (See **Explanatory Fig. 1**)

The maximum relative displacement is defined as the difference between the highest and the lowest solder joint heights of BGA package mounted on the ideally flat seating plane, where none of solder joints are open.



Explanatory Fig. 1 Calculation of the maximum relative displacement immune from open solder joints

3.4 Solder ball bridges after BGA board level assembly

The occurrence of the solder ball bridges depends on how much package warps during reflow process. The mechanisms of the solder ball bridges are described below:

(1) If the package warpage is less than the maximum permissible warpage just above the melting point, all solder balls are once soldered to the lands on PWB.

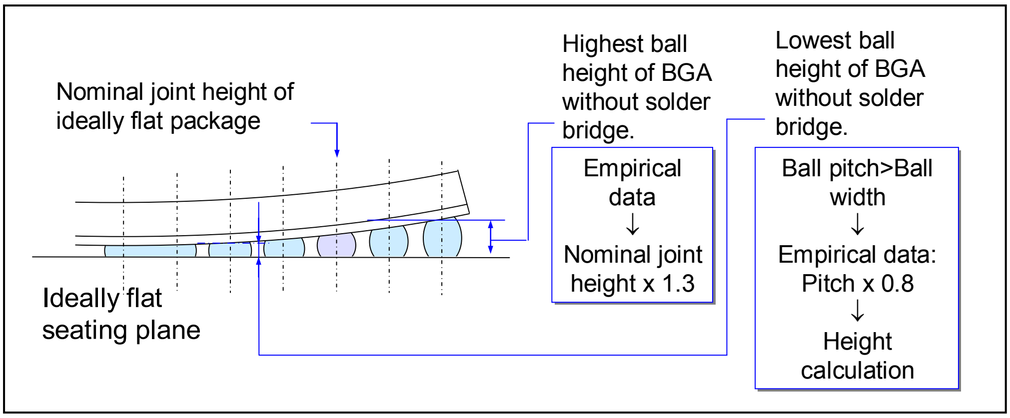
(2) Further elevation of the temperature makes some balls flattened while others stretched because of the increase in package warpage.

(3) The collapsed balls have larger diameters, while the stretched balls become thinner but are still connecting the package and PWB owing to surface tension.

(4) When the diameters of the collapsed balls expand beyond the certain percentage of the ball pitch (80 % of the ball pitch obtained from the experimental data), the failure rate of the short circuits increases.

Therefore, the maximum relative displacement of the package without the solder bridge is the difference between the height of the stretched balls (the highest joint height) and that of the flattened balls (the lowest joint height) whose diameter is 80 % of the ball pitch. (See **Explanatory Fig. 2**)

The maximum relative displacement is defined as the difference between the highest and the lowest joint heights of BGA package mounted on the ideally f lat seating plane, where none of solder joints bridge.



NOTE: Constants of the calculations are obtained from the experiment and used for simplicity.

Explanatory Fig. 2 Calculation of the maximum relative displacement immune from solder ball bridges

3.5 Maximum permissible package warpage of BGA and FBGA

3.5.1 The maximum permissible package warpage of BGA and FBGA is described in **Explanatory Table 1**, which is calculated from the experimental data.

3.5.2 Given that PWB is an ideally flat seating plane, the maximum relative displacement from the seating plane is the difference between the highest and lowest joint heights of BGA which is immune from the open solder joints or solder ball bridges.

3.5.3 The maximum permissible package warpage of BGA and FBGA is determined to be 80 % of the maximum relative displacement, where either open solder joints or solder ball bridges was not seen. The other 20 % is given to the permissible warpage of PWB. The ratio reflects the difficultness in maintaining straight of the package versus PWB at elevated temperature, i.e. complexity in the materials and structure of package vs. PWB.

3.5.4 The criteria of maximum permissible package warpage for solder joints without open or short circuits are obtained separately. Less than 10 μm of difference indicate that the open solder joints and solder bridges are the phenomena caused by the same reason but viewed from opposite sides. The current magnitudes of package warpage barely satisfy the budget allocation of the tolerance, 80 % to the package. However, along with the progress in technology, the methodology to reduce the package warpage will be established, and then the criteria will be reviewed.

Explanatory Table 1 Maximum permissible package warpage for BGA and FBGA

Unit: mm

Solder ball pitch	0.4	0.5	0.65	0.8		1.0	1.27
Condition of solder ball height [a]	0.20	0.25	0.33	0.35	0.40	0.50	0.60
Condition of solder paste thickness after reflow [b]	0.08	0.10	0.11	0.13		0.14	0.15
Nominal solder joint height of the ideally flat package	0.18	0.23	0.29	0.31	0.36	0.43	0.5
Highest solder joint height of BGA without open solder joint [c]	0.28	0.35	0.44	0.48	0.53	0.64	0.75
Lowest solder joint height of BGA without open solder joint [d]	0.16	0.20	0.25	0.27	0.31	0.37	0.44
Highest solder joint height of BGA without solder bridge [e]	0.24	0.29	0.38	0.40	0.46	0.55	0.66
Lowest solder joint height of BGA without solder bridge [f]	0.12	0.15	0.20	0.19	0.25	0.28	0.34
Max relative displacement of BGA without open solder joint [g]	0.12	0.15	0.19	0.21	0.22	0.27	0.31
Max relative displacement of BGA without solder bridge [h]	0.12	0.14	0.18	0.21	0.21	0.28	0.32
Max permissible package warpage (Absolute value) [i]	0.10	0.11	0.14	0.17	0.17	0.22	0.25
Coplanarity at room temperature (For reference)	0.08	0.08	0.10	0.10	0.10	0.20	0.20

NOTE: Assumptions of the calculations are

- The structure of the lands on PWB is non solder mask defined;
- The diameter of the lands on PWB is the same as that of package;
- Solder joint height between package and PWB is the distance between the face-to-face copper lands;
- Thicknesses of the metal masks for solder paste printings are
  - 0.10 mm for 0.4 mm pitch FBGA,
  - 0.12 mm for 0.5 mm and 0.65 mm pitch FBGA, and
  - 0.15 mm for 0.8 mm, 1.0 mm, and 1.27 mm pitch BGA;
- Opening diameter of the solder printing mask is the same as that of the lands on PWB.

Table footnote:

[a] It follows the specification in **JEITA EDR-7315** and **JEITA EDR-7316**.

[b] It is the thicknesses of molten solder paste on copper lands without any component attached, supposed 50 % of solder paste is metal content (solder).

[c] It is the sum of the solder ball height and the molten solder-paste thickness, where the solder connections are immune from open circuit.

[d] It is 87 % of the nominal standoff height of the ideally flat package. The ratio is obtained from the empirical data taken from the intentionally concave-warped sample.

[e] It is 130 % of the nominal standoff height of the ideally flat package. The ratio is obtained from the empirical data taken from the intentionally convex-warped sample.

[f] It is the sum of the molten solder and the solder ball height when the ball diameter expands to 80 % of the ball pitch. It is known that the balls do not bridge as far as the collapse of solder balls does not make the ball diameter expand beyond 80 % of the ball pitch.

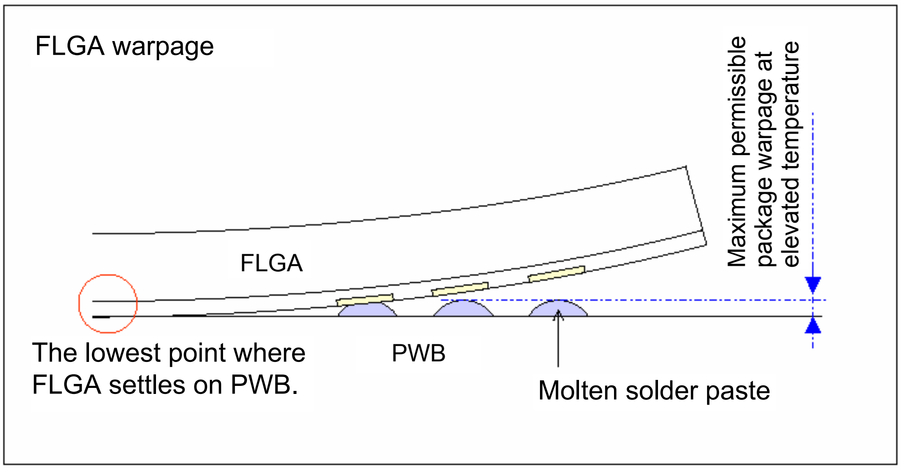
[g] It is the difference between the highest and the lowest solder joint height, where open solder joint is not seen.

[h] It is the difference between the highest and the lowest solder joint height, where solder ball bridge is not seen.

[i] It is 80 % of the maximum relative displacement.

3.6 Maximum permissible package warpage of FLGA

Given that PWB is an ideal seating plane, the maximum package warpage is defined to be the thickness of molten solder paste. (See **Explanatory Fig. 3**) However the maximum permissible package warpage depends on the amount of the solder paste, the criteria for FLGA are specified in **Explanatory Table 2** for semiconductor suppliers.



Explanatory Fig. 3 Package warpage of FLGA at elevated temperatu

Explanatory Table 2 Maximum permissible package warpage for FLGA

Unit: mm

Land pitch	0.4	0.5	0.65	0.8
Condition of thickness of molten solder	0.08	0.10	0.11	0.13
Maximum permissible package warpage (Absolute value)	0.08	0.10	0.11	0.13
Coplanarity at room temperature (For reference)	0.08	0.08	0.10	0.10

3.7 Discussion with the TSC on Jisso Technology Standardization

After drafting this specification, the task force requested the TSC on Jisso Technology Standardization to review this specification and to hold the joint ad hoc meeting to promote harmonization of the opinions between suppliers and users. Most of the issues raised by TSC were corrected or added, but there were some disagreements left. Chief request was to verify if the measurement data from different types of instruments are well accorded with. With the collaboration of measuring instrument suppliers, the bimetal samples were measured by 3 types of instruments.

Since the TSC on Jisso Technology Standardization did not have enough data to comment on the criteria of the maximum permissible package warpages, they would review the criteria one year later after the collection of the data of the package warpages and the board assembly yields.

4. Industry property rights

The task force surveyed the industrial property rights that directly related to the measurement methods and the maximum permissible warpage but did not find any of them.

5. Relation to the international standard

There is not any international standard (**IEC**) related to the warpage measurement method at elevated temperature but the **JESD22B112** published by **JEDEC**, USA. The comparisons between **JESD22B112** and this specification are shown below:

Item	**JESD22B112**	This specification (**JEITA**)
Object	Surface mount devices	BGA, FBGA, FLGA, but excluding QFP
Warpage direction	Convex warpage results in the package corners being closer to the seating plane than the center of the bottom surface of the package. Concave warpage results in the package corners being farther from the seating plane than the center of the bottom surface of the package.	Same as **JESD22B112**
Measuring zone	Unspecified	a) For the packages whose standoff height is more than 0.1 mm, such as BGA and FBGA, the measuring zone is the area where terminals are located. This area is bordered by the lines connecting the centers of the outermost neighboring solder balls. If there are thermal balls at the package center, their area is also considered as a part of measuring zones. b) For the packages whose standoff height is 0.1 mm or less, such as FLGA, the measuring area is the substrate surface except certain edge margin. The width of this margin L depends on the capability of each measuring instrument (0.2 mm recommended).
Package warpage sign	Convex warpage is plus. Concave warpage is minus.	Plus or minus sign of package warpage determined by the sign of the sum of the largest positive displacement and the largest negative displacement of the package profile on both measurement zone diagonals.
Package warpage	“Deviation from planarity” is the difference in height between the highest point and the lowest point on the package body bottom surface measured with respect to the seating plane.	The difference of the largest positive and the largest negative displacements of the package warpage in the measuring zone with respect to the reference plane, preceded by package warpage sign. This reference plane is derived using the least square method with the measuring zone data.
Measuring instrument	Shadow moiré only	The measurement methods of the package warpage are shadow moiré or laser reflection method.
Calibration	Concave or convex ground glass made of ultra-low expansion material	Unspecified
Measurement points	Warpage measurements should be viewed on the substrate side without solder balls attached.	The measurement points shall not be on the crown of solder balls but on the substrate surface of the package. Only when the behavior of the package top surface (mostly marking surface) is verified to coincide with that of the substrate surface, the measurement from the top surface is allowed.

Item	**JESD22B112**	This specification (**JEITA**)
Solder ball removal	• A simulated solder ball attachment process is recommended to subject the test samples to the same thermal exposure. • Verification of the technique used to remove the solder balls must be conducted.	• If the samples are prepared without solder balls, they shall be subjected to the simulated reflow profile. • In the case of removal of the solder balls, it is recommended to use mechanical removal rather than hot reflow.
Peripheral lead packages	For lead frame based packages, either the top or bottom for the package body surface can be measured.	Peripheral lead packages are excluded in the scope of this specification.
Sample	A minimum of 3 samples shall be measured to determine variation within an assembly lot. It is recommended that samples be measured in both the moisture soaked and dry states. If this test method is used for monitoring then the package warpage may be measured in only the dry state.	• Standard sample size is a minimum of 3 samples with pretreatment. • The same sample shall not be subjected to the repetition of the reflow profile cycles.
Pretreatment of the samples	The minimum moisture soaked condition shall be the rated moisture sensitivity level per **J-STD-020**. It specifies that the waiting time for the measurement after pretreatment shall be 4 h or less.	Pretreatment conditions shall conform to **JEITA ED-4701/300** to measure the package warpage. Waiting time for measurement shall be no longer than 5 hours after the pretreatment.
Thermocouple	Thermocouple of gauge 30 or finer is recommended. 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. (Original document quotes the commercial name for the polyimide tape.)	A thermocouple of gauge 30 (ϕ0.25 mm) or flat tip type is recommended. When polyimide tape is used, a thermal sheet is applied between the thermocouple bead and the package surface.
Temperature measurement	Ideally, a temperature ramp rate that can closely match the reflow profile should be used. The equipment should be configured to achieve as fast a ramp rate as possible without introducing significant delta temperature differences between the top and bottom of the package body.	The temperature profile of the warpage measurement does not necessarily simulate that for production. Higher priorities are placed on - maintaining the temperature constant during the measurement, - never exposing the samples unnecessary duration to high temperature. Samples shall be proceeded to the next measurement as soon as possible, - avoiding temperature surge to prevent the overshoot, and - minimizing the temperature difference between the top surface and the substrate surface.
Reflow oven	Thermal chambers equipped with assisted convective heating are highly recommended.	Unspecified
Data	- A plot showing total warpage magnitude versus temperature with the (+) and (-) conventions assigned. - 3-D contour plots of package shape as a function of peak reflow temperature. - Diagonal line scans showing total warpage magnitude across the diagonal of the component.	• Temperature dependency of the package warpage • 3D plots of surface topography at each temperature • Diagonal profile of the package at each temperature
Recommended datasheet	Unspecified	• Typical temperatures for measurement and recommended datasheet are described.
Maximum permissible package warpage	Unspecified	• Maximum permissible package warpages for BGA, FBGA, and FLGA are specified in this specification.

6. Deliberation members

The scheme of this standard was made by the Subcommittee on Integrated Circuit Packages and deliberated by the Task force of the package warpage measurement at elevated temperature.

The participated members are:

<Technical Standardization Committee on Semiconductor Device Packages>

TSC chair	Chiaki Takubo	Toshiba Corp.

<Subcommittee on Integrated Circuit Packages>

SC chair	Hiroyuki Shigeta	Sony Corp.

<Task force on package warpage measurement standardization at elevated temperature>

Leader	Hirofumi Nakajima	NEC Electronics Corp.
Member	Koujiro Shibuya	NEC Electronics Corp.
	Akio Nakamura	Oki Electric Industry Co., Ltd.
	Hiroyuki Shigeta	Sony Corp.
	Hitoshi Shibue	Sony Corp.
	Yasuhiro Koshio	Toshiba Corp.
	Tsuyoshi Kanazawa	Toshiba Corp.
	Daisuke Otani	Toshiba Corp.
	Takayuki Maeda	Texas Instruments Japan Ltd.
	Kazunari Kosakai	Fujitsu Ltd.
	Takahiro Nakano	Matsushita Electric Industrial Co., Ltd.
	Takanori Hashizume	Renesas Technology Corp.
	Hiroshi Kawakubo	Renesas Technology Corp.
Special members	Tomoya Kiga	Sony EMCS Corp.
	Takanori Miyata	Cermatronics Boeki Co., Ltd.
	Nobuhiko Takahashi	Hitachi Technologies and Services, Ltd.
	Yoshio Ichikawa	Cores Corp.