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The Effect of Thermal Loaded Bend Test on the Solder Joint Reliability

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Abstract
With the function of today's electronic devices become more and more complicate, the high I/O flip chip ball grid array package (FCBGA) is used more popularly in recent years. The FCBGA package is always subjected to thermal loading when in use. For accelerating the reliability access, the thermal effects is often checked by using bend tests instead of the time consuming thermal cycling tests. However, most of the bend tests are performed at room temperature. But in reality, the load is applied at the state of elevated temperature. The study will investigate the thermal reliability issue by bend test with consideration of temperature effects.

In the study, the reliability of FCBGA is explored by a four-point bend test executed at different controlled temperature. The test vehicle is put in a heated chamber and the resulting daisy chain resistance and strains are monitored to check its failure. Both the monotonic and cyclic tests are used. However, during the monotonic bend test, the failure mode is found to be the delamination of the heat spreader instead of the solder balls cracking. It is then conducted with room temperature only by checking the failure mode of heat spreader delamination. The cyclic bend test was done with various temperature loading conditions. Based on the results from the monotonic test, it is then reduced the loading so that the heat spreader failure won't occur prior to the solder ball fatigue failure is observed. The strain gages are mounted near the component corner to get the strains of the test board when under bending. A data logger records the daisy chain resistance simultaneously during the test. The component failure is detected with a self-written program by judging when the failure resistance of the daisy chain is large than 20% of its initial resistance.

The test results at various temperature showed that the component life cycle is reduced with the increase of the temperature during the cyclic bend test when under a fixed maximum deflection setting. If tested at room temperature by varying the maximum deflection, the component life cycle is also reduced with the increase of the maximum deflection in the cyclic bend test. Through the fitted curve of all these test data, it is then possible to get relating equations among the variables of temperature, deflection, and life cycle. An extra test is conducted to verify these deduced equations with an error of six percent approximately. The methodology can be used to predict the component life cycle at elevated temperatures based on the test results at room temperature.

Introduction
Nowadays, the development of electronic products tends to be miniaturized but with more integrated functions. To follow this trend, the electronic components are designed recently with high I/O count in a single package. The high I/O Flip Chip BGA (FCGBA) is one of the new package design of this kind. If any one of the solder balls failed during the manufacturing process or in final customer use, the electronic device might be not function normally. It is then essential to check the component reliability after the package is developed especially before it is launched for the mass production. The reliability assessment can be conducted typically by thermal and mechanical stress tests. The accelerated thermal cycling test (ATC) is commonly used regarding the thermal consideration. And shock, vibration and bend tests are among those issues in the mechanical stress tests. However, most of the mechanical stress tests are performed at room temperatures. But in reality, the components are used at elevated temperature that is beyond the room temperature. The study will then focus on the mechanical stress test at elevated temperatures for an advanced high I/O Flip Chip BGA (FCGBA) with 2209 solder balls. It is believed to be closer to the real working conditions and could predict the component life more precisely from the tests.

A schematic of the *high I/O Flip Chip BGA (FCGBA)* is shown in Figure 1. As mentioned above, there are more than two thousand solder balls in the package. The electronic signals between chip and circuit board are communicated through these solder balls. The solder balls do play an important role in the reliability of the FCGBA component. The Accelerated Thermal Cycle (ATC) test is a widely adopted reliability test method in the electronic industry. However, the ATC test is expensive and time consuming. It is then necessary to adopt an efficient test method to evaluate the board level reliability for a new package design.

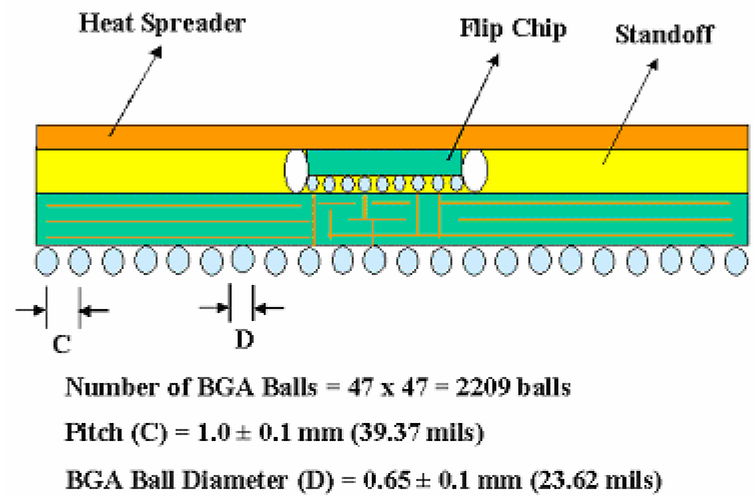

Figure 1 -The Schematic of the Test Component

Bend test is usually the one among mechanical stress tests utilized in relating to the ATC test results. The bend test discussed in this paper will include: (1) the cyclic bend test at various temperatures to find out the relation between temperature and life under certain force loading, (2) the cyclic bend test with a series of deflections (force loadings) to obtain the connection between deflection and temperature (3) the monotonic bend test to realize the maximum force that this type component can endure.

Theory of Bend Test

There are two types of bend tests typically: the three-point bend test, and the four-point bend test. The relating schematic figure, shear force diagrams, and bending moment diagrams of a four-point bend test are shown in Figures 2. As shown in the figure, if the component is put between the span of the two loads P, it is subjected to bending moment only without the shearing force. This is what called as "pure bending" in mechanics. This kind of bending is closer to the real loading when the printed circuit board is in use. Therefore, a four-point bend test is adopted for all the bend tests conducted in this paper.
The maximum deformation at where the roller applied for the four-point bend test can be listed as equation (1).

$$Y = \frac{Pa}{24EI}(3L^3 - 4a^2) \qquad \textbf{(1)}$$

The resulting bending moment, bending stress between the two loading span can be represented as equations (2) through (5) respectively:

$$M = Pa = \frac{EI}{\rho} \qquad \textbf{(2)}$$

(3)

$$\sigma = E\varepsilon \qquad \textbf{(4)}$$

$$\sigma = \frac{EY}{\rho} \qquad \textbf{(5)}$$

The stain and strain rate on the test sample can then be expressed as:

$$\varepsilon = \frac{Y}{\rho} \qquad \textbf{(6)}$$

$$\dot{\varepsilon} = \frac{\dot{Y}}{\rho} \qquad \textbf{(7)}$$

where Y : the maximum deflection of the test board. It is located at the mid-span of upper loading fixture.
P : the applied force.
a : the distance between upper loading roller and the bottom supporting roller.
L : the span of bottom supporting fixture.
E : the Young's modulus.
I : the moment inertia of the test sample.
ρ: the curvature for the deflection curve of the test sample.
(Note; ρ=1/R, R is the radius of curvature)

From above equations, the relationship between deflection curvature and the loading span as shown in Figure 3 is:

1. The larger deflection Y, the smaller curvature resulted. Also, from equation (2), it can be seen that the smaller curvature is always corresponding to larger bending moment as seen in Figure 4.
2. If the span of bottom fixture L is fixed, then parameter "a" can be increased so as to get larger bending moment.

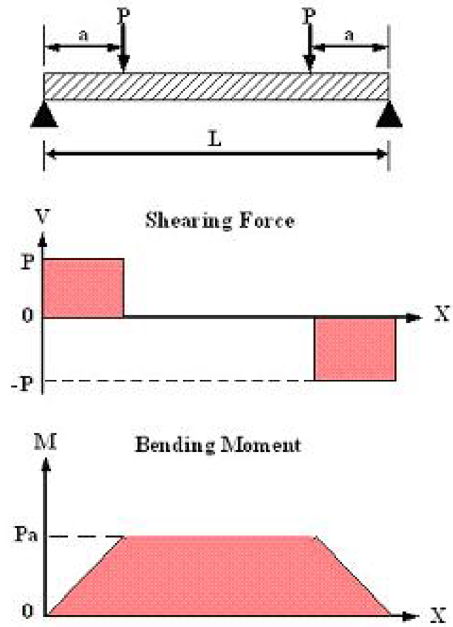

Figure 2 -Shear Force and Bending Moment Diagram

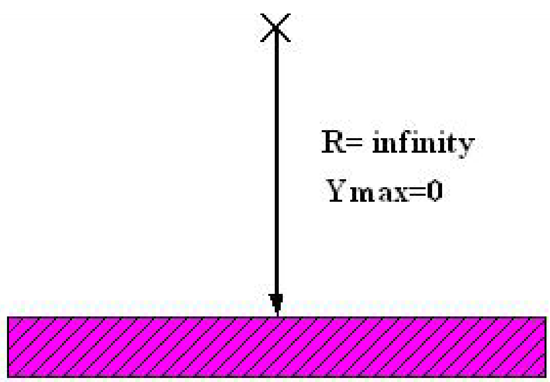

Figure 3 -The Radius of Curvature of the Test Sample is Equal to Infinity When There is No Deflection

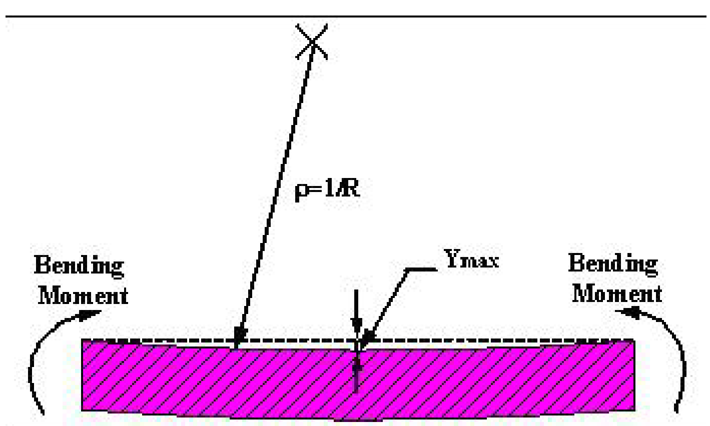

Figure 4 -The Schematic of Relating Radius of Curvature, Ymax and Bending Moment

Experimental Setup

The tests conducted in the study are to explore the effect of thermal loaded bend test on the solder joint reliability. The experiment is done on a micro-force material testing machine. Figure 5 is the material testing machine, which has capacity of applying a maximum force of 10kN and its oven can offer -70°~300° environmental thermal loading. Figure 6 is the designed four-point bend fixture, and the external force will be transformed into bending moment through this test fixture.

Figure 5 - The Micro-Force Material Testing Machine

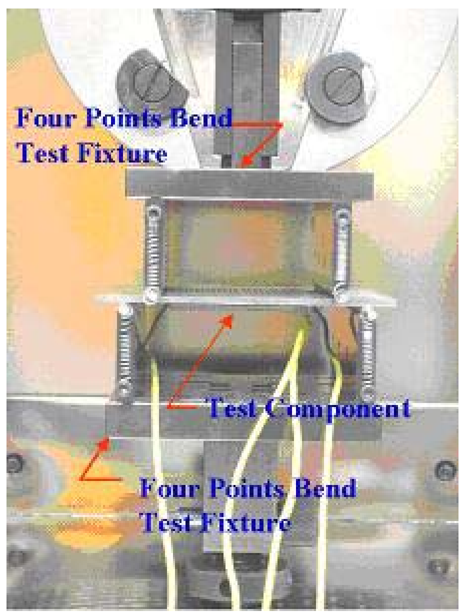

Figure 6 -The Four Point Bend Test Fixture

The configurations of all the bend test equipments are shown in Figure 7. In order to investigate the effect of thermal loaded bend test on the solder joint reliability. The test sample was put into the heating chamber of the test machine and then to perform the bend test. However, for the sake of checking whether the temperature setting in the heating chamber is same as that of the test sample, a thermocouple is placed against the test sample surface to measure the temperature near the sample. Figure 8 shows the measurement location of the thermocouple and Figure 9 is the temperature readings from both the heat controller and thermocouple recorder. It can be seen that there is a slightly difference between them.

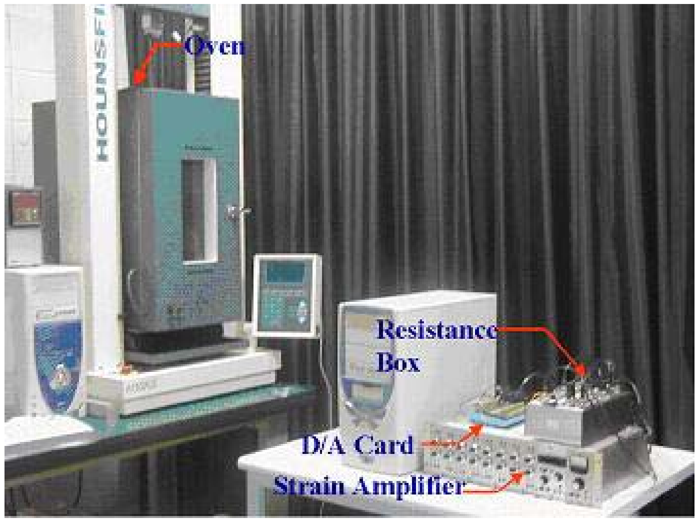

Figure 7 – The Schematic of Bend Test Setup

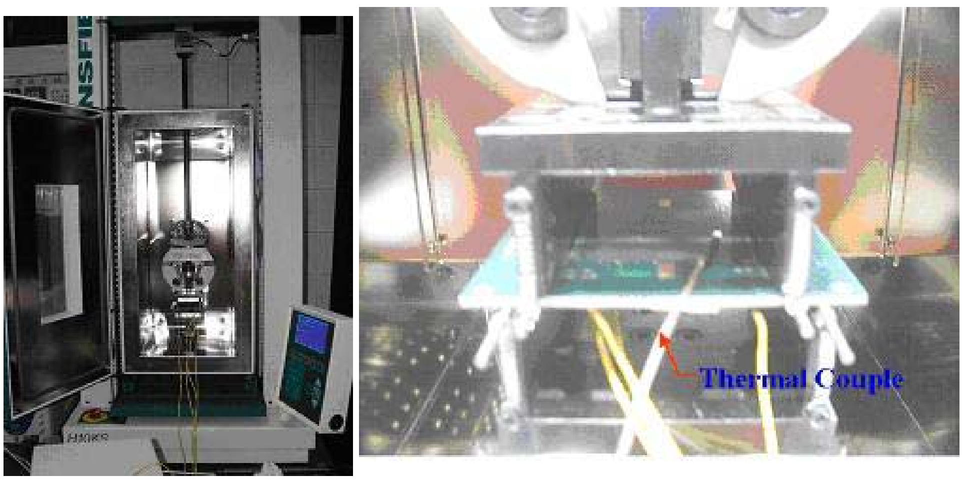

Figure 8 - The Schematic of the Test Specimen Put into the Heating Chamber of Material Testing Machine

(a) (b)

Figure 9 -The Chamber Temperature Read from (a) Heating Controller and (b) Thermocouple Recorder

In order to find out when FCBGA component fails, the daisy chain circuit on the component is used to monitor the status of the solder ball resistance during the bend test. The daisy chain connects all the solder balls of the test component into a circuit with a certain resistance value. If one of the solder balls failure on the daisy chain observed, the resistance of the daisy chain circuit will be higher than its normal value. Figure 10 is the test sampele and its daicy chain layout, and Figure 11 is an example of the daisy chain resistance for the FCBGA component under normal and failed conditions when subjected to a cyclic loading test. The corresponding resistance are shown at the bottom of figure. This figure explains that when the component solder ball cracks(i.e., figure on the right), the daisy chain resistance becomes larger than that of the normal status(i.e., figure on the left).

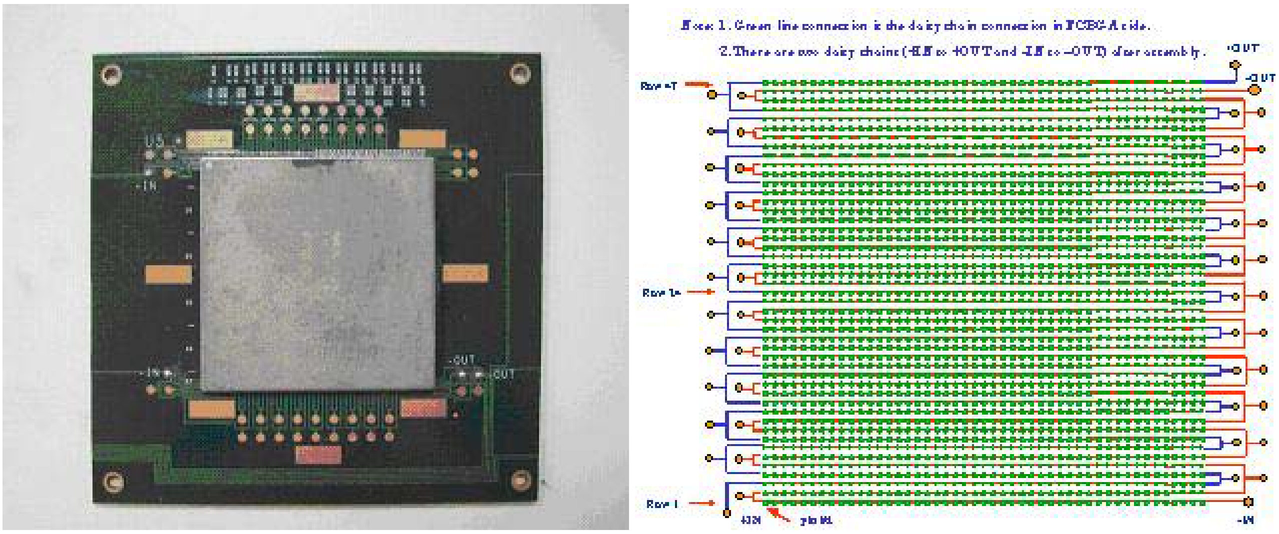

Figure 10 -The Layout of Daisy Chain Circuit

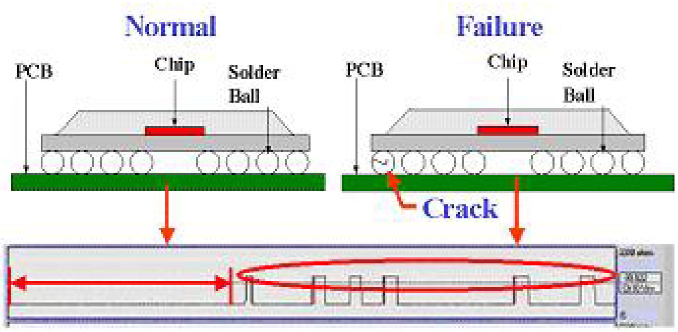

Figure 11 - Example of the Daisy Chain Resistance for Component under Normal and Failure Conditions in Test

Throughout the test, the dynamic resistance data of the daisy chain is monitored and recorded by a data acquisition system. Figure 12 is the instrument of the data acquisition system. There are three components: 1.resistance box to transform the resistance value into voltage signal, 2.D/A card to acquire the voltage signal and calculate its relative resistance value, 3.computer to record all the resistance value during test onto a hard disk. Finally, the resistance data must be checked by a self written program by C language to judge if there are any resistance variations which has exceeded the failure criteria. The flow chart for acquring the dynamic resistance is illustrated as shown in Figure 13.

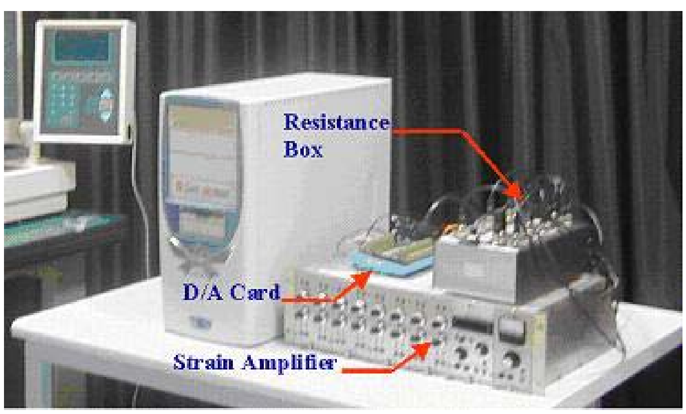

Figure 12 - The Data Acquisition System

Figure 13 - The Flow Chart for Acquiring the Dynamic Resistance Data

Four-Point Monotonic Bend Test Results

The original purpose for the four points monotonic bend is to check the durability of the solder balls when subjected to bending. However, it is out of expectation to find that the delamination of heat spreader is observed while the daisy chain resistance has no variation when the monotonic bend test proceeds. This situation continues even if the heat spreader is completely separated from the top of the FCGBA. Therefore, the failure mode in this case is solely the delamination of the heat spreader. The major discussion in this paper is on what is the maximum strain when the delamination occurs. Figure 14 is the delamination of FCBGA under monotonic bend test. And Figure 15 is the close-up of Figure14. At the moment when the heat spreader on the components separated from the FCBGA, there are accompany click sounds heard. What noteworthy is that the delamination on components occur almost at the same time judging from the sound heard. Figures 16 and 17 are the heat spreader and FCGBA after they are separated completely.

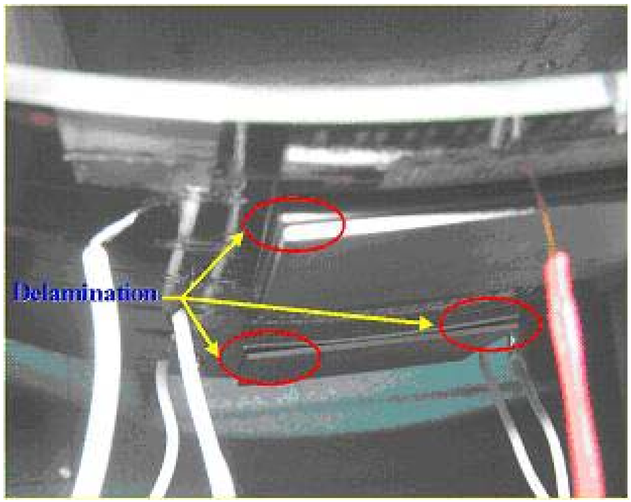

Figure 14 - Schematic of the Delamination of Heat Spreader

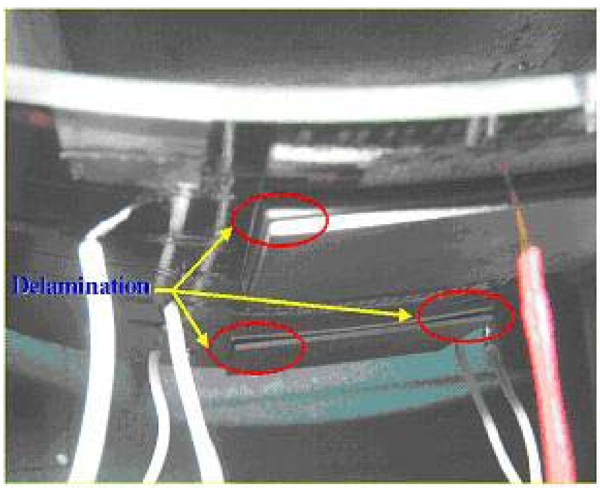

Figure 15 - The Close-up of the Heat Spreader Delamination

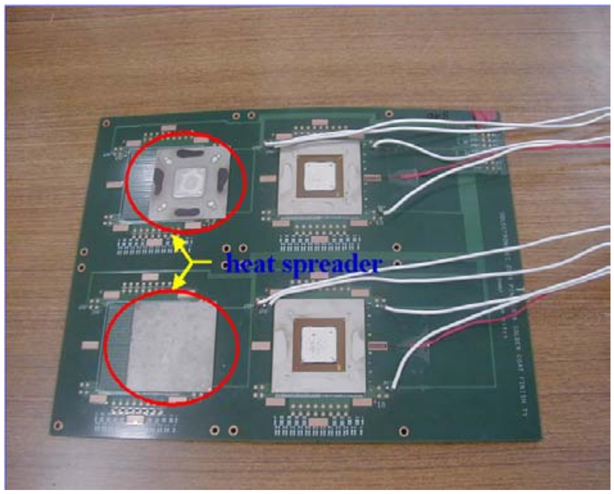

Figure 16 - The Heat Spreader is Peeled off from the Component after Completely Delaminated

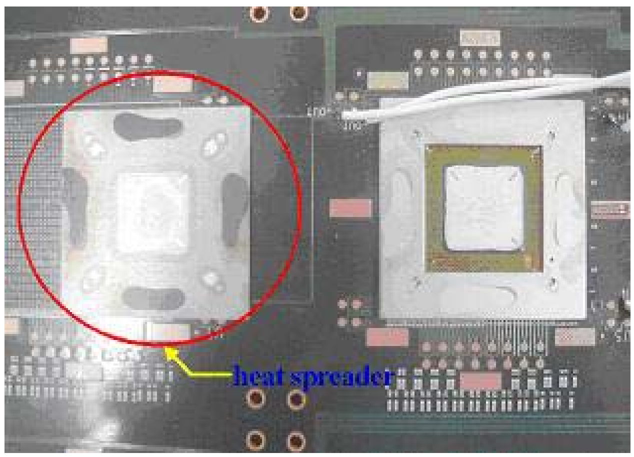

Figure 17 - The Close-up of Figure 16 with the Heat Spreader Taken off

All the test results are listed as shown in Table 1. From this table, it can be found that the mean force of test boards is 823N accordingly and the mean of strain tested for test boards are 4,535 μstrain.respectively.

Table 1 - The Monotonic Bend Test Results for Components Tested

Monotonic Bend Test Results for Components Tested							
Board #	**Component**		**Initial Resistance (ohm)**	**Strain when open (ustrain)**	**Deflection when open (mm)**	**Force (N)**	**Remarks**
1	U1	+IN to +OUT	398	4621	12.347	838	
		-IN to -OUT	465				
	U5	+IN to +OUT	401	4260			
		-IN to -OUT	467				
2	U1	+IN to +OUT	340	4270	10.99	771	
		-IN to -OUT	396				
	U5	+IN to +OUT	351	4260			
		-IN to -OUT	410				
3	U1	+IN to +OUT	385	4460	10.97	776	
		-IN to -OUT	448				
	U5	+IN to +OUT	446	4430			
		-IN to -OUT	518				
4	U1	+IN to +OUT	288	4610	11.11	772	
		-IN to -OUT	338				
	U5	+IN to +OUT	298	4590			
		-IN to -OUT	350				
5	U1	+IN to +OUT	286	4622	13.697	766	
		-IN to -OUT	333				
	U5	+IN to +OUT	275	4633			
		-IN to -OUT	322				
6	U1	+IN to +OUT	366	4661	13.577	888	
		-IN to -OUT	426				
	U5	+IN to +OUT	377	4653			
		-IN to -OUT	439				
7	U1	+IN to +OUT	334	4720	14.624	952	
		-IN to -OUT	391				
	U5	+IN to +OUT	368	4703			
		-IN to -OUT	429				
			Mean	**4535**	**12**	**823**	

Four-Point Cyclic Bend Test

To discuss the thermal loading effect of FCBGA, the test sample is placed in the chamber and the cyclic bend is conducted at different specified temperature, i.e.20°, 40°, 60°, 80°, 100° and 120°. When higher than these temperature settings, the solder balls get softer apparently, it is then not set in the test. The descending displacement is set as 0.3 mm and this indicated that the maximum forced is fixed. During test, the data acquisition system acquires the daisy chain resistance continuously and the data was checked to know whether the resistance is over the failure definition. All the test results are listed as Table 2. From Table 2, the life of FCBGA component at higher temperatures is less than that at low temperatures, and the trend of the FCBGA component life under various temperatures is plot as Figure 18. In this Figure, the dots are the experimental data from the cyclic bend test and the curve is a fitted result. Observing from Figure 18, the relation between temperature and life can be represented by the exponential function

$$Life(T) = 34{,}203e^{-0.0409T} \qquad (8)$$

where T is temperature in (°C), Life (T) is the cycle when the components failed in the cyclic bend test. As mentioned this is based on the fixed descending displacement of 0.3 mm. i.e. with the same applying force.

In the test, the further study about the concern of deflection versus life is also conducted with the planned experiments. In the experiment, a series deflection, i.e. 0.3mm, 0.4mm, 0.5mm, 0.6mm and 0.7mm, is applied on the test sample while the temperature is kept the same at room temperature. This reflects that the forces thus applied are varied. It is then able to find the corresponding component life at various deflections. The entire test results are listed as shown in Table 3. And all the data are plotted as shown in Figure 19. Similar to the Figure 18, the dotted data points are from the experimental results and the curve is fitted from these experimental data. For all the rests at room temperature, the fitted curve can be expressed as:

$$Life(\delta) = 1{,}038{,}340e^{-13.082\delta} \quad (9)$$

Where δ is the deflection (mm), Life (δ) is the life cycle as function of displacementδfor the cyclic bend test. As indicated before, the different deflections stand for the different forces applied.

Based on the foregoing experimental data, the relation between the component life cycle for tests at room temperature and at higher temperatures can be derived. The baseline for this derivation is under the condition of the same deflection of 0.3mm as tested earlier. Equations (8) and (9) can be combined together so as to estimate the equivalent deflection when tested at room temperature which is equivalent to test at specified elevated temperature with the same component life cycle. The resulting equation can be expressed as:

$$\delta_{room-temp} = 0.260 + 0.003T \quad (10)$$

where $\delta_{room-temp}$ is the equivalent deflection in (mm) if tested at room temperature, T is the designated test at higher temperature in (°C).

From equation (10), the equivalent deflection can be calculated. For example, an extra cyclic bend test is arranged at the test temperature of 90(°), and another experiment at room temperature is conducted later with the equivalent deflection of 0.53 (mm) as calculated from equation (10) by substituting 90 into the variable temperature T. Through the two intentionally designed cyclic bend tests, the life at 90° is found to be at 1217.5 (cycles), which is noted as red triangular mark as shown in Figure 18. And when using the equivalent deflection of 0.53 (mm) to do the bend test at room temperature, it is found to have a life cycle of 1142 (cycles) as indicated in red triangular mark shown in Figure 19. The difference is 6% between these two approximately. In other words, when we tested the sample at room temperature and obtain the life cycle of 1142(cycles), we can expect that it can withstand approximately the same life cycle at an elevated temperature of 90(°). Furthermore, if more tests can be performed with different deflection to obtain results similar to Figure 18, it is then possible to conduct tests at room temperature while assuring the component to endure the same test cycle at a calculated higher temperature.

Table 2 - The Cyclic Bend Test Results at Various Temperatures

Temperature (℃)	Component		Failed Cycles	Mean Cycles
20	U1	+IN to +OUT	8819	12875.5
		-IN to -OUT		
	U5	+IN to +OUT	16932	
		-IN to -OUT		
40	U1	+IN to +OUT	7463	8150.5
		-IN to -OUT		
	U5	+IN to +OUT	8838	
		-IN to -OUT		
60	U1	+IN to +OUT	2619	2896
		-IN to -OUT		
	U5	+IN to +OUT	3173	
		-IN to -OUT		
80	U1	+IN to +OUT	920	1359.5
		-IN to -OUT		
	U5	+IN to +OUT	1799	
		-IN to -OUT		
100	U1	+IN to +OUT	518	526.5
		-IN to -OUT		
	U5	+IN to +OUT	535	
		-IN to -OUT		
120	U1	+IN to +OUT	248	251.5
		-IN to -OUT		
	U5	+IN to +OUT	255	
		-IN to -OUT		

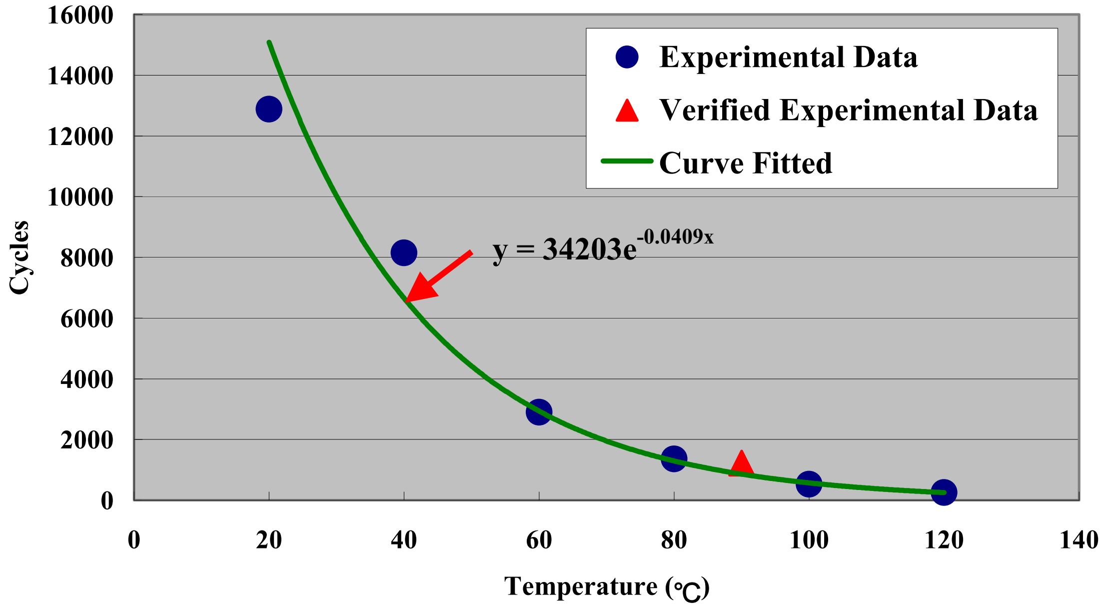

Figure 18 - The Plot of the Component Life at Various Temperatures when at Constant Deflection of 0.3 mm

Table 3 - The Cyclic Bend Test Results at Various Deflections at Room Temperature

Deflection(mm)	Component		Failed Cycles	Mean Cycles
0.3	U1	+IN to +OUT -IN to -OUT	8819	12875.5
	U5	+IN to +OUT -IN to -OUT	16932	
0.4	U1	+IN to +OUT -IN to -OUT	7326	7583
	U5	+IN to +OUT -IN to -OUT	7840	
0.5	U1	+IN to +OUT -IN to -OUT	1902	2122
	U5	+IN to +OUT -IN to -OUT	2342	
0.6	U1	+IN to +OUT -IN to -OUT	452	512
	U5	+IN to +OUT -IN to -OUT	572	
0.7	U1	+IN to +OUT -IN to -OUT	39	71.5
	U5	+IN to +OUT -IN to -OUT	104	

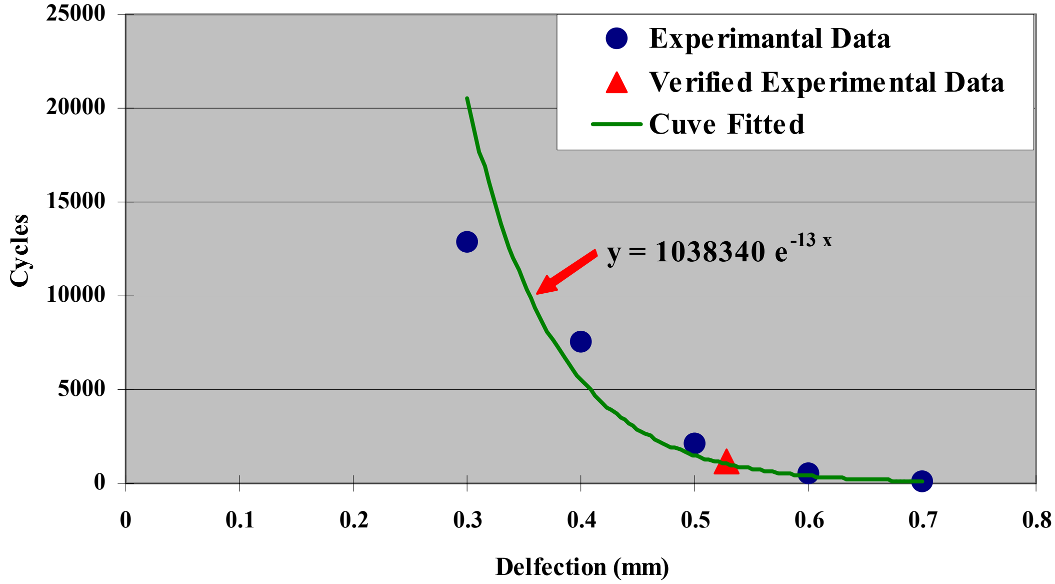

Figure 19 - The Plot of the Component Life with Various Deflections at Room Temperature

Conclusion

In this study, the reliability of FCBGA was explored by a four-point bend test executed at different controlled temperatures and deflections. Through the bend tests results, the following conclusions can be summarized:

(1) When conducting the monotonic bend test, the failure mode found is solely the delamination of the heat spreader from the chip surface. The mean force of test boards is 823N and the mean strain for test boards is 4,535μstrain respectively.

(2) From the cyclic bend test, the relating fitted equation of life versus temperature and deflection can be obtained correspondingly. It is found that the component life decreases with the increase of the temperature when tested at certain maximum deflection. And the component life decreases with the increase of the maximum deflection when tested at room temperature.

(3) Through the relation of life versus temperature and deflection, the equivalent deflection at room temperature can be deduced from the results of higher temperatures. Furthermore, if with more test results of various temperatures and deflections, the methodology can be used to estimate the component life cycle when at elevated temperature simply by calculation based on the test results at room temperature.

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References

1. S. Shetty, V. Lehtinen, A. Dasgupta, V. Halkola and T. Reinikainen, "Fatigue of Chip Scale Package Interconnects Due to Cycle Bending," Transactions of the ASME, Journal of Electronic Packaging, pp.302~308, Vol. 123, September 2001.
2. U. Daya Perera, "Evaluation of reliability of μBGA solder joints through twisting and bending", Microelectronics Reliability, Vol. 39, pp. 391-399, 1999.
3. J. Lau, T. Marcotte, J. Severine, A. Lee, S. Erasmus, T. Baker, J. Moldaschel, M. Sporer and G. Burward-Hoy, "Solder Joint Reliability of Surface Mount Connectors", Journal of Electronic Packaging, Vol. 115, June 1993.
4. J. Lau, K. Gratalo, E. Schnelder, T. Marcotte, and T. Baker, "Solder Joint reliability of Large Plastic ball Grid Array Assemblies Under Bending, Twisting, and Vibration Conditions," Circuit World, Vol. 22, No.1, 1995.
5. S. J., Ham and S. B., Lee, Experimental Study for Reliability of Electronic Packaging under Vibration, Experimental Mechanics, Vol.36, No.4, pp.339-344, 1996.
6. Q.J., Yang, G.H., Lin, H.L.J, Pang and Z.P., Wang, Vibration Reliability Test of a PBGA Assembly, IEEE/CPMT Electronic Packing Technology Conference, pp.258-263, 1998.
7. IPC-9701, Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments, Jan. 2002.

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Contents

- Introduction
- Experimental Setup
- Monotonic Bend Test
- Cyclic Bend Test
- Conclusions

Introduction

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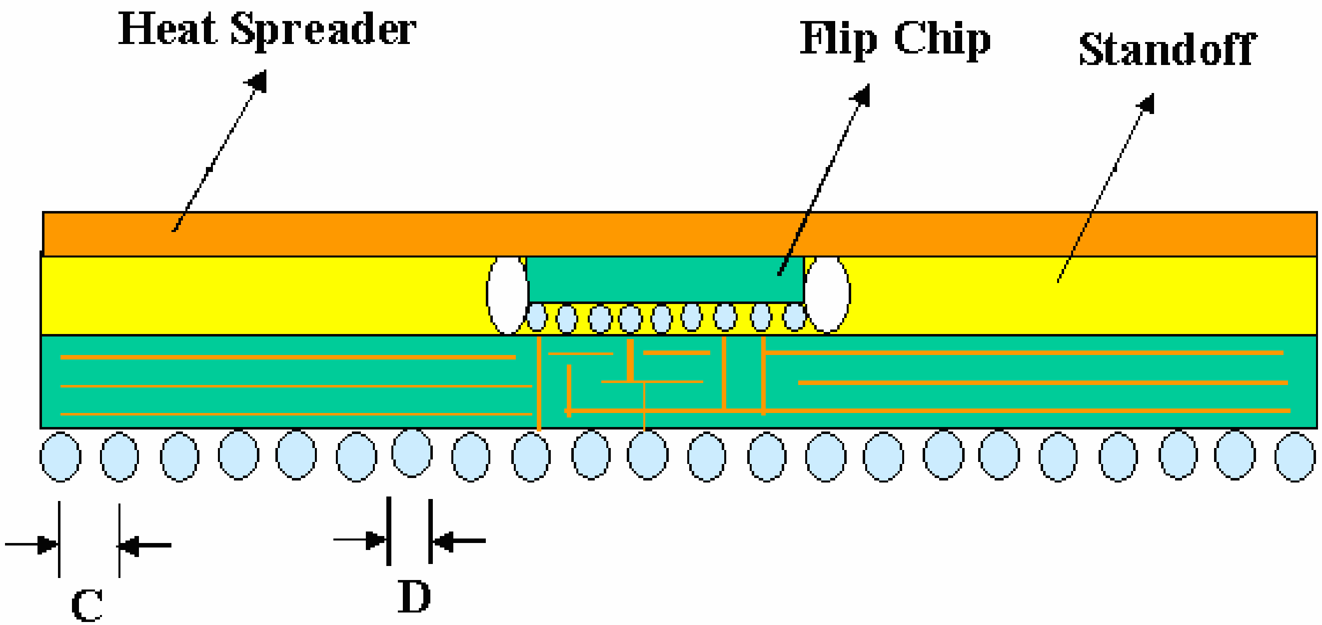
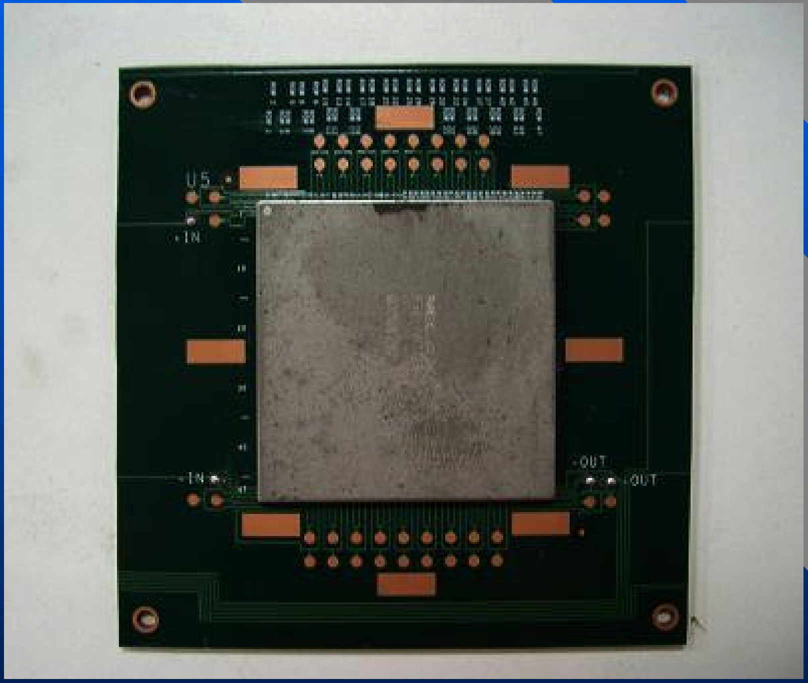


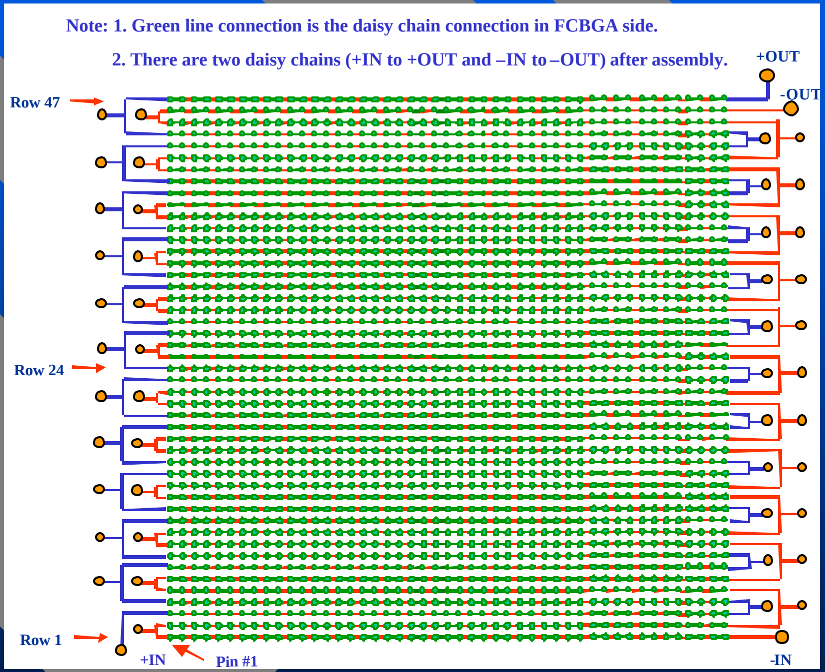
Number of BGA Balls = 47 x 47 = 2209 balls

Pitch (C) = 1.0 ± 0.1 mm (39.37 mils)

BGA Ball Diameter (D) = 0.65 ± 0.1 mm (23.62 mils)

Test Sample and Daisy Chain





Experimental Setup

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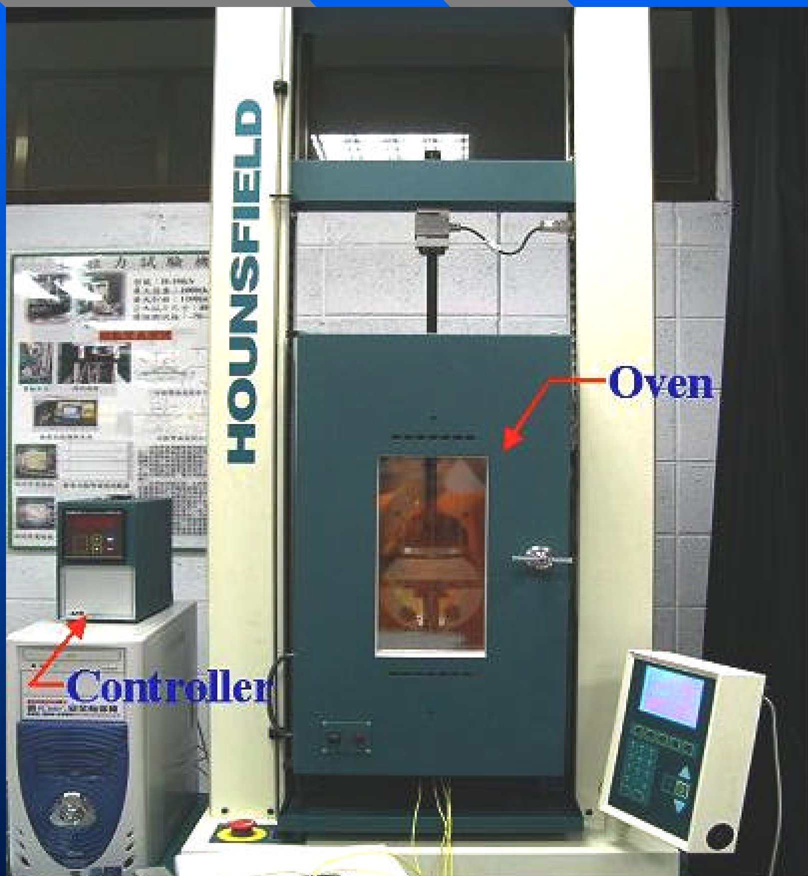
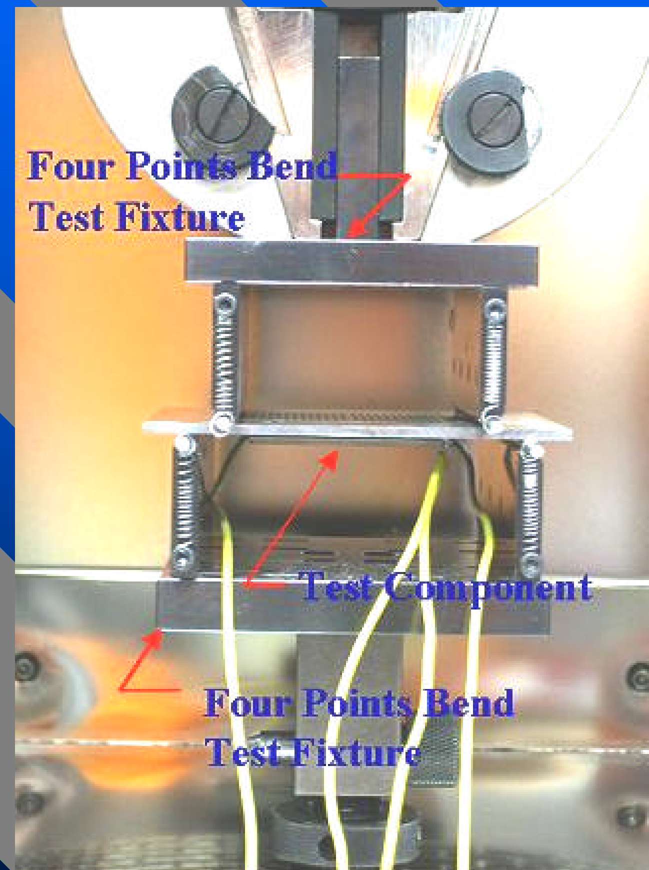
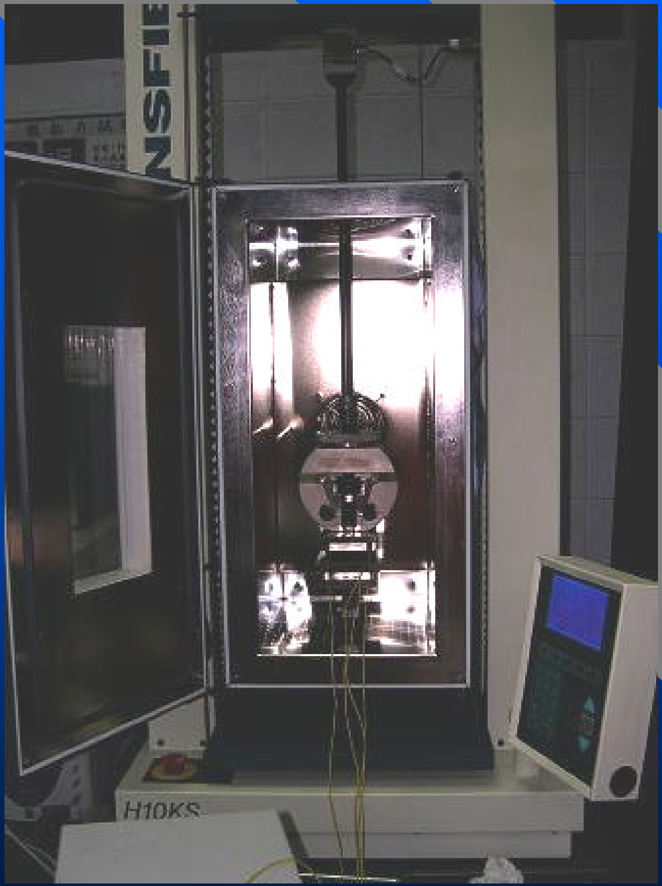
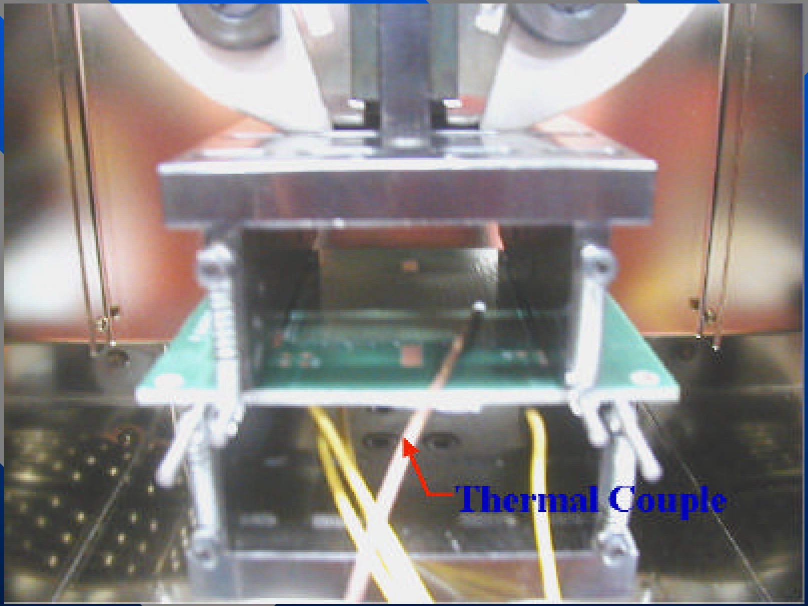


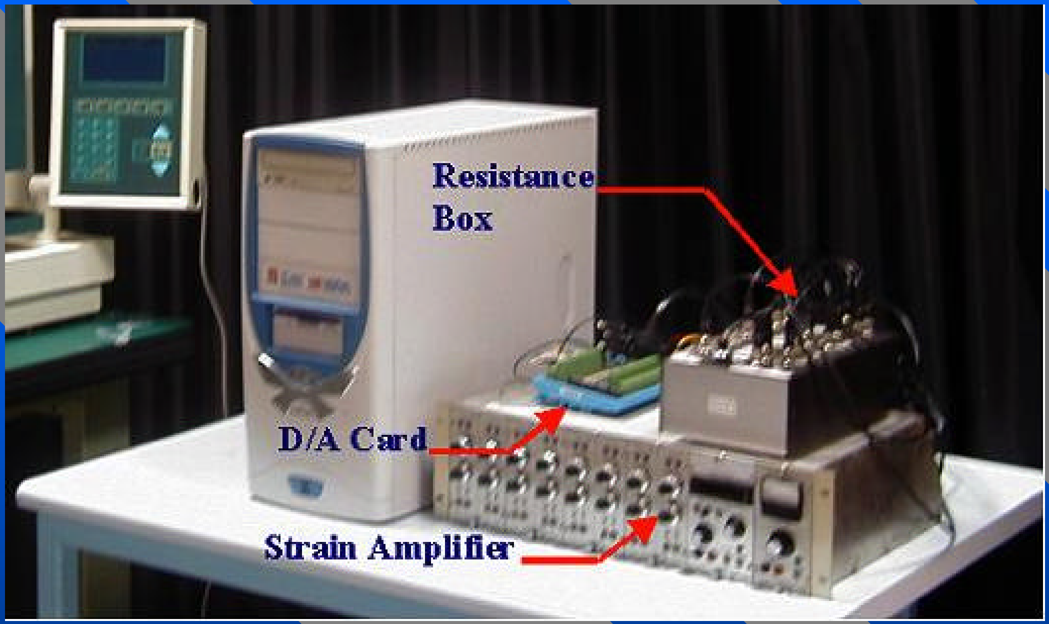


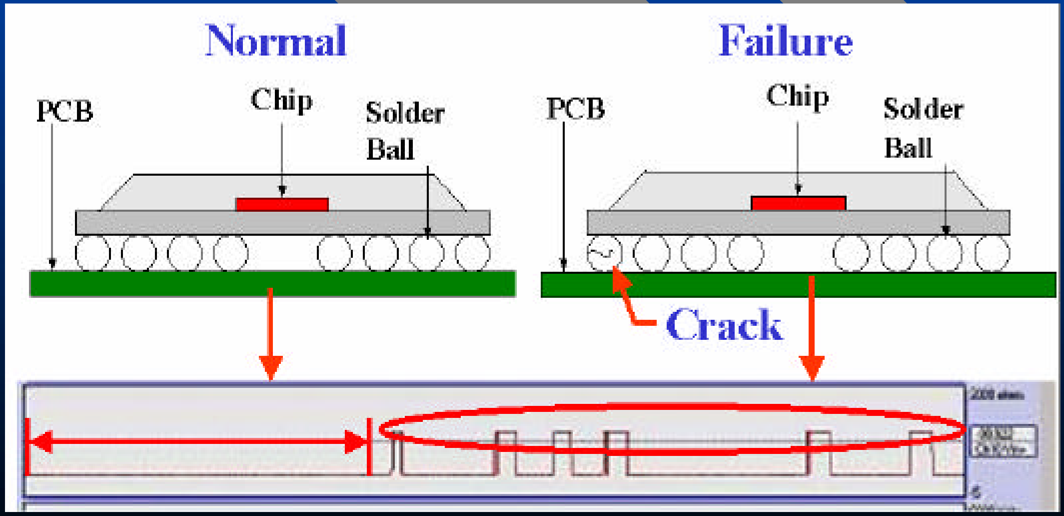
The Schematic of the Test Specimen Put into the Heating Chamber of Material Testing Machine





The Daisy Chain Resistance for IC Component under Normal and Failure Status



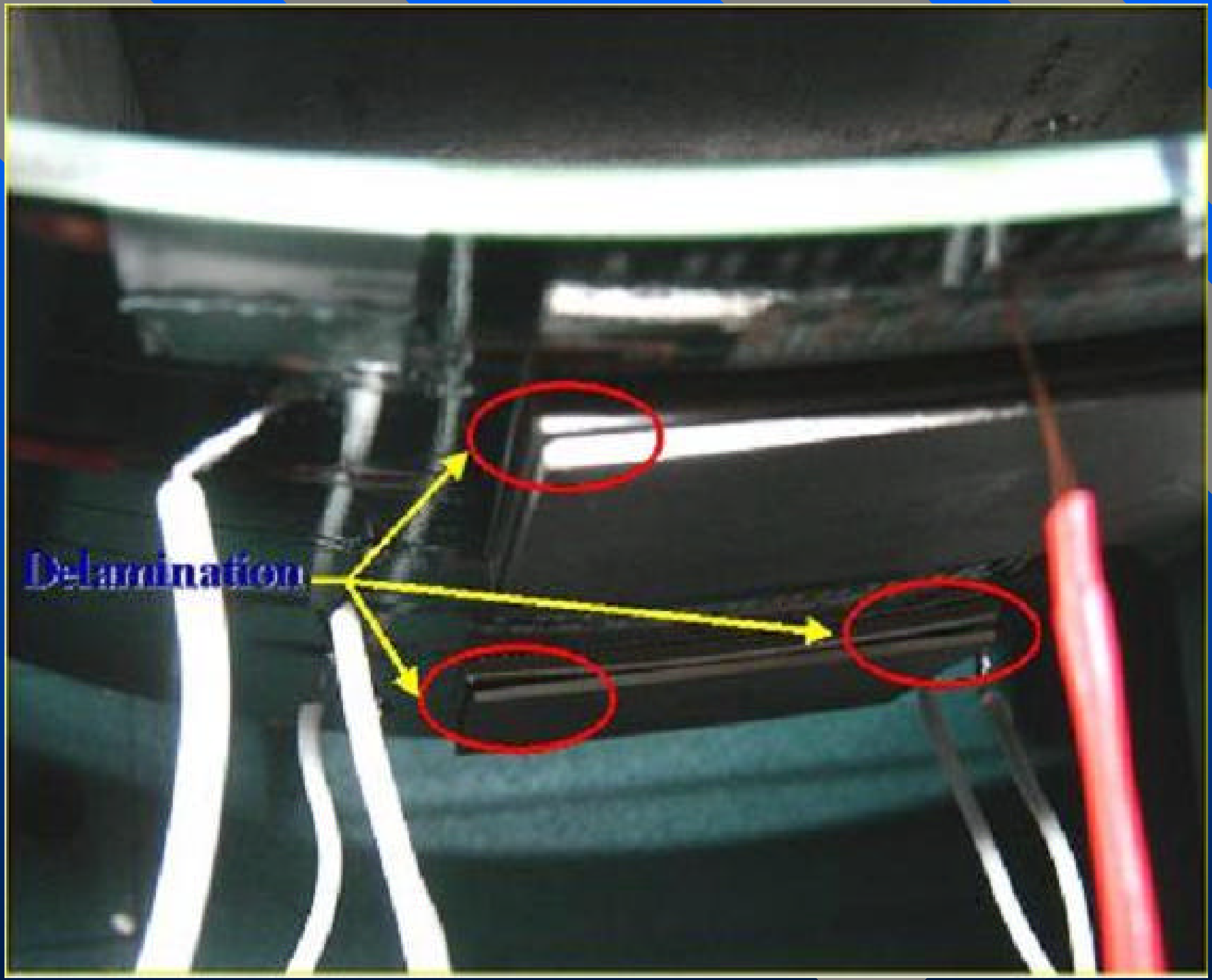


Monotonic Bend Test
(at Room Temperature)

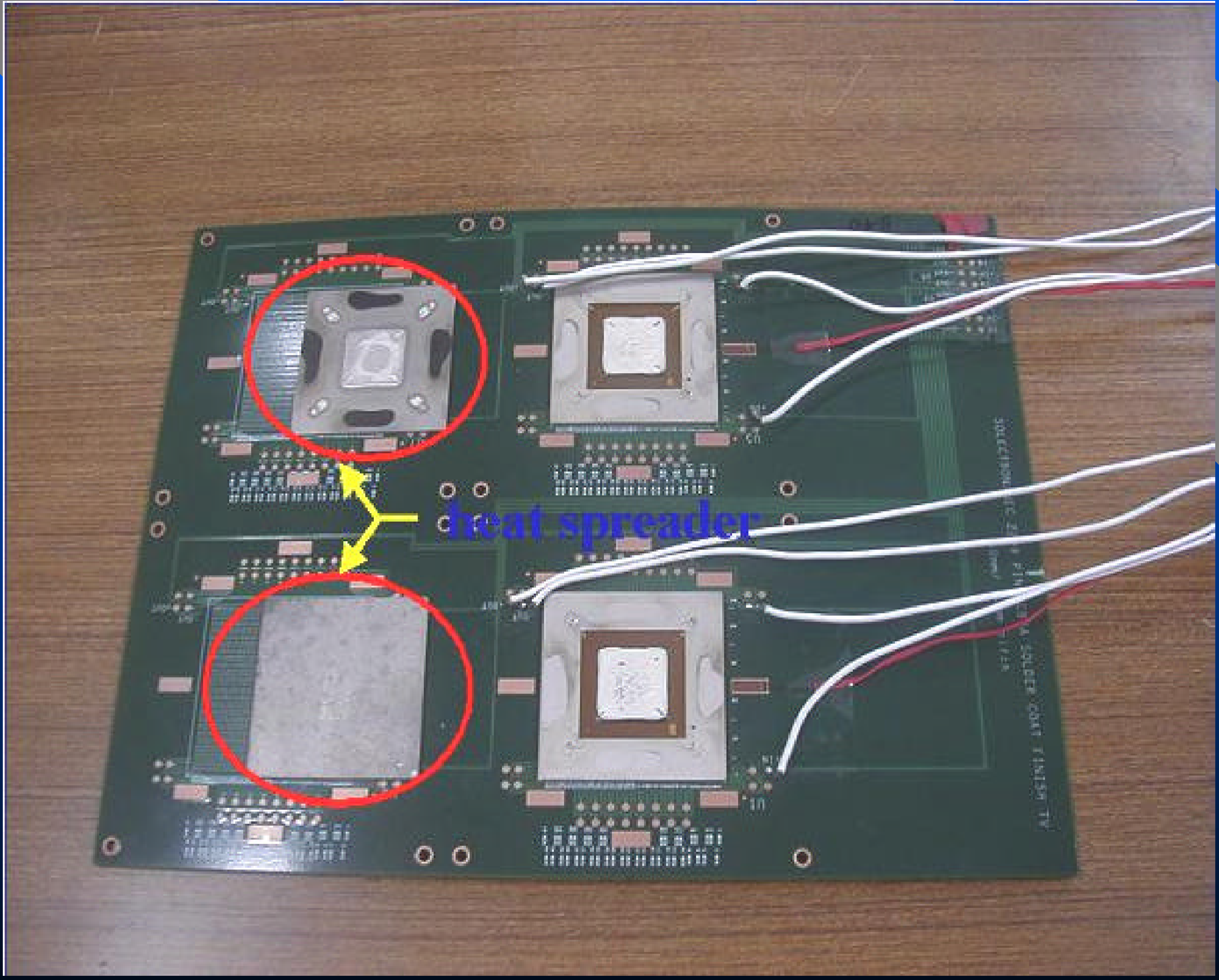
The Monotonic Bend Test Results for Components Tested

Monotonic Bend Test Results for Components Tested							
Board #	Component		Initial Resistance (ohm)	Strain when open (ustrain)	Deflection when open (mm)	Force (N)	Remarks
1	U1	+IN to +OUT	398	4621	12.347	838	
		-IN to -OUT	465				
	U5	+IN to +OUT	401	4260			
		-IN to -OUT	467				
2	U1	+IN to +OUT	340	4270	10.99	771	
		-IN to -OUT	396				
	U5	+IN to +OUT	351	4260			
		-IN to -OUT	410				
3	U1	+IN to +OUT	385	4460	10.97	776	
		-IN to -OUT	448				
	U5	+IN to +OUT	446	4430			
		-IN to -OUT	518				
4	U1	+IN to +OUT	288	4610	11.11	772	
		-IN to -OUT	338				
	U5	+IN to +OUT	298	4590			
		-IN to -OUT	350				
5	U1	+IN to +OUT	286	4622	13.697	766	
		-IN to -OUT	333				
	U5	+IN to +OUT	275	4633			
		-IN to -OUT	322				
6	U1	+IN to +OUT	366	4661	13.577	888	
		-IN to -OUT	426				
	U5	+IN to +OUT	377	4653			
		-IN to -OUT	439				
7	U1	+IN to +OUT	334	4720	14.624	952	
		-IN to -OUT	391				
	U5	+IN to +OUT	368	4703			
		-IN to -OUT	429				
			Mean	4535	12	823	

Schematic of the Delamination of Heat Spreader



The Heat Spreader is Stripped off from the Component after Completely Delaminated

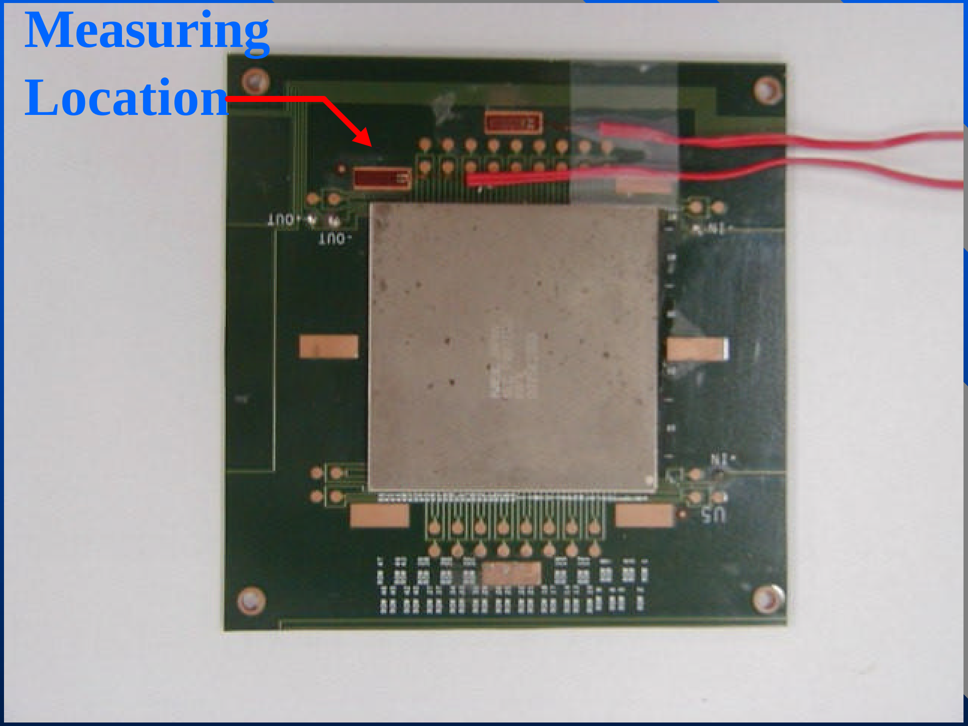


Summary

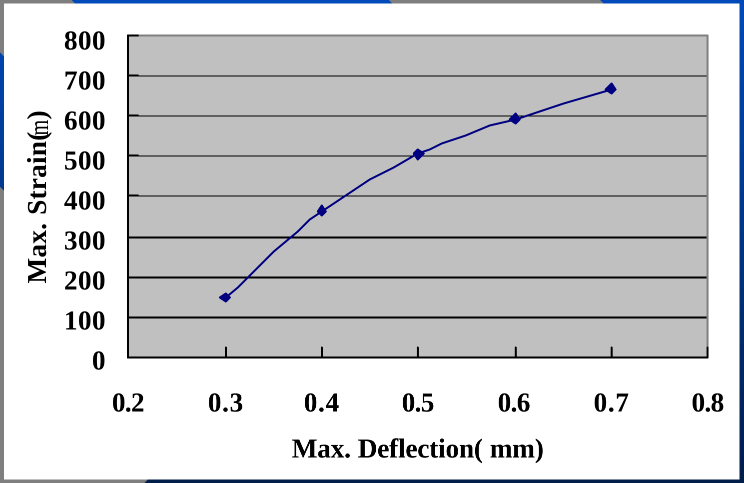
- When conducting the monotonic bend test, the failure mode found is solely the delamination of the heat spreader from the chip surface. The mean force of test boards is 823N and the mean strain for test boards is 4,535 μstrain respectively.

Four-Point Cyclic Bend Test

Deflection vs. Strain



Max. Deflection (mm)	Max. Strain(m)
0.3	148
0.4	363
0.5	504
0.6	594
0.7	667



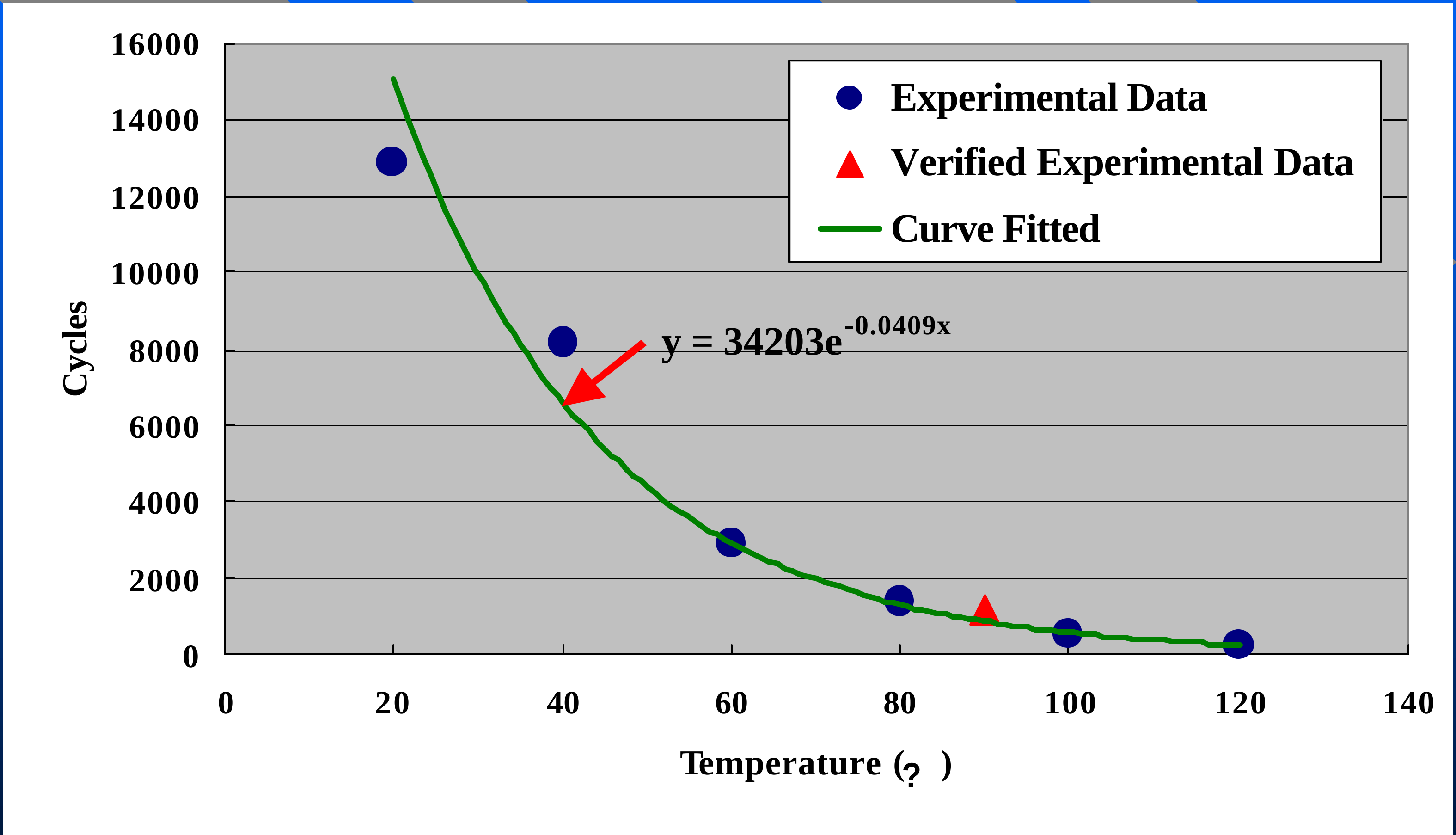
Four-Point Cyclic Bend Test
(at Different Temperature Settings)

The Cyclic Bend Test Results at Various Temperatures

Temperature (?)	Component		Failed Cycles	Mean Cycles
20	U1	+IN to +OUT	8819	12875.5
		-IN to -OUT		
	U5	+IN to +OUT	16932	
		-IN to -OUT		
40	U1	+IN to +OUT	7463	8150.5
		-IN to -OUT		
	U5	+IN to +OUT	8838	
		-IN to -OUT		
60	U1	+IN to +OUT	2619	2896
		-IN to -OUT		
	U5	+IN to +OUT	3173	
		-IN to -OUT		
80	U1	+IN to +OUT	920	1359.5
		-IN to -OUT		
	U5	+IN to +OUT	1799	
		-IN to -OUT		
100	U1	+IN to +OUT	518	526.5
		-IN to -OUT		
	U5	+IN to +OUT	535	
		-IN to -OUT		
120	U1	+IN to +OUT	248	251.5
		-IN to -OUT		
	U5	+IN to +OUT	255	
		-IN to -OUT		

The Plot of the Component Life at Various Temperature

(at Constant Maximum Strain of 148 μstrain)

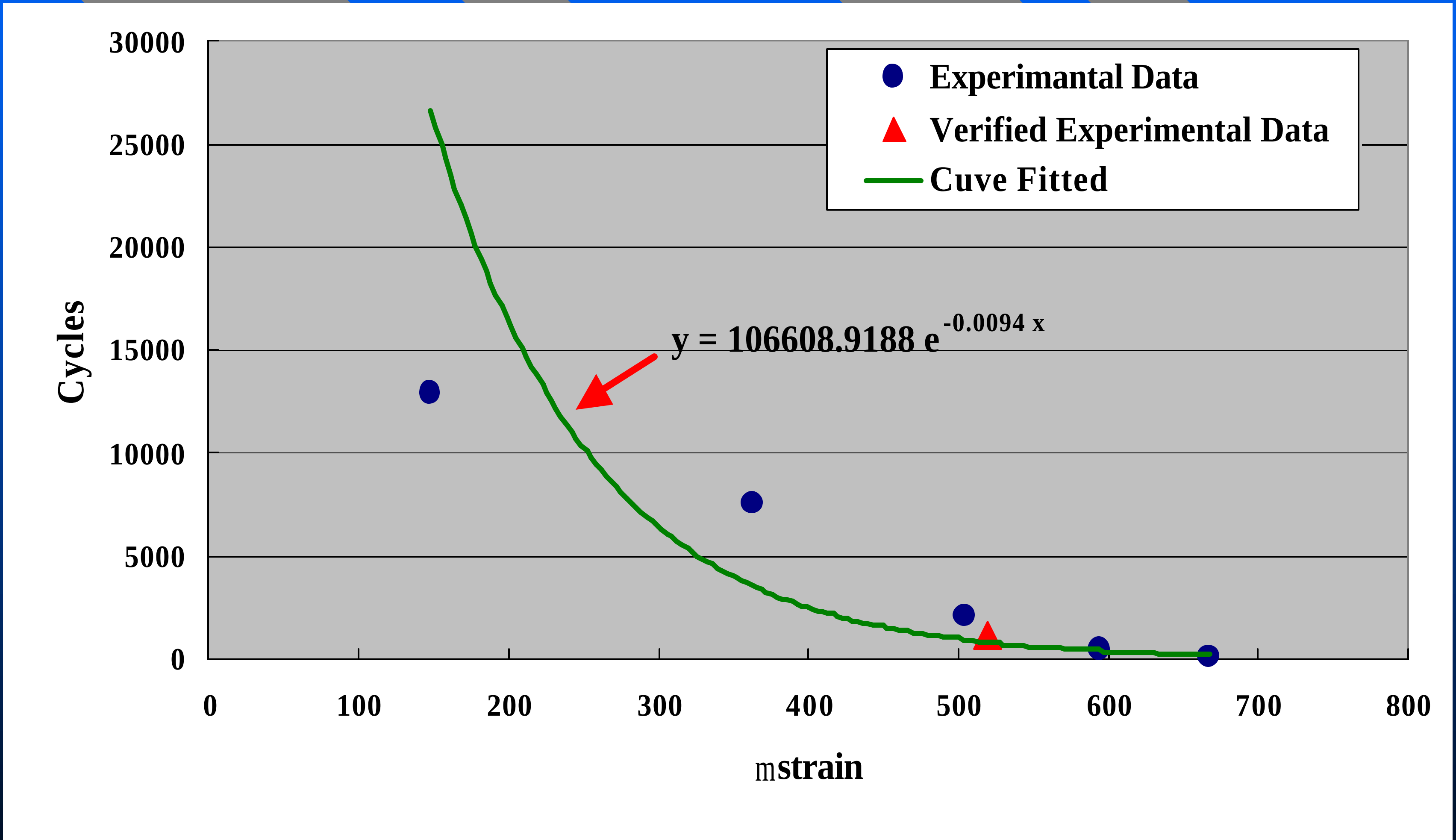


The Cyclic Bend Test Results at Various Loading Strain at Room Temperature

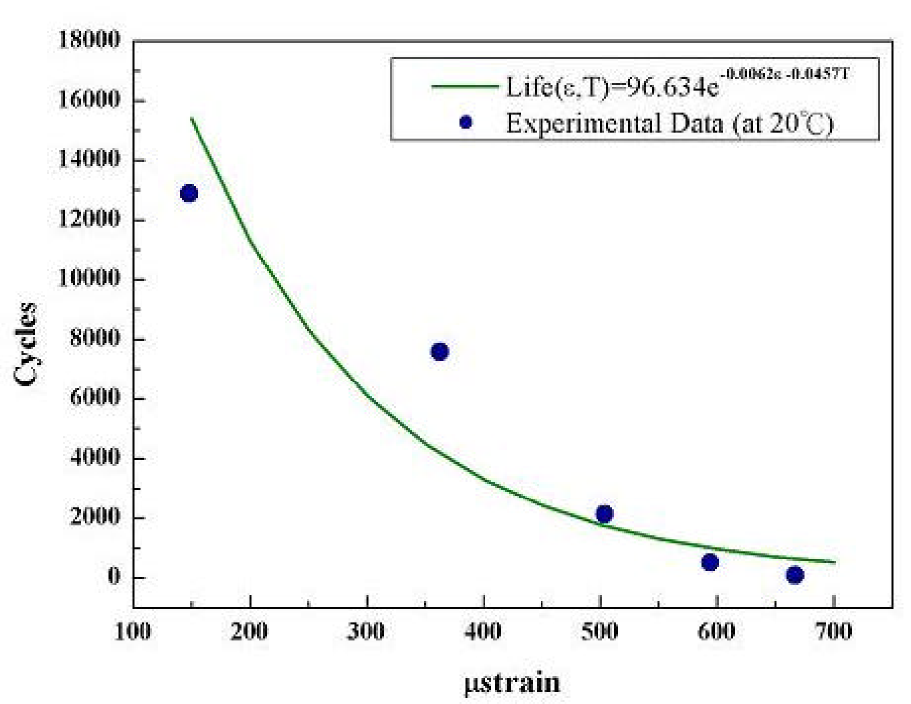
Deflection(mm)	Max. Strain(me)	Component		Failed Cycles	Mean Cycles
0.3	148	U1	+IN to +OUT -IN to -OUT	8819	12875.5
		U5	+IN to +OUT -IN to -OUT	16932	
0.4	363	U1	+IN to +OUT -IN to -OUT	7326	7583
		U5	+IN to +OUT -IN to -OUT	7840	
0.5	504	U1	+IN to +OUT -IN to -OUT	1902	2122
		U5	+IN to +OUT -IN to -OUT	2342	
0.6	594	U1	+IN to +OUT -IN to -OUT	452	512
		U5	+IN to +OUT -IN to -OUT	572	
0.7	667	U1	+IN to +OUT -IN to -OUT	39	71.5
		U5	+IN to +OUT -IN to -OUT	104	

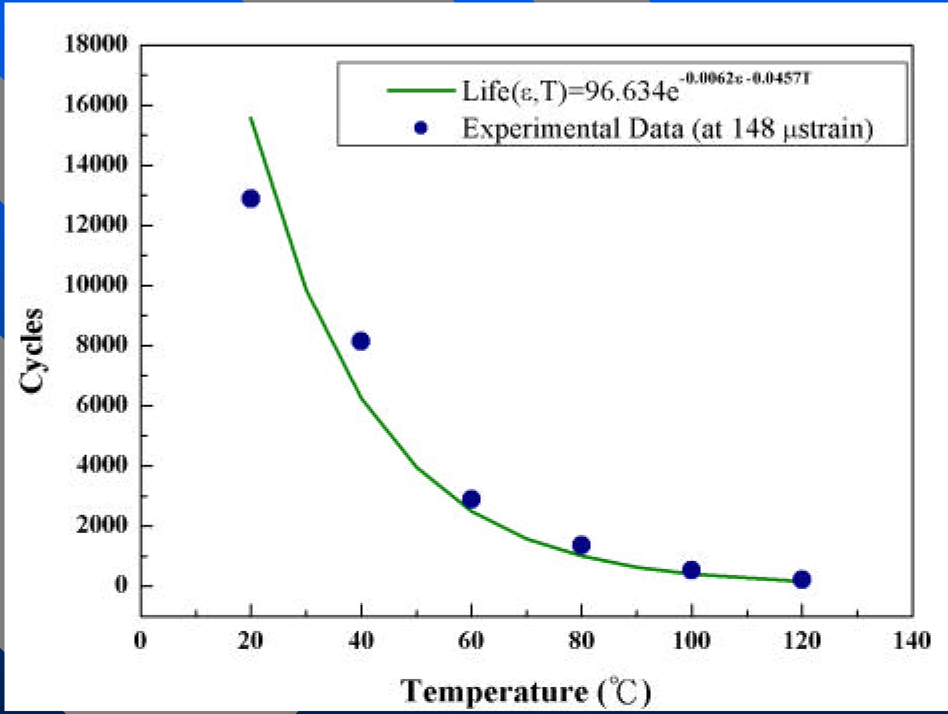
The Plot of the Component Life with Various Loading Strain

(at Room Temperature)



The Life Equation Relating to Strain and Temperature





$$Life(e,T) = 96{,}634e^{-0.0062e - 0.0457T}$$

Summary

- The relation between temperature and life at specific maximum strain

$$Life(T) = 34{,}203e^{-0.0409T}$$

- The relation between loading strain and life at room temperature

$$Life(e) = 106{,}608e^{-0.0094e}$$

- The life equation relating to strain and temperature

$$Life(e, T) = 96{,}634e^{-0.0062e - 0.0457T}$$

Note: Life in Cycles

Conclusions

- When conducting the monotonic bend test, the failure mode found is solely the delamination of the heat spreader from the chip surface. The mean force of test boards is 823N and the mean strain for test boards is 4,535 μstrain respectively.

- From the cyclic bend test, the relating fitted equation of life versus temperature and deflection can be obtained correspondingly. It is found that the component life decreases with the increase of the temperature when tested at certain maximum deflection. And the component life decreases with the increase of the maximum deflection when tested at room temperature.

- Through the relation of life versus temperature and loading strain, the equation relating to both loading strain and temperature can be deduced.

The End

Thank You Very Much