Daisy Chain Samples

Application Note

July 2003

The following document refers to Spansion memory products that are now offered by both Advanced Micro Devices and Fujitsu. Although the document is marked with the name of the company that originally developed the specification, these products will be offered to customers of both AMD and Fujitsu.

Continuity of Specifications

There is no change to this document as a result of offering the device as a Spansion product. Any changes that have been made are the result of normal documentation improvements and are noted in the document revision summary, where supported. Future routine revisions will occur when appropriate, and changes will be noted in a revision summary.

Continuity of Ordering Part Numbers

AMD and Fujitsu continue to support existing part numbers beginning with "Am" and "MBM". To order these products, please use only the Ordering Part Numbers listed in this document.

For More Information

Please contact your local AMD or Fujitsu sales office for additional information about Spansion memory solutions.

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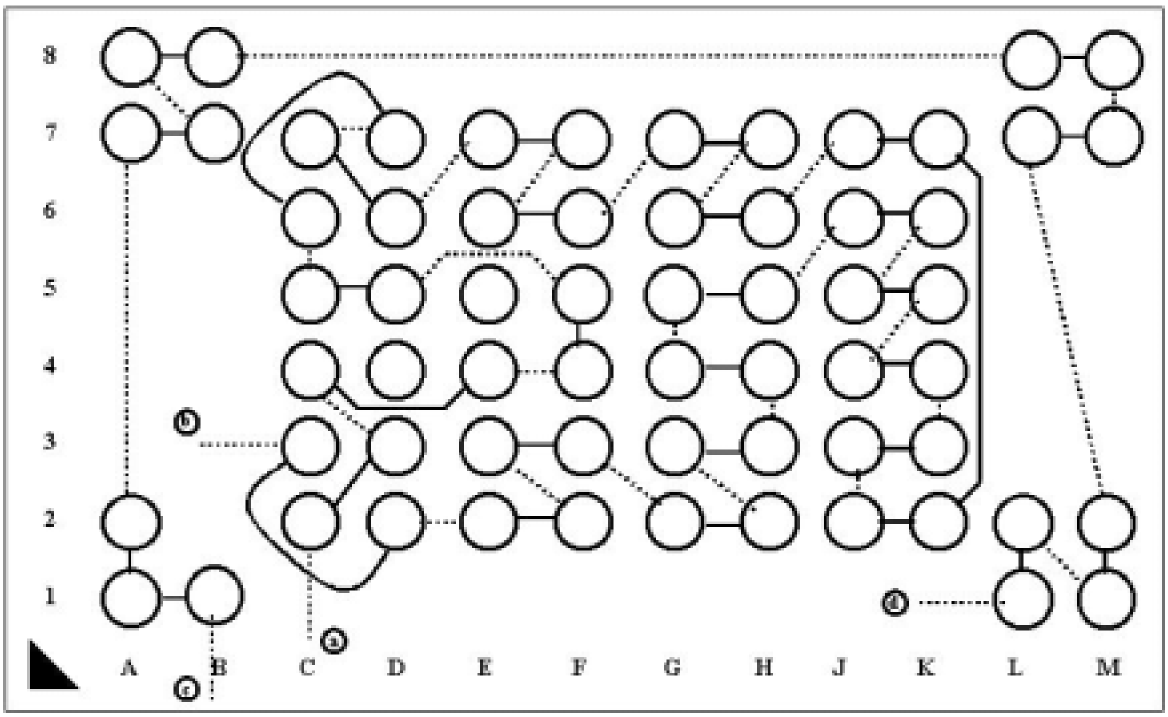
Daisy Chain Samples

Application Note

Daisy Chain samples are non-functional parts with a pattern of inter-connected balls. These samples are typically assembled onto a printed circuit board (PCB) with matching patterns. Once assembled on the matching PCB, all balls are connected creating a continuous network. Refer to Figure 1.



Notes:

1. *"_____" Solid traces are Daisy Chain patterns on the FBGA package.*
2. *"- - - - -" Dash traces are Daisy Chain patterns on the PCB.*
3. *'a', 'b' are the input and output of the network for the device.*
4. *'c', 'd' are the input and output of a separate network for the support balls.*

Figure 1. FBGA 32 Mb and 64 Mb Silicon Daisy Chain with Matching PCB Schematic (Top View)

Daisy Chain samples are primarily requested by OEMs to perform assembly evaluations. Prior to production, an OEM will generally solder daisy chain samples on to a daisy chain PCB and perform Open/Short testing to check for misalignments. This test will help an OEM characterize its assembly process and equipment prior to full production.

Daisy Chains are also used in Second Level Solder-Joint Board Reliability studies. The daisy chain samples are assembled onto the matching PCB and subjected to temperature cycling in an oven. Board Level Reliability tests are tools to help predict and measure the expected life of packages. For more in depth information on Second Level Solder-Joint Board Reliability, please refer to "Reliability Evaluation of Chip Scale

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Packages" by Ranjit Gannamani, Viswanath Valluri, Sidharth, and MeiLu Zhang.

Currently AMD has three types of FBGA daisy chains: Stitched Daisy Chains, Metal Mask Daisy Chains and Substrate Daisy Chains. Since the main purpose is to characterize assembly process and equipment, OEMs typically have no preference on the type of daisy chain used.

DESCRIPTIONS:

Stitched Daisy Chains

The functional substrate is used with a dummy silicon slug. Daisy chain patterns are produced by shorting pairs of adjacent bond-fingers on the substrate via wire bonding. There are no wire bonds from the dummy silicon slug to the substrate.

Metal Mask Daisy Chains

The functional substrate is used with a special daisy chained wafer. There is no active circuitry on the wafer, only the simulated bond-pads. Adjacent bond-pads are shorted via metal mask. Daisy chain patterns are produced by wire bonding the bond-fingers on the substrate to the bond-pads on the wafer.

Substrate Daisy Chains

A dummy silicon slug is used with a special daisy chained substrate. Shorting adjacent balls on the substrate produces daisy chain patterns.

ORDERING INFORMATION

AMD standard products are available in several packages and operating ranges. The order number (Valid Combination) is formed by a combination of the following:

Am29LV160D WC D 2 2 B

SUBSTRATE TYPE
A = Top or internal/intermediate layers shorted on the substrate
B = Bottom layer shorted on the substrate
C = Wirebond

DAISY CHAIN CONNECTION
1 = Daisy chain connection is on the die (metal mask)
2 = Daisy chain connection is on the substrate

SOLDER MASK OPENING AND GROUND PLANE
1 = No ground plane
2 = 0.25 mm solder mask opening
3 = 0.27 mm solder mask opening
5 = 0.50 mm solder mask opening
6 = 0.55 mm solder mask opening

DAISY CHAIN

PACKAGE TYPES
PB = 80-ball Fortified Ball Grid Array (FBGA) 1.00 mm pitch, 13 x 11 mm package
PC = 64-ball Fortified Ball Grid Array (FBGA) 1.00 mm pitch, 13 x 11 mm package
WC = 48-ball Fine Pitch Ball Grid Array (FBGA) 0.80 mm pitch, 9 x 8 mm package
WH = 63-ball Fine Pitch Ball Grid Array (FBGA) 0.80 mm pitch, 12 x 11 mm package
WM = 48-ball Fine Pitch Ball Grid Array (FBGA) 0.80 mm pitch, 12 x 6 mm package

DEVICE NUMBER/DESCRIPTION

Valid Combinations for BGA Daisy Chain			
Density	**Package**	**Order Number**	**Package Marking**
16 Mb	9 x 8 Fine Pitch BGA (WC) 13 x 11 mm Fortified BGA (PB)	AM29LV160DWCD22B AM29BDD160GPBD62B	LV160DD22B BDAFGD62B
32 Mb	12 x 6 mm FBGA (WM)	AM29DL323DWMD22B	DL323DD22B
64 Mb	12 x 11 Fine Pitch BGA (WH) 13 x 11 mm Fortified BGA (PC)	AM29DL640DWHD22B AM29LV640DPCD62B	DL640DD22B LCEDD62B

To place an order, please contact your local AMD sales representative. For a current list of contacts via the Internet go to http://www.amd.com/support/sales.html

RELIABILITY EVALUATION OF CHIP SCALE PACKAGES

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ABSTRACT

This paper evaluates various Chip Scale Packages (CSP's) with respect to board level reliability under accelerated temperature cycling stress tests. The solder joint reliability of three different types (based on substrate material) of Fine Pitch Ball Grid Array (FBGA) packages and the MicroBGA package is compared. The results are analyzed using Weibull data analysis and extrapolated to low cumulative percentage fails. The effect of package and board design parameters such as solder ball size and board thickness is also presented.

Key words: CSP, BGA, FBGA, solder joints, reliability.

INTRODUCTION

The goal of smaller and portable electronic products is driving the development of CSPs. CSPs are close to the die size and are much smaller than conventional packages. In 8Mb density Flash memory for example, a TSOP48 (Thin Small Outline Package) measures about 18.4mm x 12mm whereas a comparable CSP (FBGA) would measure only 6mm x 9mm.

Often, different CSPs offer similar reliability at the component or package level. Once they are mounted on boards, their ‘second level’ or ‘board level’ reliability could however be very different, and is based on the unique material set and construction of each package type. This study was undertaken to evaluate (i) the board level reliability of some CSPs of different construction, and (ii) the effect of package and board design parameters such as solder ball size and board thickness.

PACKAGES EVALUATED

The following packages were evaluated: (i) FBGA with Polyimide (PI) tape substrate, or FBGA-PI, (ii) FBGA with BT (Bismaleimide Triazine) substrate, or FBGA-BT (BT is the rigid epoxy glass laminate used in the conventional plastic ball grid arrays), (iii) FBGA with ceramic substrate, or FBGA-Cer, and (iv) MicroBGA. Each package has a different material set and structural construction.

Figure 1, Figure 2 and Table 1 illustrate the key differences between the various FBGAs. The FBGA-PI uses a thin 0.08mm PI tape substrate, while the FBGA-BT uses a relatively thick 0.36mm BT substrate. Both packages conform to the same overall package height of ≤ 1.2mm, which is the maximum package body height specified in the JEDEC FBGA specification. Consequently, the FBGA-BT uses 0.3mm solder balls while the FBGA-PI uses 0.4mm solder balls. The differences between the physical dimensions of the FBGA-Cer and FBGA-BT are minimal.

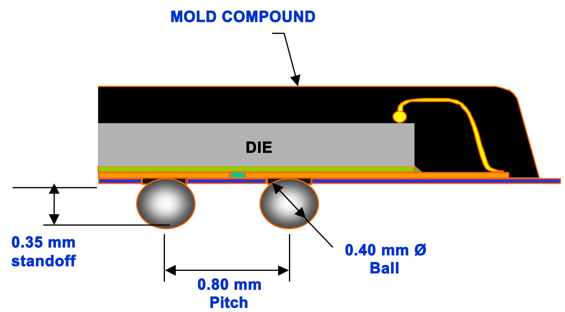

Figure 1. Cross-section of FBGA-PI

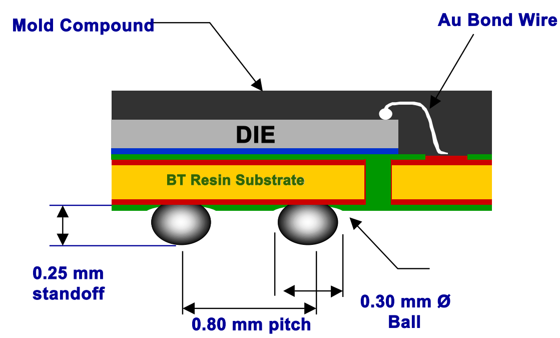

Figure 2. Cross-section of FBGA-BT

	FBGA-PI	FBGA-BT	FBGA-Cer
Ball size	0.4mm	0.3mm	0.3 mm
Solder	eutectic	eutectic	eutectic
Substrate thickness	0.08 mm	0.36 mm	0.35 mm
Substrate material	Polyimide	BT resin	Alumina
Die thickness	0.3 mm	0.26 mm	0.26 mm
Avg Pkg height (measured) when mounted on boar	0.96 mm	1.07 mm	1.18 mm

Table 1. Differences in FBGA construction

The basic construction of these FBGA packages is to some extent similar to that of conventional ball grid arrays. The MicroBGA (Figure 3) however has a unique construction. It uses a compliant elastomer material between the die and the polyimide tape. TAB type beam leads are bonded onto the die, and the die is ‘face down’ and exposed on the back side.

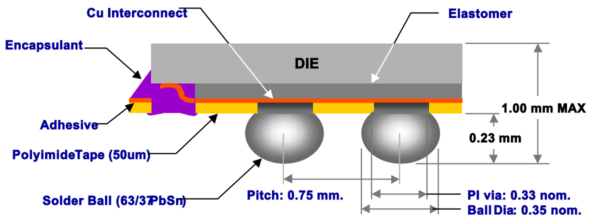

Figure 3. Cross-section of MicroBGA

TEST BOARDS

Each FR-4 test board measured 3.5" x 2". Both 20mil and 62mil boards were used in this study. Six CSPs were assembled on each board (Figure 4). On each board, half the packages were oriented at 90 degrees to the other half, and precautions were taken in the layout of the board to ensure that the data collected is free of any effects of location or orientation. The boards had Non Solder Mask Defined pads with a HASL finish. Standard best practices such as no-clean solder paste, laser cut stencils, and Nitrogen convection reflow were used in the assembly of the CSPs on the boards. Each CSP contains a daisy chained die. The daisy chain circuit is completed on the board such that each package consists of a single net through all the joints.

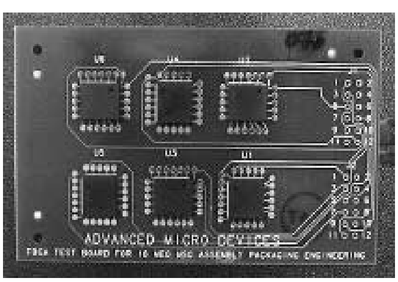

Figure 4. A typical CSP test board

TEMPERATURE CYCLING

A 0°C to 100°C, 30 minute single chamber air-to-air temperature cycling profile with 10 minute ramps and 5 minute dwells was used. This is one of the commonly used test profiles in the industry. An event detector was used to monitor the daisy chained test boards in real time. The event detector was set to record resistance spikes greater than 300 ohms for 200 nanoseconds. Any spike greater than 300 ohms was considered as "open". A package was considered failed when the first open was followed by 10 additional opens within 10% of the time of the first open. The thermal cycling chamber was profiled before starting the test, to ensure a uniform temperature across the different boards in the chamber. Wherever possible, the tests were continued to 63% fail or greater.

MODELING TECHNIQUE

After temperature cycling was completed, the failure data was fitted to a Weibull statistical distribution. The Weibull parameters α ($N_{63.2\%}$) and β (slope) were obtained for the test, and the data extrapolated to a low cumulative failure percentage (100 PPM). The test data was then extrapolated to field use conditions and the projected field life (at 100 PPM) calculated, in order to enable a more intuitive comparison of the reliability of the different packages. The Norris-Landzberg modified Coffin-Manson equation [1] was used to calculate the acceleration factor. The two example field conditions used in this paper are shown in Table 2.

Example Field Conditions	
Temperature Swing	Cycles / Day
40 C / 60 C	1
-15 C / 25C	1

Table 2. Example field conditions

RESULTS

Extensive temperature cycling data on the different CSPs was collected. The test program included various experimental splits with different combinations of package and board types. For clarity, the presentation of the results has been divided into the following five sections.

(A) Comparison of Different Package Types

The Weibull plots for the 8x9mm FBGA-BT, 8x9mm FBGA-PI, MicroBGA, and 6x9mm FBGA-Cer are shown in Figure 5. Here, the FBGA-Cer CSP contains the 8Mb density Flash device, while the other three CSPs contain the 16Mb density Flash device. This data was collected on 20mil (0.5mm) boards under 0/100 degC cycling.

The Weibull slope and cycles to 63.2% failure (N63.2%) are shown in Table 3. The Weibull plots show that the FBGA-BT and MicroBGA packages have significantly larger N63.2% values than the FBGA-PI and FBGA-Cer packages. It is too be noted that the initial MicroBGA failures are not solder joint failures and a discussion follows in a later section. From Figure 5 and Table 3, it can be seen that the slope of the distribution is different for various sets of data and hence a direct comparison of N63.2% fails is not feasible for the whole set of data. It is pertinent to compare the results at low PPM cumulative percentage failure mark. Hence, the 100 PPM number, which seems to be a very conservative number accepted in the industry, was chosen. Figure 6 shows comparative life projections in the two example field conditions defined in Table 2.

In termsof board level reliability, it can be seen from Figure 6 that the FBGA-BT and MicroBGA ranked much higher than the other packages. Both these packages demonstrated

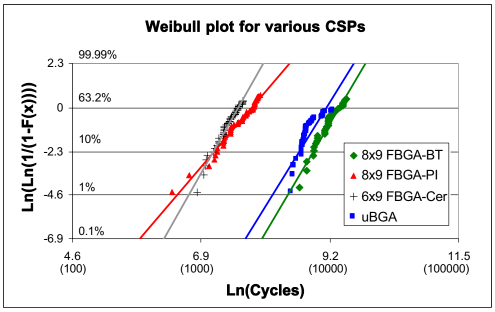

Figure 5. Weibull plots for various CSPs

Package	N63.2 (cyc)	Beta	# fails / SS
8x9 mm FBGA-BT	11586	5.0	39 / 48
8x9 mm FBGA-PI	2295	3.9	52 / 60
6x9 mm FBGA-Cer	1918	5.2	46 / 60
MicroBGA	9240	4.8	35 / 60

Table 3. Weibull parameters for various CSPs

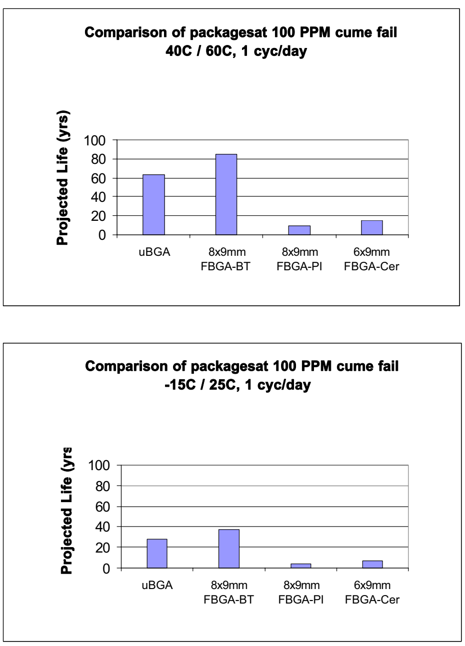

Figure 6. Field life projections

lifetimes considerably higher than the requirements of most customer applications. The 8x9mm FBGA-PI and 6x9mm FBGA-Cer data translated to lower field life projections. The life projections in "years" shown in Figure-6 are for those two specific field conditions only. The estimation of lifetimes would vary depending upon the specific field conditions and the model used to calculate the acceleration factors between test and field. However, the key observation to be made is that the relative size of the different bars is a true representation of the comparative reliability of the different CSPs at the board level.

The higher reliability of the FBGA-BT package can be attributed to the thick and rigid BT substrate isolating the silicon die (low CTE) from the solder joint and the board. In the case of the MicroBGA package, the compliant elastomer material isolates the silicon die from the solder joint and the board, and contributes to the high reliability. The comparatively lower reliability of the FBGA-PI is due to the fact that the package construction is dominated by the low CTE Silicon die. As seen in the package cross section, it is only the die attach layer and the Copper traces on the PI substrate that separate the solder ball from the die. The PI tape itself is not in the path; it has openings that define the pads for ball attachment. The lower reliability of the FBGA-Cer packages was expected since there is both global and local CTE mismatch with the FR-4 board. A potential use of this package might be on Ceramic boards, but that issue is not discussed in this study.

On completion of the tests, failure analysis was carried out on a sample of the test vehicles. Figure 7 shows micro-sections of the FBGA-PI and FBGA-BT test boards. Solder joint cracks at the interface on the component side are seen. This is consistent with the classic BGA solder joint failure mechanism that is well documented in the literature. Figure 8 shows the results of the failure analysis on some of the initial MicroBGA failures. A lifted beam lead was detected. The isolation of the low CTE die by the compliant elastomer results in the beam leads absorbing most of the cyclic fatigue stress in temperature cycling.

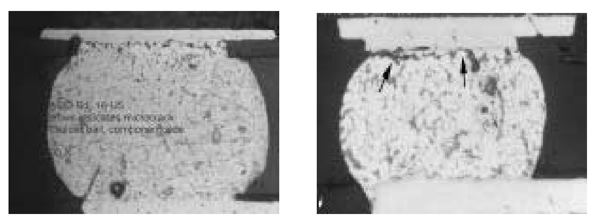

Figure 7. Failure analysis of FBGA-PI (left) and FBG BT (right). Cracks on component side.

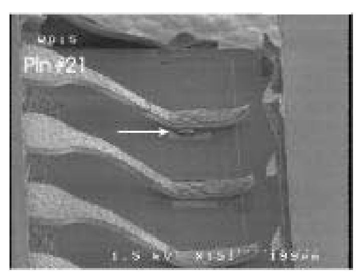

Figure 8. Failure analysis of MicroBGA

In these experiments, the FBGA-BT packages (0.3mm solder balls) were assembled on test boards that were initially designed for the FBGA-PI package (0.4mm solder balls). The test boards were designed to have 0.3mm pads that matched the 0.3mm openings in the PI tape (where the solder balls are attached) of the FBGA-PI package. The corresponding opening in the solder mask of the FBGA-BT package is 0.25mm. It is hence expected that the use of test boards designed or optimized for the FBGA-BT package could result in even better FBGA-BT data than that presented here.

(B) Effect of Package Body Size in FBGA-PI

The FBGA-PI test discussed in the earlier section was on the 8x9mm body size, which is the package for the 16Mb density Flash product. The 6x9mm FBGA-PI, the package size for the 8Mb density device, was also put on the 0/100 degC test. In this case also, 20mil test boards were used. Figure 9 shows the Weibull plots for both the 8x9mm and 6x9mm FBGA-PI packages. The relevant Weibull parameters are in Table 4 and field life projections in Figure 10. As seen in the Weibull plots and the field life projections, the larger 8x9mm package demonstrated a lower lifetime than the 6x9mm package. This difference is attributed to the larger package body size and the larger die size of the 16Mb device, i.e. the domination of the low CTE Silicon die is more pronounced in the larger package for the higher density Flash product. Based on these findings, it was anticipated that even larger packages for higher density products (32/64Mb) would show poorer solder joint lifetimes in the FBGA-PI package due to the same reasons.

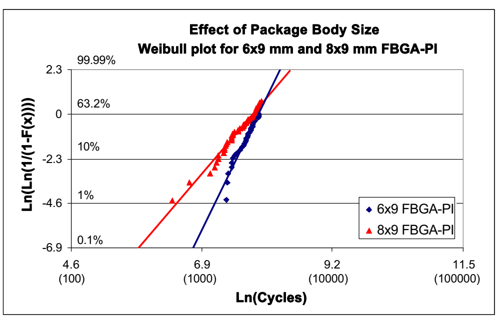

Figure 9. Effect of package body size in FBGA-PI

Package	N63.2 (cyc)	Beta	# fails / SS
8x9 mm FBGA-PI	2295	3.9	52 / 60
6x9 mm FBGA-PI	2685	6.0	38 / 60

Table 4. Weibull parameters for different body sizes

(C) Use of Larger Solder Balls on FBGA-PI

Design / package changes to improve the board level reliability of the FBGA-PI were investigated. Design parameters that may impact the board level reliability are substrate material, substrate thickness, mold compound

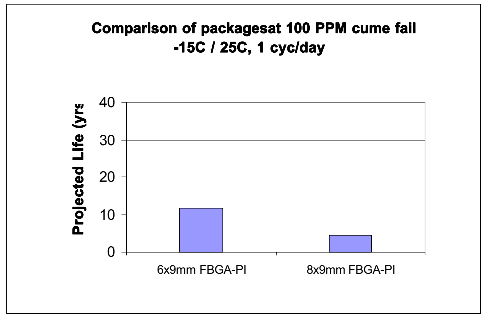

Figure 10. Field life projections

material, die attach compliancy, solder ball size, etc. The package design variable evaluated here was solder ball size. The solder ball size on the initial FBGA-PI package was 0.40mm nominal. This ball size was increased to 0.45mm nominal. Though the ball size was increased, the overall height of the package was maintained below 1.2mm. The PI tape opening was increased from 0.3mm to 0.38mm. The new test boards had 0.35mm pads. Based on industry practice, this was deliberately maintained a little smaller than the 0.38mm PI tape openings on the new FBGA-PI package.

Figure 11 shows the Weibull plots for both the 0.4mm ball and 0.45mm ball FBGA-PI packages. The relevant Weibull parameters are in Table 5. Figure 12 shows the field life projections for the FBGA-PI packages with 0.40mm and 0.45mm solder balls. As expected, the use of the larger solder balls results in an improved solder joint lifetime.

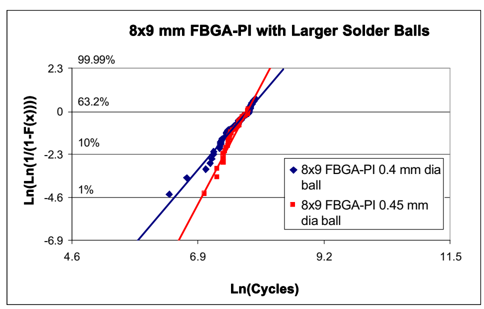

Figure 11. Use of larger solder balls on FBGA-PI

Package	N63.2 (cyc)	Beta	# fails / SS
8x9 mm FBGA-PI, 0.40 ball	2295	3.9	52 / 60
8x9 mm FBGA-PI, 0.45 ball	2424	5.5	40 / 60

Table 5. Weibull Parameters for solder ball size

From the Weibull plots it can be seen that it is challenging to quantify the improvement due to the use of larger solder balls. While the N63.2% values are relatively close, the different slopes tend to amplify the difference between the two datasets, especially when projected to lower PPM. For example, if a 1000 PPM criterion is used, the improvement obtained (of 1.8X) is significantly lower than that shown in Figure 12 (2.1X). To get an average picture of the whole data the slopes from the two datasets were pooled to obtain a common slope of 4.7, and an N63.2% fitted to both datasets. Now comparing N63.2% values results in an improvement of 1.13X with the use of larger solder balls.

From this analysis it is seen that even in a best case scenario for the larger solder balls, the improved lifetime is still lower than that of the FBGA-BT and MicroBGA packages.

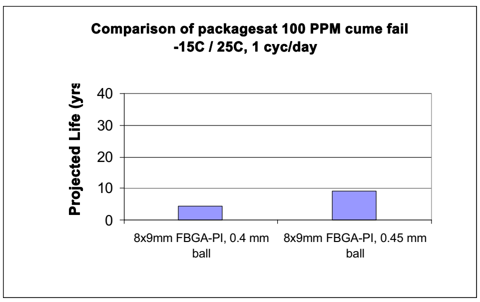

Figure 12. Field Life Projection

It should also be noted that at 0.45mm, the solder ball size is quite close to the maximum possible for the solder ball array with a pitch of 0.8mm, in order to retain sufficient room to route traces to internal solder balls. Additionally, the eventual move to a 0.5mm pitch solder ball array (necessitated by shrinking die sizes due to improved fab processes, and the need for smaller form factor packages) will make the use of a 0.45mm ball impossible. The FBGA-BT package that currently uses 0.3mm solder balls would be able to transition to a 0.5mm solder ball pitch without requiring a change in ball size.

(D) Evaluation of Test Vehicles built on 62 mil Boards

All the data discussed in earlier sections was collected on test boards that were 20mil thick. Testing (0/100 degC cycling) was also carried out on 62mil (1.6mm) boards to evaluate the effect of these thicker boards on the solder joint lifetimes. Figure 13 shows the Weibull plots for the 6x9mm FBGA-PI on both 20mil and 62mil boards. Figure 14 shows similar plots for the 8x9mm FBGA-BT package. The relevant Weibull parameters are listed in Table 6. It should be noted here that the FBGA-BT / 62mil board data presented here is preliminary. This will be updated as more failures are collected.

It can be seen from Figure 13 that the same challenge of quantifying the difference (as outlined in the previous section) exists for these two sets of FBGA-PI data as well. Using the technique of pooling to a common slope of 7 and recomputing the N63.2% values, it is found that on an average, the solder joint life on thinner board exceeds that on the thicker board by 1.34X for FBGA-PI package. The slope (beta) for the thicker board was higher than that for thinner board, and so projections to a low PPM value showed minimal difference (Figure 15).

For the FBGA-BT package the results are preliminary as the tests on 62mil boards are still in progress. Initial data shows minimal difference as the failures obtained so far have lined up on the existing data on the 20mil boards (see Figure 14 and preliminary life projections in Figure 15).

It should also be noted that that the 62mil boards were assembled at a different site. Hence, while these may not be exact comparisons the information presented is still useful to demonstrate that there is no significant difference in the lifetimes projected even when the same packages are assembled on thicker boards.

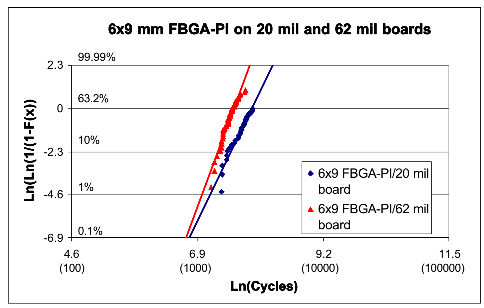

Figure 13. FBGA-PI on 20 and 62mil boards

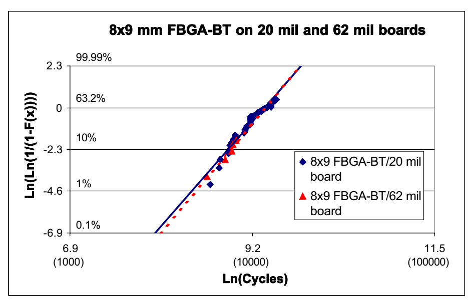

Figure 14. FBGA-BT on 20 and 62mil boards

Package	N63.2 (cyc)	Beta	# fails / SS
6x9 mm FBGA-PI, 20mil board	2685	6.0	38 / 60
6x9 mm FBGA-PI, 62mil board	1932	7.9	45 / 48
8x9 mm FBGA-BT, 20mil board	11586	5.0	39 / 48
8x9 mm FBGA-BT, 62mil board	11757	5.2	5 / 30

Table 6. Weibull parameters

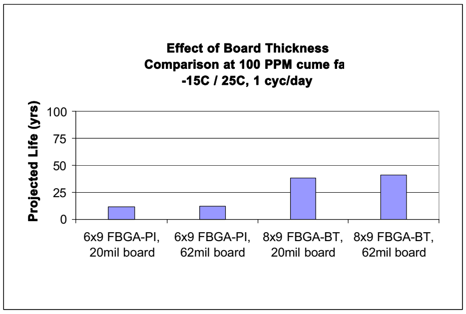

Figure 15. Evaluation on 62mil boards

(E) Temperature Cycling at -40 / 100 degC

A limited amount of data was also collected at the -40/100 degC, 30 minute cycle test condition on 20mil boards. Table 7 is a summary of that data. The 8x9mm FBGA-BT and the 8x9mm FBGA-PI packages were evaluated. The test was terminated at 2507 cycles. At that point, there were zero fails (0/60) of the FBGA-BT test vehicles and extensive failures (49/60) in the FBGA-PI test vehicles. While no field projections are included here, this information again gives an indication of the relative robustness of the two packages.

Test Condition: -40 / 100 degC		
	8x9 FBGA-BT	8x9 FBGA-PI
Cycles completed	2507	2507
Data	No fails out of 60	49 fail out of 60
First fail at:	n/a	754
Test status	Stopped	Stopped

Table 7. Board Level Reliability Data at –40/100 degC test condition

CONCLUSIONS

(i) In the packages evaluated, the FBGA-BT and MicroBGA demonstrated lifetimes considerably higher than the FBGA-PI and FBGA-Ceramic packages. These differences in board level reliability can be explained by the differences in package construction and material sets.

(ii) In the FBGA-PI package, the larger 8x9mm package for the higher density 16Mb device (larger Silicon die) demonstrated lower reliability than the 6x9mm package for the 8Mb device. Based on this trend, it was anticipated that even larger packages (for 32/64Mb) would show lower solder joint lifetimes in the FBGA-PI construction.

(iii) The use of the larger solder balls (0.45mm vs. 0.4mm) on the FBGA-PI package resulted in an improved solder joint fatigue life. Even in the best case scenario for the larger solder balls, the improved lifetime was still lower than that of FBGA-BT and MicroBGA packages. Feasibility of using a 0.45mm ball size would be challenged as migration to 0.5mm ball pitch is made.

(iv) At 100 PPM no significant difference in the board level reliability was detected for both the FBGA-BT and FBGA-PI packages assembled on the thicker 62mil boards when compared to those mounted on the 20mil boards.

(v) Limited data at the -40/100 degC test condition indicates the relative robustness of FBGA-BT over FBGA-PI with respect to board level reliability, that is consistent with the rest of the 0/100 degC data discussed in this paper.

ACKNOWLEDGMENT

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REVISION SUMMARY

Revision A (January 26, 2001)

Initial release.

Revision A+1 (October 25, 2001)

Ordering Information

Replaced section with updated ordering part number information.