

Performance and Reliability of a Cavity Down Tape BGA Package

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Abstract

As the demand for increased I/O has gone up, so has the interest in ball grid array packaging. It is well recognized in the packaging industry that as the pin counts increase above 208, BGA packages become more attractive due to their small form factor and ease of board attachment. However, along with the general trend for higher i/o, an increasing percentage of integrated circuits are also running at over 200 MHz and 4 watts of power. These IC requirements surpass the capability of standard QFP and PBGA packages. To satisfy this demand, there has been a major push for high performance BGA packages which are considerably more cost effective than ceramic package alternatives. Tape BGA packages provide an excellent cost/performance solution in this market segment and are gaining a great deal of attention. With the fine line capability of flexible circuits (down to 25 micron lines and spaces), the wire bond fingers can be moved in very close to the die. This enables die shrink in pad limited die and reduces the wire length which is often the main source of package self inductance. Excellent thermal properties are achieved by directly attaching the die to a thermally conductive copper stiffener or heat spreader. The CTE of the copper also matches closely with that of the board to maximize the thermal cycle reliability. This product can be provided at a competitive price due to the minimization of materials and a simplified production process. The result is a low-cost/high-performance package with excellent reliability. This paper will discuss the electrical and thermal performance of this package as well as the reliability.

Introduction

The recent gain in popularity of ball grid array (BGA) packages has been propelled by the numerous advantages which BGAs have demonstrated over conventional packaging techniques such as quad flat packs and pin grid arrays. As the need grows for higher i/o, BGA packages become more desirable due to their reduced real estate requirements [1]. In addition, BGAs are relatively low cost with good to excellent electrical and thermal characteristics [2]. Perhaps the key advantage of this package style is the ease of board level assembly. The relatively coarse pitches typically associated with BGA packages (1.27 and 1.5 mm) allow for routine solder paste deposition and placing of the component. Many types of BGA packages can be placed up to a half pad off center (typically 300 μ m or more) and will self align upon reflow of the solder balls[3]. The result is

card assembly defect levels less than 2 ppm compared to 48 ppm for 0.5 mm pitch QFPs [4]. The inability to easily inspect the BGA solder joints and repair defects are potential concerns which have been addressed in the industry through better assembly process control and the implementation of methods for removing and replacing defective BGA components [5,6].

Ball grid array packages have proven themselves to be the package of choice for pin counts above 208 due to their high performance and low defect levels at board assembly compared with high pin count QFPs [7]. Their excellent fit into the existing infrastructure has enabled them to compete on a cost basis as well. With this being the case, the next issue which die manufacturers must address is - what type of BGA will best meet the requirements of a particular device? Although package cost is always a major consideration for most die, better electrical and thermal performance are becoming increasingly important as die grow more sophisticated. Not only must the die manufacturer choose between plastic, tape, and ceramic BGAs, they must also choose amongst the various BGA configurations within each of these groups. A former Tech Search International publication reported on 13 different tape ball grid array configurations alone [8]. This paper will address one of these architectures to discuss its electrical and thermal performance and demonstrate its excellent reliability through thermal cycle testing and life predictions.

Product Configuration and Characteristics

The TBGA carrier being offered is in response to the market need for a lower cost TBGA which allows the wire bonding of a die. Since approximately 97% of die are currently wire bonded, this vast infrastructure is already in place in the assembly industry. These TBGA carriers are supplied in a strip format similar to a leadframe or PBGA which allows assemblers to easily utilize their existing infrastructure for die attach, wire bonding, encapsulation and ball attach. A representative carrier strip made up of four 35mm 352i/o units is shown in Figure 1. The following Figure 2 is a cross section schematic of a completed TBGA. This structure provides excellent thermal characteristics, since the backside of the die is directly adhered to the metal stiffener/heat spreader. The thin adhesive layer (1-2 mils) between the circuit and stiffener allows a great deal of heat to be dissipated from the stiffener, through the solder balls, and into the circuit board. This is a significant advantage since it

enables all the solder balls to act as thermal vias as opposed to only those under the die as with standard PBGAs. As a result, up to 90% of the heat can be dissipated through the board. This is an especially attractive attribute for applications involving confined space such as portable computers. In addition, this spreading of the heat over the whole package may allow more uniform heating of the board beneath the package, thus limiting any warpage that may occur in packages with thermal vias beneath the die only. Uniform heating may also be an advantage during rework by minimizing board damage during the removal and replacement of the package.

High Density Flex

The use of microflex circuitry in fabrication of a TBGA offers a number of advantages over other substrate types. One major advantage is the finer pitch capability. Current capabilities allow 35 μm lines and spaces with microflex circuitry (improving to 25 μm lines and spaces in the near future) while most PCBs are limited to 75 μm lines and spaces or greater. Finer pitch enables routing of more balls with a low cost single metal layer flex circuit, whereas, a PCB may require 2 or more layers and thus be less cost effective. Flex circuitry will provide further advantage as the ball pitch on BGAs continues to decrease from 1.27 mm to 1.0mm or less.

Perhaps of even greater importance, these fine feature dimensions make it possible to position the wire bond fingers closer together and therefore move them closer to the die itself. For instance one could design pads with a width of 90 μm and a space of 35 μm for a total pitch of 125 μm . This is much finer than the minimum of 165 μm currently available with BT boards (for an equivalent 90 μm pad width). The advantages of this are three-fold. First of all, positioning of the pads closer to the die makes for a shorter wire bond length and therefore considerably reduces the self inductance of the wire. Many in the industry feel wire bonding can not keep up with the requirements of high speed devices due to the typically high self inductance of the wires. However, by reducing the wire length from 5 mm or longer on standard PBGAs to as little as 1mm, the self inductance decreases by almost 4 nH, thus enabling wire bonding to keep up with the increasing high speed demands. This effect is illustrated in Figure 3, where the cumulative self inductance of a signal path is shown from a solder ball, along the package circuit line, and through the wire itself to the die pad. With a printed circuit board, modeling shows the inductance of the trace on the package to be approximately 0.3 nH/mm, while for the 3M version of TBGA this inductance is 0.2 nH/mm [9]. This reduced inductance is due to the closer proximity of the circuit line to the copper stiffener compared to an enhanced PBGA (25 μm compared to 100 μm). The self inductance in a 25 μm diameter gold wire has been estimated to be 1 nH/mm [10], considerably higher than that on the circuit trace itself.

Therefore, to minimize the total self inductance of the system, the objective is to keep the signal close to the reference plane on the package as long as possible, which

illustrates why it is so important to minimize the wire length in the system. As can be seen in the example in Figure 3, even though the self inductance of trace on the TBGA is higher due to the longer length of the trace from the ball to the bond pad, the total self inductance is considerable less when the bond wire is taken into account. The message here is to make sure that the wire length is accounted for when evaluating the total inductance of an individual package.

A second advantage of the shorter wire lengths is the reduced chance for wire sweep. With wire sweep as less of a concern, a smaller diameter wire can be used (for instance 25 μm instead of 30.5 μm) which better enables finer pitch bonding on the die. In addition, the shorter wires have lower loop height which ensures complete coverage by the encapsulant while maintaining the required 10 mil standoff of the encapsulant from the board during surface mounting.

The third advantage has to do with die shrink. As the circuit trace width on the die continues to decrease from 0.5 to 0.35 μm and below, there is a strong desire to pack everything tighter to reduce the size of the die and therefore its cost. With some packages the wire length is already at a maximum and shrinking the die further would stretch the wire beyond its limits. On a TBGA package the wire bond fingers can be moved in closer thus eliminating the wire length problem and enabling the die to shrink much further.

Solder Ball Reliability

As seen from Figure 2, the flex is adhered with the circuit side toward the stiffener. This orientation enables the polyimide substrate to be used as the solder mask, therefore eliminating the need to perform additional processes for depositing a precise solder mask. The solder mask process can be costly and the epoxy based materials can pose reliability issues in difficult tests such as pressure cooker and moisture resistance. At 3M, a chemical etching process is used to create holes in the polyimide. With this process, all the vias are created simultaneously in an economic fashion. The sloping sidewalls caused by the diffusion controlled etching process have been determined to be beneficial since they aid in capturing the solder ball when it is placed prior to reflow attach and more importantly, this gradual slope enables the solder ball to maintain its natural shape after reflow attach. That is, there is no dielectric material which impinges into the solder ball, as is the case when soldermask material is used to define the solder ball pad [11].

For example, Figure 4 shows a cross section of a ball in an etched via compared to one in a soldermask defined via. Impingement of the soldermask into the solder ball creates a sharp corner in the ball which can act as a stress concentration site and permit a crack to more easily form under an applied load. This effect is quantified by measuring the shear strength of solder balls on standard solder mask defined pads compared to the etched via structure. A shear test essentially measures the load required to initiate a crack, since increasing force is applied until a crack forms, at which point catastrophic failure immediately occurs through the solder. Results of shear testing 30 mil solder balls from pads of various sizes are shown in Figure 5. For each pad size the

etched via produced 15 - 30% higher shear results than a SMD pad on either a BT substrate or a flex substrate.

Stress concentration sites can also manifest themselves in lower fatigue life as it reduces the number of cycles required to induce a crack. Fatigue comparisons were performed by cycling a fixed load on an individual solder ball attached to a substrate. The substrate was held on end (in a vertical position) and a rod with a 32 mil hole was slipped over the solder ball and used to impart the stress in the plane of the package at a displacement rate of 0.5 inches/min (which resulted in a cycle rate of 30 cycles/min). The machine was then cycled from +500 grams to -500 grams until the 30 mil eutectic solder ball fractured from the pad; this test setup is shown in Figure 6. A load of 500 grams was chosen since it produced a cycles to failure of between 1000 and 3000, a number on the same order of magnitude as might be expected in an extreme thermal cycle test (a higher number of cycles simply required too much time for the test). A total of 10 solder balls were tested for the 3M etched ball pads and compared to an equivalent number of measurements from a solder mask defined pad on a PBGA and a SMD pad on another TBGA structure. The results shown in Figure 6 reveals a significant (over 2x) improvement with the chemically etched ball pad openings compared to the SMD pads. This test is NOT meant to provide any life predictions of a package in a use environment since it does not take into account a number of factors such as stress relaxation and temperature effects. It is simply a means of comparing the fatigue resistance between different types of solder joints. However, it does appear that the elimination of the stress concentration site does indeed enable more cycles until crack initiation.

Board Level Reliability

Of course the strength of the solder joint and its fatigue properties are only two of the important aspects associated with the expected thermal cycle life of a package. Another critical factor is the actual stress on the ball caused by the CTE mismatch in the system. The copper stiffener on a TBGA package has a CTE of 16.6 ppm/°C which matches closely with most circuit boards to minimize the actual stress on the solder joint. Results from earlier board level thermal cycle testing (-55/125°C) of 340I/O 29 mm packages is shown in Figure 7. Three components had been surface mounted to multifunctional FR4 boards with 475µm diameter (19 mil) solder mask defined ball pads. Packages with ball pad diameters of 400, 500, and 600 µm were used to determine the effect of these various sizes on the reliability of the package. Each package had a 8mm die attached in the

cavity and was encapsulated and was populated with 750 µm (30 mil) eutectic solder balls (62/36/2Ag). The packages were daisy chained such that each row of solder balls could be individually monitored with a 4 point probe, thus enabling identification and analysis of any failed solder joints. When a daisy chain series of solder joints showed a total resistance change greater than 1 ohm the package was identified as a failure and was pulled from the test. The boards were cycled between a chamber at a temperature of -58°C to another at 133°C at a rate of 3 cycles/hour (a 5 minute transition period with 5 minutes of dwell at the required temperature of -55 or 125°C). The chambers were set below and above the required temperature points to ensure the full 5 minute dwell time was achieved. The cumulative failure results were fit to a two parameter Weibull distribution with excellent fit; this distribution being characterized by the equation:

$$F(t) = 1 - \exp(-(t/\alpha)^\beta)$$

- where,
- α is the characteristic life (cycles to 63.2% failed devices)
- β is the shape parameter (slope)
- t is the number of cycles

These board level thermal cycle results are shown in Figure 8 and the numerical results are shown in Table 1. For the largest 600 µm ball pads the characteristic life was calculated as 6239 cycles and the slope (or β value) was determined to be 18.2, which compared favorably to a similar size 360i/o PBGA with characteristic life of 3500 cycles and β of 5.8 [12]. Even the packages with the smallest 400µm ball pads had very favorable reliability results ($\alpha = 5046$ cycles and $\beta = 11.2$). An example of a typical solder joint fracture is shown in Figure 9. As one would expect, as the pad sizes on the package increased, an increasing percentage of the failures occurred at the board side of the solder joint. However, even when the pad size on the package was 75 µm smaller than that on the board, there were still many failures on the board side. Thermal cycle testing from 0/100°C of similar packages has also been ongoing for over a year at a rate of 2 cycles/hour. Over 21,000 cycles have been accomplished thus far with no failures detected.

Package Level Reliability

This fully assembled TBGA package has been tested and qualified by users such as TI among others. Such testing has included 240 hours of PCT, 1000 thermal cycles - 55/125°C, 1000 hours heat aging 150°C, all with level 4

Table 1: Board level thermal cycle results for TBGA package with copper stiffener.

TBGA Sample Type 29mm, 340i/o	Ball Opening Diameter	# Parts	α ($N_{63\%}$)	β	$N_{0.01\%}$ 100ppm	Fit %
Cu cavity stiffener w/ encapsulated 8mm die	400 µm	40	5046	11.2	2219	99.4
“	500 µm	69	5776	10.0	2300	99.9
“	600 µm	35	6239	18.2	3760	98.9

moisture preconditioning. The product has also been qualified to JEDEC level 3 moisture conditions with evidence to suggest level 2 is possible with die under 10mm in size. The failure mechanism for large die at level 1 or 2 is typically caused by delamination of the encapsulant from the face of the die. It has been suggested that modifications to the encapsulant material or a polyimide coating on the die face would improve this encapsulant/die adhesion.

The carrier strip itself is easily capable of passing level 1 without experiencing voids or delamination of the structure. Its robustness is due to the high temperature thermoplastic polyimide adhesive (Tg of 220°C). This material has excellent bond strength and its high modulus below the Tg prevents the formation of moisture pockets during the reflow process. Softer adhesives can allow moisture from the polyimide substrate layer to create interfacial voids since the vapor pressure of the outgassing moisture overcomes the modulus and bond strength of the adhesive. The much higher modulus and bond strength of the polyimide adhesive prevents void formation which forces the moisture to escape out of the surface. Consequently, the TBGA substrate can easily survive level 1 moisture testing without formation of voids or delamination.

Wire Bond Results

Not only does use of the high temperature thermoplastic polyimide adhesive produce a reliable package but its high modulus (over 1000 MPa) at temperatures below the Tg provides a firm surface on which to wire bond. Softer adhesives tend to absorb the ultrasonic energy, thus preventing an adequate bond [13,14]. The viscosity of the material at lamination temperatures also enabled the wire bond fingers to be directly embedded into the adhesive without the material flowing onto the surface of the bond pads. A great deal of wire bonding has been successfully performed to this TBGA carrier with various wire bond machines and at a wide range of temperatures and bond parameters. An example of typical gold wire bonds is shown in Figure 10 (note the short 50 mil wire length).

Thermal Performance

With the die attached directly to the thermally conductive copper stiffener one would expect excellent thermal performance for this package structure, as is indeed the case. Although a portion of the heat is dissipated from the surface of the heat spreader, the greatest amount is actually dissipated through the balls and into the circuit board. Each ball on the package actually provides a thermal path to drive heat into the board where it is dissipated more efficiently due to its much greater surface area. This strategy is particularly important when the package is in a system with minimal or no airflow such as a laptop computer. To maximize the heat flow into the board one needs to minimize the thickness of dielectric layers between the stiffener and the solder ball pads. This dielectric layer (adhesive) in the 3M configuration is quite thin - approximately 25 μm (1 mil). Theta Ja values for a 35 mm package with a 7.5 mm die are shown in Figure 11. For a 5 watt die the mean plus 3 sigma

value ranges from 12.5°C/W to 8.4°C/W depending on the amount of airflow. These measurements were taken on a 4 layer JEDEC size test board.

Grounded Stiffener Structure

Positioning the circuit side of the flex toward the stiffener also provides an electrical advantage as it has been determined that the close proximity of the traces to the metal stiffener enables this stiffener to act as a floating reference plane, thus reducing the inductance and signal cross talk between parallel traces [15]. This effect, in addition to the benefits of reduced wire lengths, enables this one metal layer TBGA to satisfy the electrical needs of many high performance die. However, for some applications in which there are many signals switching simultaneously, a separate Vss ground plane is required to minimize the inductance to the ground and in turn minimize the effect of ground bounce. In order to obtain this ground plane, the natural tendency is to migrate towards a two metal layer flex circuit, however, this can be fairly costly due to the additional complex process steps involved in its production. This higher cost can push the 2ML TBGA beyond where it is competitive with other solutions such as 2ML BT circuit boards in an enhanced PBGA. To resolve this issue, the approach at 3M is to electrically interconnect the copper stiffener to provide an active Vss ground plane. After all, the stiffener is already an integral part of the package, so it makes economic sense for it to be utilized to increase the electrical performance as well.

The patent pending construction being proposed in this paper uses a via location next to the desired ground ball. This via consists of a ring of copper with an inner diameter of approximately 16 mils (400 μm). When the polyimide substrate is etched to expose the solder ball pads, a hole is also etched to expose this copper ring. The ring is then aligned with a hole in the adhesive used for laminating the flex to the stiffener. After lamination of the flex to the stiffener, this via location is simply filled in with a high temperature (10Sn/90Pb) solder paste and reflowed at a temperature of 320°C. This solder alloy is used in order to prevent reflow during the ball attach or board attach process. A diagram and cross section view of this structure is shown in Figure 12.

Positioning the vias next to the ground ball locations produces a reliable interconnect since the package to board mismatch stress is not transferred to this joint. In addition, this process may allow for a generic circuit layout with numerous ground via locations designed in. The user could then choose which ball locations on the package to ground for each specific die application, thus enabling economies of scale for the flex circuit and faster turn times since these parts can be placed in inventory.

The process for filling the vias is fairly straightforward. A standard screw driven dispensing machine is used since this allows accurate position and volume placement of the solder paste into the via locations with simple programming. Hard tooling is not required for each design, as would be the case for a stencil process. The reflow takes place in a standard belt oven. The parts are then cleaned in DI water to

remove the flux residue. Performing this process is more cost effective than producing a 2ML TBGA which not only requires 2ML flex tape but also the deposition of a costly photodefinable soldermask to define the ball pads.

Reliability of Grounded Stiffener

The grounded stiffener TBGA was designed as a simple extension to the proven 3M TBGA structure in order to maximize the probability for success. Consequently, most of the additional testing done on this product was performed to specifically verify the robustness of the solder filled via. Tests performed include heat aging, accelerated thermal cycling (-55/125°C), and pressure cooker testing. Each test was performed with the package surface mounted to test boards (four layer boards constructed with multifunctional FR4). Testing the packages premounted to boards ensured they had seen temperature and stress conditions typical of a package in use. Board level testing also made it easier to take accurate electrical resistance readings of the vias. Four point probe resistance was taken of a path through one ground via across the ground plane and through another ground via. Thus, each reading actually included the resistance of two vias. A failure was judged to be a resistance change of over 10 miliohms. A total of 8 readings were taken per part on 28 parts. Resistance readings remained essentially unchanged for 4000 thermal cycles as was the case for 2000 hours of heat aging and 168 hours of pressure cooker testing ($\Delta R < 1\text{mohm}$). Results are shown in Table 2. These results were expected since this is, afterall, a fairly robust solder joint with little external stress exerted on it.

The ground plane in this configuration is typically utilized with select ground pads on the die being wire bonded to a ground ring on the package. This ground ring is in turn connected to the stiffener with solder filled vias at the corner locations. The stiffener is grounded to the circuit board through specific solder ball locations. In instances where the backside of the die requires grounding, a single piece stiffener with a chemically etched cavity is used. A further improvement in the electrical path from the die to the ground plane can be achieved by eliminating the ground ring and

instead wire bonding directly to the stiffener, as shown in Figure 13. Of course the edge of the stiffener would require selective plating of a bondable material such as Ag, Pd, or Au.

In many instances several ground balls on the outer edge of the package can be grouped together with a large metal feature and grounded with one or more vias. Likewise power islands can be created with large metal areas which are connected to a power ring with wide traces for minimum inductance.

Electrical Performance Measurements

To obtain electrical properties of the 35 mm 3M Grounded Stiffener TBGA package, high frequency characterization was performed using an HP8510C Network analyzer and HP Microwave Design System (MDS) software. A detailed description of the test methodology is covered elsewhere [15]. To adequately assess the performance of the various traces in the package, three trace pairs of varying lengths (short/medium/long) were selected for measurement. A summary of the equivalent circuit parasitic parameters from three trace pairs of varying lengths in the package is shown in Table 3 and the equivalent circuit model of the package electrical interconnect is shown in Figure 14. These measured values compare very favorably with similar measurements from competitive BGA substrate technologies. It should be noted that these measurements include the solder ball but do not include the wire bond in the package. As described earlier, because of the fine line and spacing capability of 3M Microflex relative to other BGA package substrate technologies, further improvements in overall packaging parasitics would also be realized by the reduction in bond wire length that is possible with this package architecture.

The electrical performance of the 3M TBGA package with a grounded stiffener is strongly influenced by the proximity of the ground reference plane to the signal traces. The unique construction of the 3M TBGA affords a dielectric separation of only 25 microns between the signal traces and the ground reference plane. This minimizes the mutual inductance and capacitance which, in turn, decreases the

Table 2. Board Level Reliability Results for Grounded Stiffener

Test Condition	Test Specification	Duration	Results (#failures/#tested)
High Temp. Storage Life (150°C)	JESD22-A103-A	1000 hours	0/14
		2000 hours	0/14
Temperature Cycling (-55 to +125°C)	JESD22-A104-A	1000 cycles	0/28
		1450 cycles	0/28
		2000 cycles	0/28
		2435 cycles	0/28
		2935 cycles	0/28
		4000 cycles	0/28
Pressure Cooker (121°C, 100% RH, 2 ATM)	JESD22-A102-B	168 hours (7 days)	0/18

Table 3. Electrical Measurement Results for Grounded Stiffener TBGA Package.

Trace Pair	L1 (nH)	L2 (nH)	M12 (nH)	C1 (pF)	C2 (pF)	Cm1(pF)	Cm2(pF)
Gnd Long-Length	3.10	2.50	0.18	1.57	1.70	0.05	0.05
Gnd Med.-Length	1.56	1.68	0.14	1.31	1.40	0.035	0.035
Gnd Short-Length	1.22	0.96	0.08	1.55	1.57	0.045	0.045

cross talk noise in the package. The proximity of the ground plane also reduces the self inductance of each signal trace which diminishes the potential for noise due to reflections and minimizes other signal fidelity issues associated with high speed signals.

In addition to lowering the transmitted noise in the package due to cross talk, reflections and other signal perturbations caused by interconnect parasitics, utilizing the stiffener for ground distribution in the package provides an extremely cost effective, low inductance ground return in the package. This minimizes noise caused by dynamic changes in the ground reference levels at the input receivers of the IC device. This is commonly called “ground bounce” and can be a significant problem in digital logic devices. To characterize this, single-port measurements with the 8510C Network Analyzer were performed on a 35 mm TBGA package design with ground connections at the outside BGA corner ball locations and at the inside corners of the ground ring in the wire bond area. Measured results indicated that inductance of a single connection between a corner BGA solder ball and the interior wire bond ground ring of a 35 mm TBGA package carries a total inductance of less than 1.1 nH. When this intrinsically low inductance is coupled with good package design practices which include careful power and ground pin assignments and sufficient power and ground wire bond connections to the IC device, effective loop inductance of less than 100 pH can be easily achieved. Consequently, this package structure appears to be well suited to handle the requirements of high performance die.

Conclusion

The wire bond tape ball grid array is an exciting new enhanced IC package technology which fits well into existing infrastructure and offers much finer pitch capability than circuit board substrates used for PBGAs. This denser circuitry enables the wire bond pads to be positioned nearer to the die thus minimizing the length of the bond wire and thus the self inductance. This ability enables continued die shrink for pad limited die. Excellent thermal performance is achieved by attaching the die directly to the copper stiffener which allows the heat to efficiently dissipate through the solder balls and into the circuit board. This package has been shown to have excellent board level reliability due to a combination of the closely matched CTE to the board and the tapered slope of the etched via which eliminates stress concentration sites. The moisture resistance of the package is excellent due to the high temperature characteristics of the

adhesive used to attach the circuit to the stiffener. The stiffener can be interconnected to provide a low inductance ground path for high speed die. The solder filled vias used to make electrical connection to the copper surface of the stiffener have been proven reliable through pressure cooker, heat aging and thermal cycling testing. In summary, the 3M TBGA represents a simple, cost effective BGA substrate technology designed to handle the needs of high performance devices.

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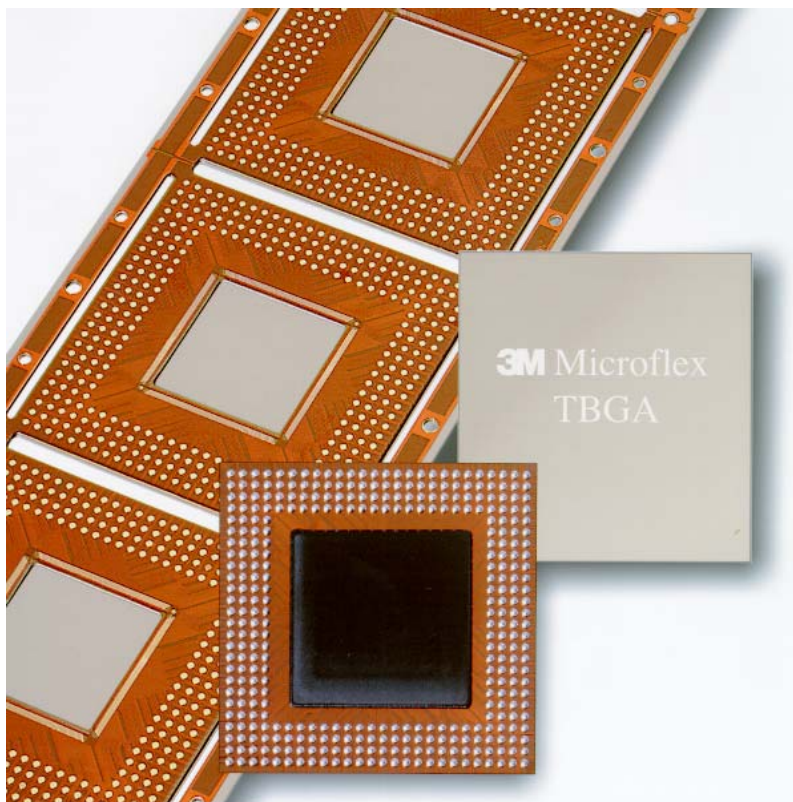


Figure 1: Cavity down TBGA carrier strip. 35mm, 352i/o.

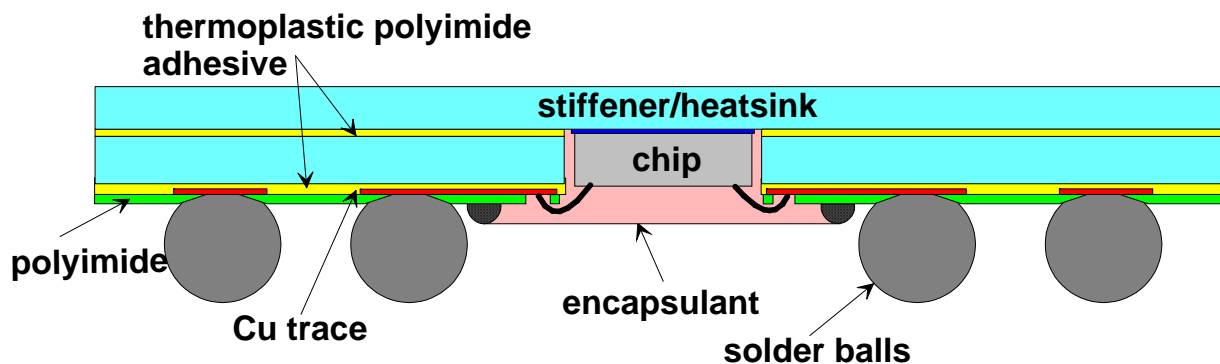


Figure 2: 3M Tape ball grid array structure. Chemical etching of the polyimide is used to define the solder ball pads and the wire bonding window.

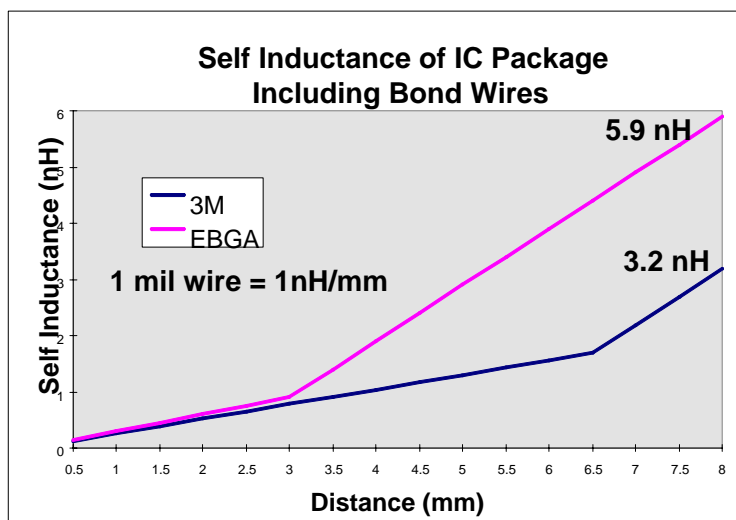
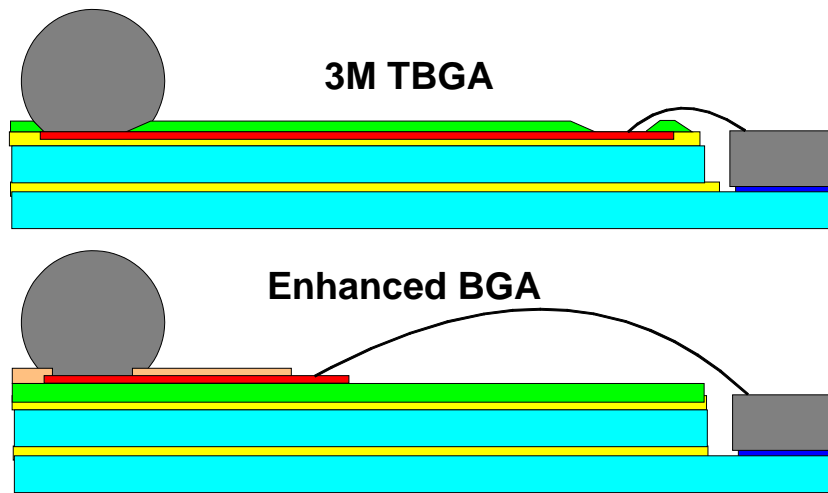
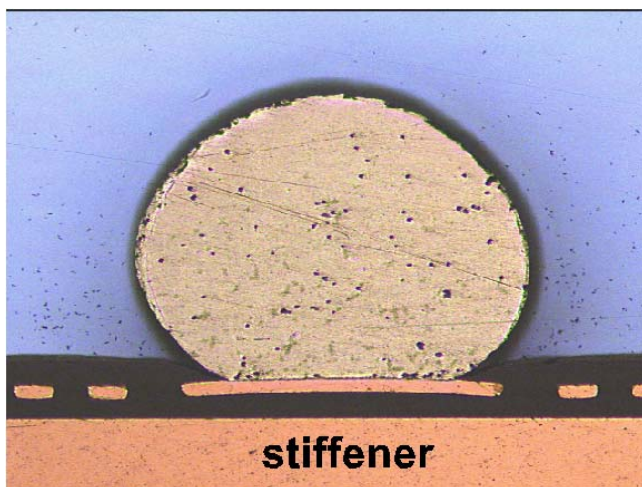
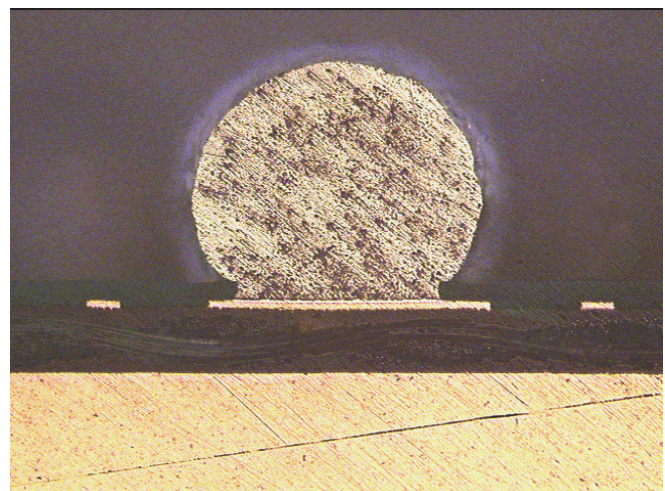


Figure 3: The cumulative self inductance along the signal path from solder ball to the die. Reduction in wire length greatly decreases the total self inductance in the system.



Etched via with no stress concentration sites.



Solder mask defined via with stress sites

Figure 4: Solder balls attached to a chemically etched via compared to a solder mask defined pad.

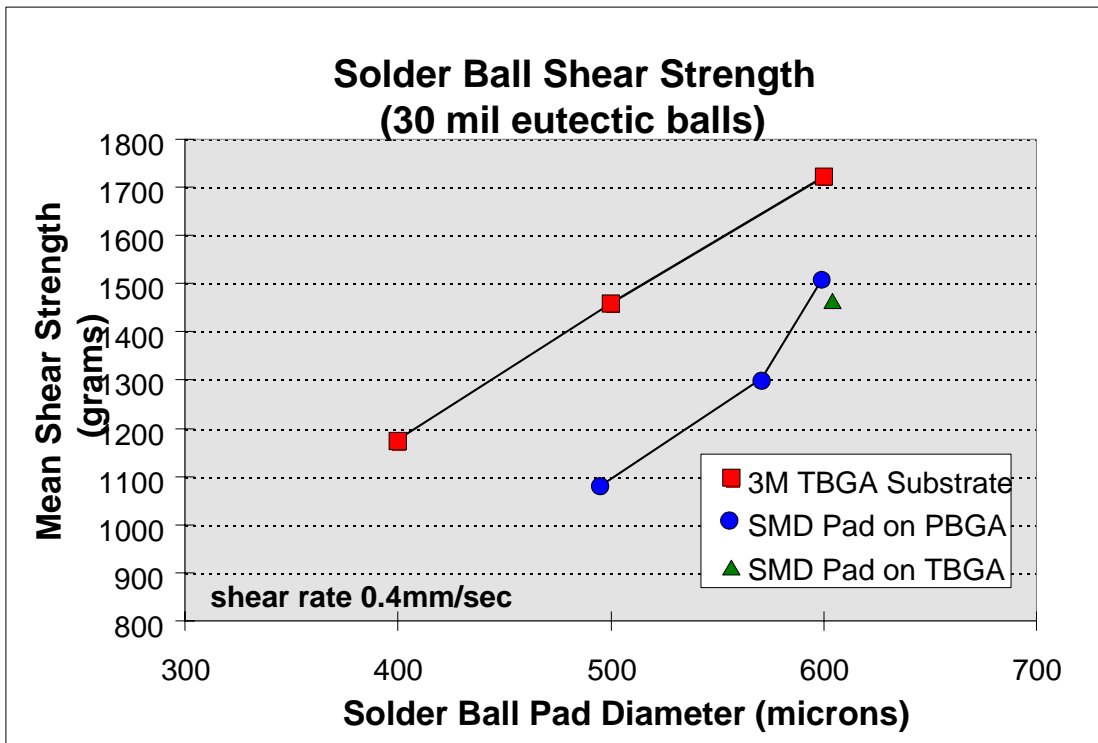


Figure 5: Solder ball shear strength on different substrate materials and pad layouts. The etched polyimide performs well versus more typical soldermask defined pads.

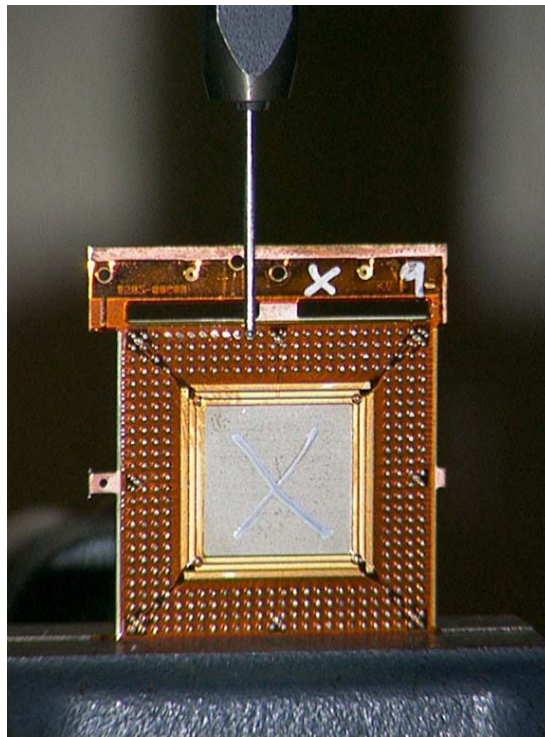


Figure 6: Test fixture and set up for performing solder ball fatigue evaluations.

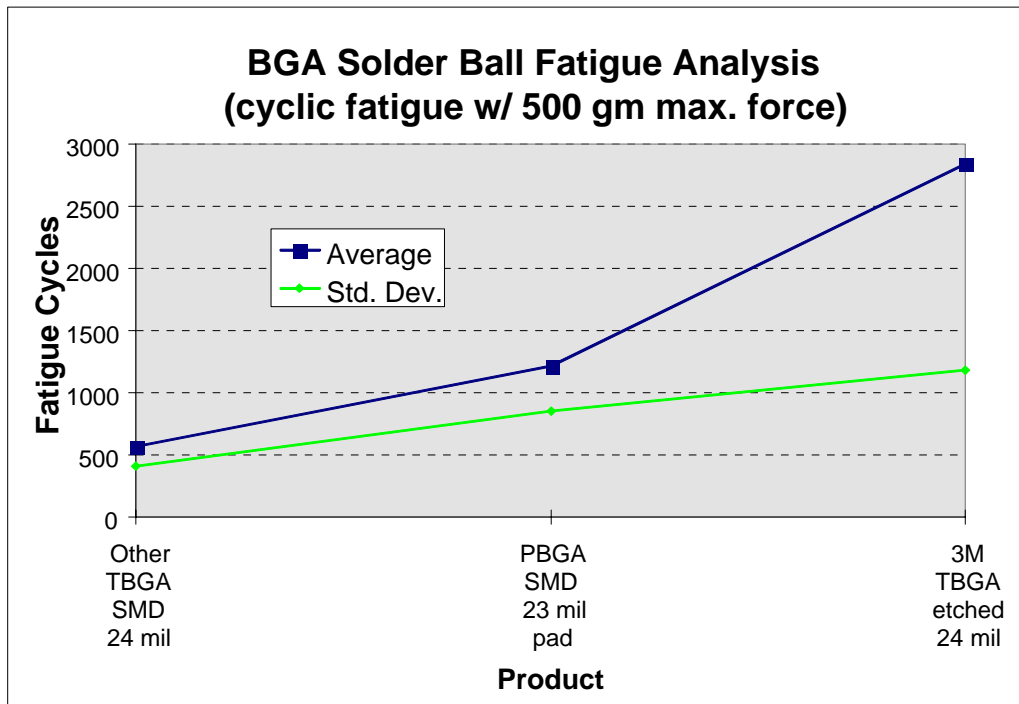
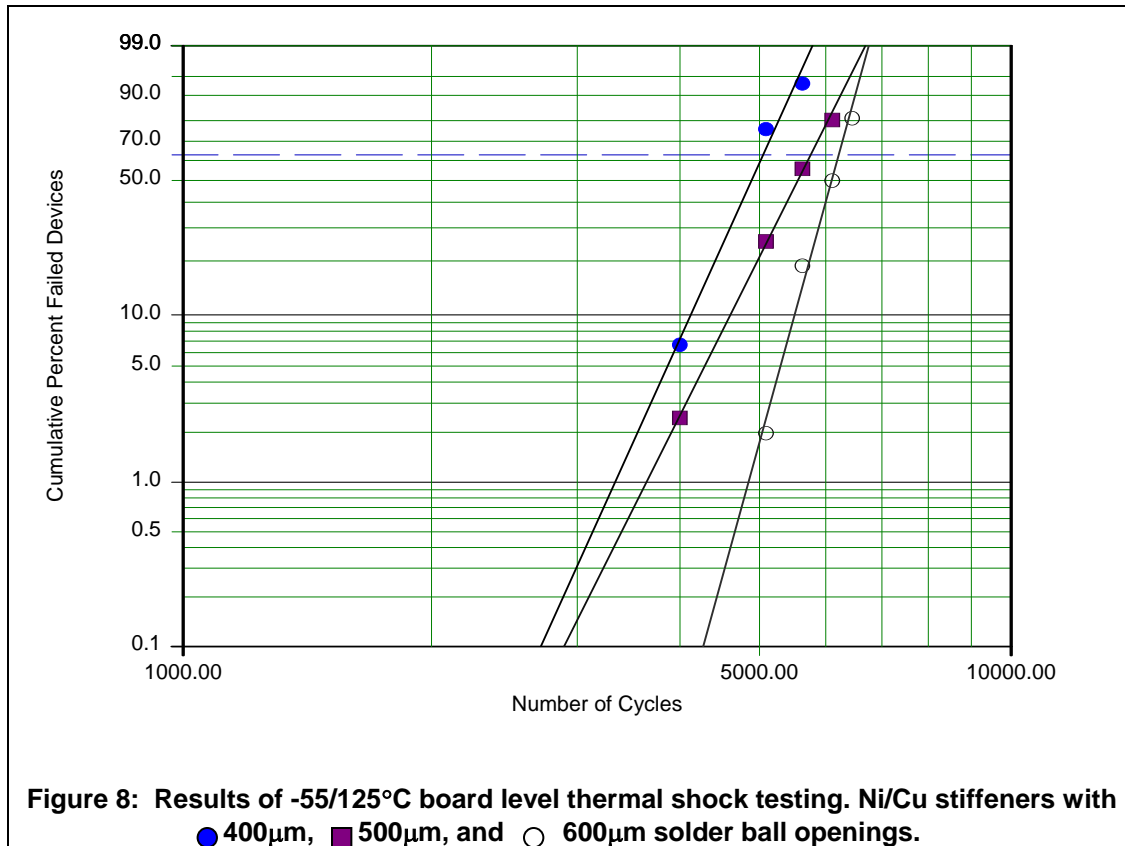


Figure 7: Results of fatigue testing individual solder balls on different pad structures. Again, the etched via performs very well in comparison.



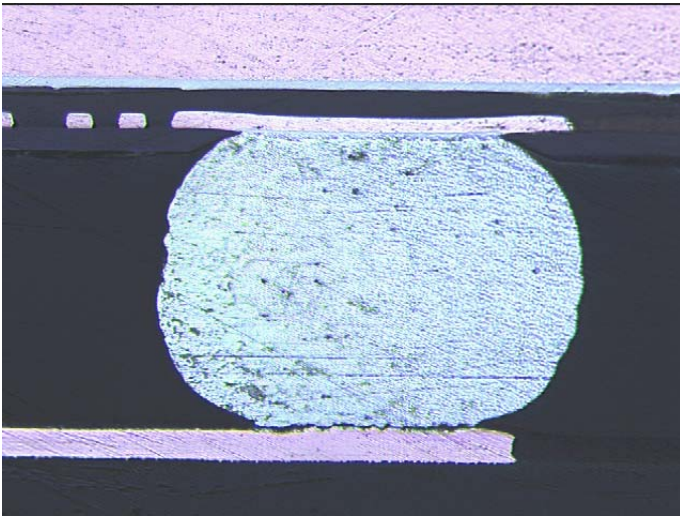


Figure 9: An example of a solder joint failure with a 500µm pad. The failure in this joint was at the board pad interface.

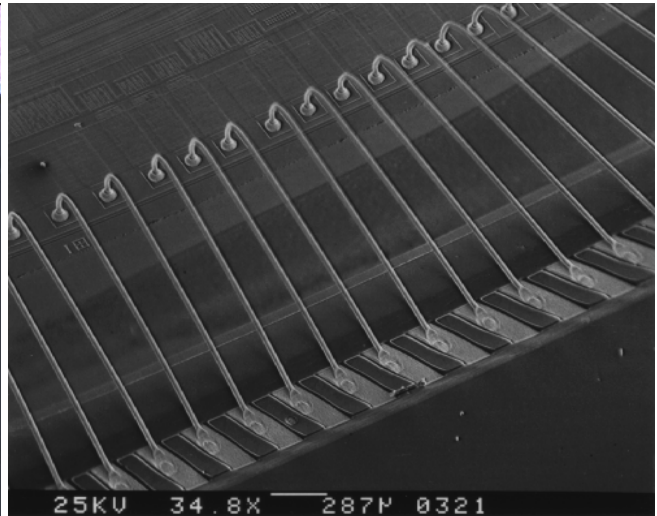


Figure 10: Wire bonds from the die to the bond pads on the TBGA package.

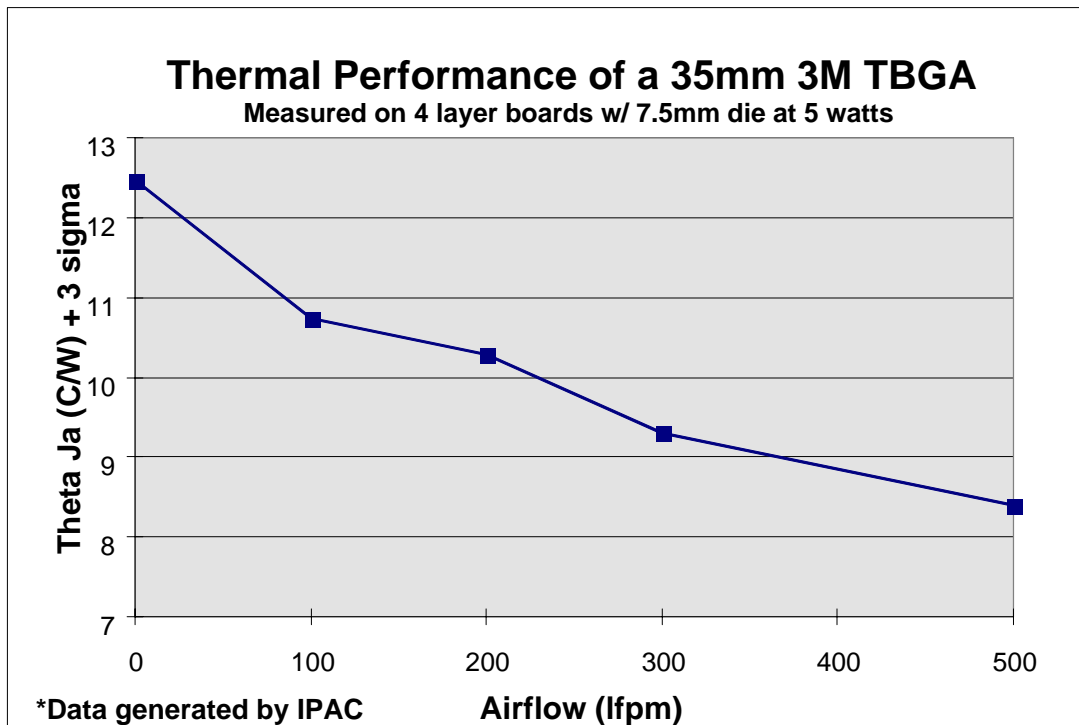


Figure 11: Thermal performance of the 3M TBGA for a 35mm package with 7.5mm die.

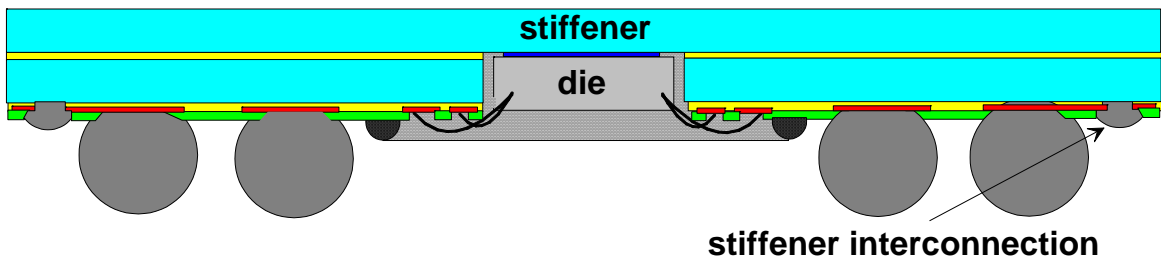
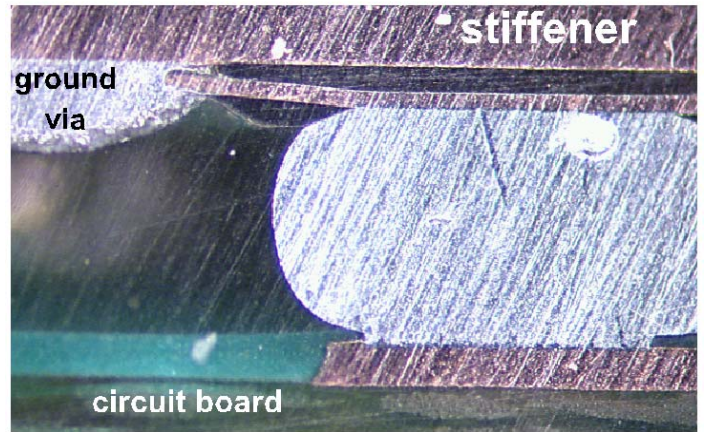
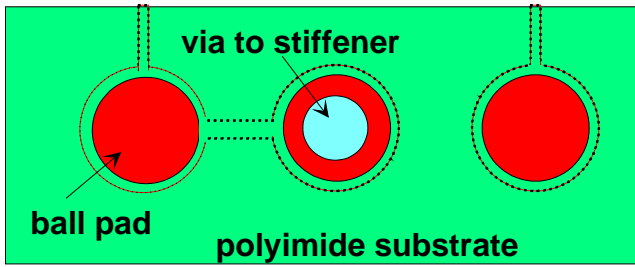


Figure 12: 3M proposed grounded stiffener configuration. A 10/90 solder alloy is used to fill in the ground locations next to the ground ball pads.

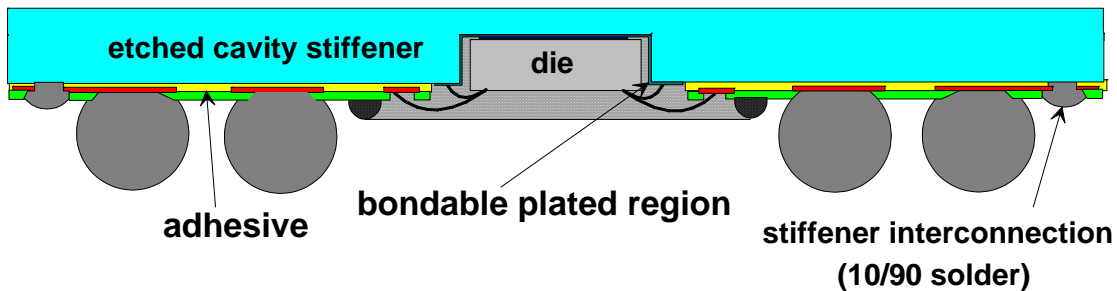


Figure 13: A single piece etched cavity stiffener in which wires are bonded directly to the stiffener.

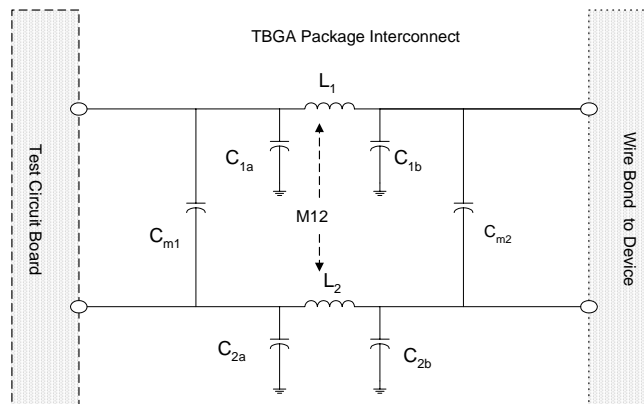


Figure 14: Characterization results and equivalent circuit interconnect model for the 3M Grounded Stiffener TBGA package.