

Temperature Cycling of Coreless Ball Grid Arrays

DfR Solutions Open House

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Agenda

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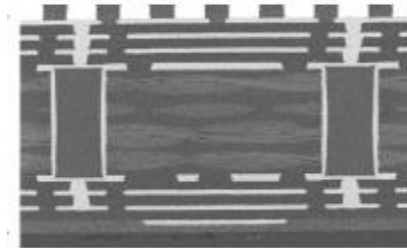
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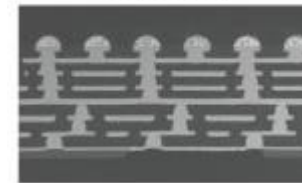
Introduction

- **Standard packages have a laminate core**
 - Thickness 200-800 μ m
 - Various E-glass options
- **Coreless packages**
 - Only “build-up” layers exist
 - Typically more prone to warpage during assembly
 - Typically have a higher CTE than standard packages
- **In this study:**
 - Large BGA package with a large die
 - No failures after 8,000 temperature cycles
- **Further investigation of this unexpected performance**

Build-up substrate
(8Layers / 3-2-3)



Coreless substrate
(8Layers)



Experimental Procedure

- Coreless BGA Package

- Footprint: 25 by 27 mm, Total thickness: 1.54 mm
- Silicon die details: 13.8 by 16.5 mm, Thickness: 750 μ m
- Stiffener ring: Single piece, Perimeter

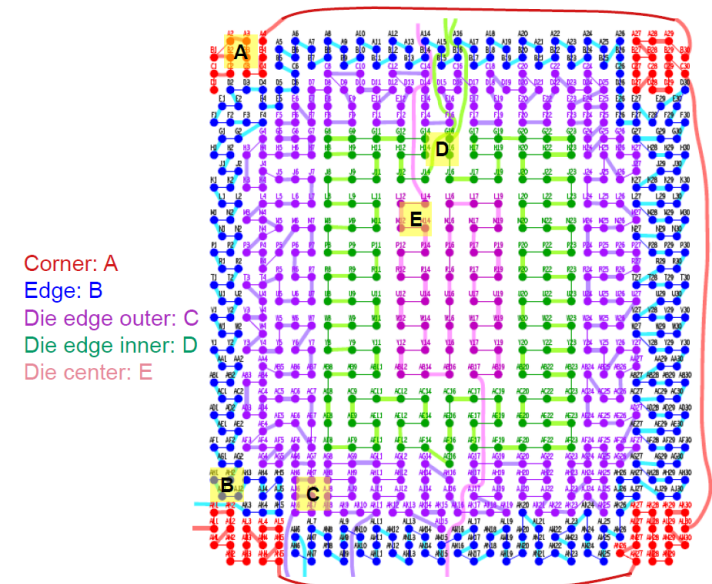
- Samples:

- 6 samples with edge bonding
- 5 samples with no bonding

- In-situ monitoring of 5 daisy chains

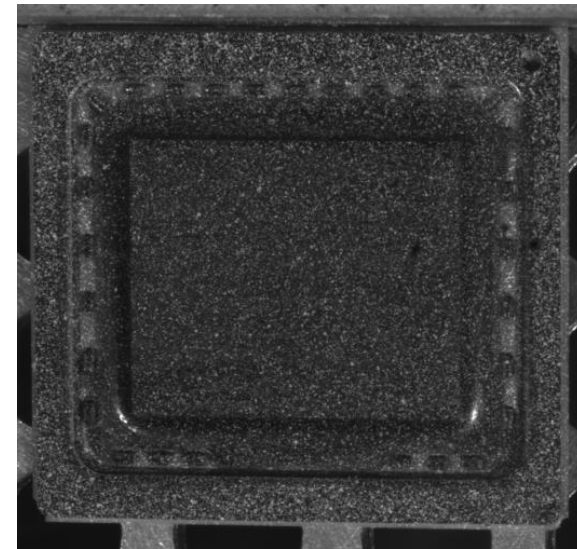
- 8027 Temp Cycles

- (-40) to 85 °C with 23 minute dwells
- 17°C/min ramp rates



Digital Image Correlation

- After testing, a sample was subjected to (differential) digital image correlation and tracking (DIC/DDIT)
 - Optical method
 - Employs tracking and image registration techniques
 - Creates accurate 2D and 3D measurements of changes in sample deformation
 - Conducted at the Optomechanics and Physical Reliability Lab at SUNY Binghamton
- **2 step process:**
 - Sample is coated with a white paint pattern
 - Deformation is measured over a range of temperatures

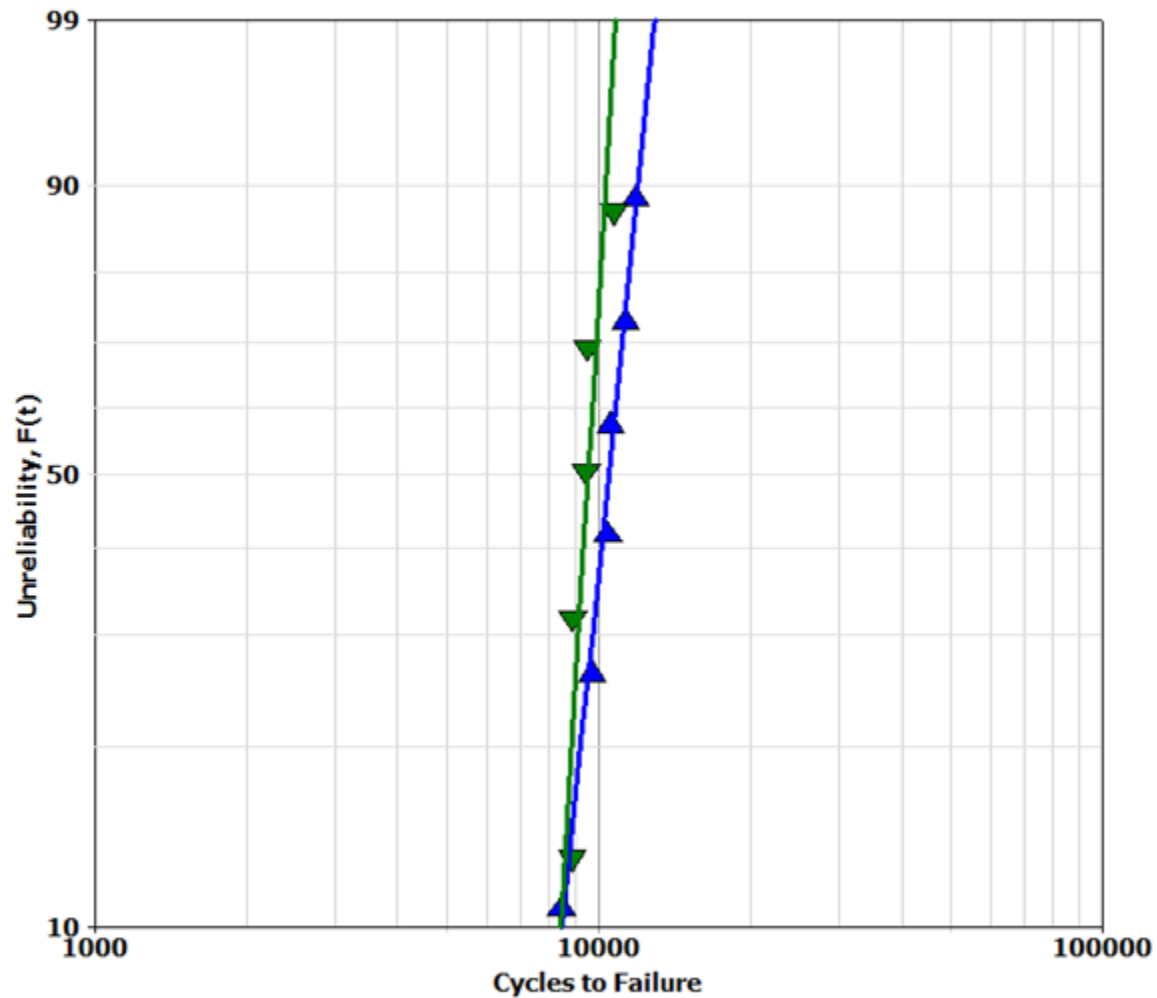


Results and Key Findings

- After no failures were found in the initial 8027 cycles another 3840 cycles were performed for a total of 11,867 cycles
- The edge bonding does not affect the performance
- The characteristic life of this package is 10,425 cycles
- DIC results show a CTE match between the board and the bottom of the package
- Warpage of the package was measured at $\sim 80\mu\text{m}$

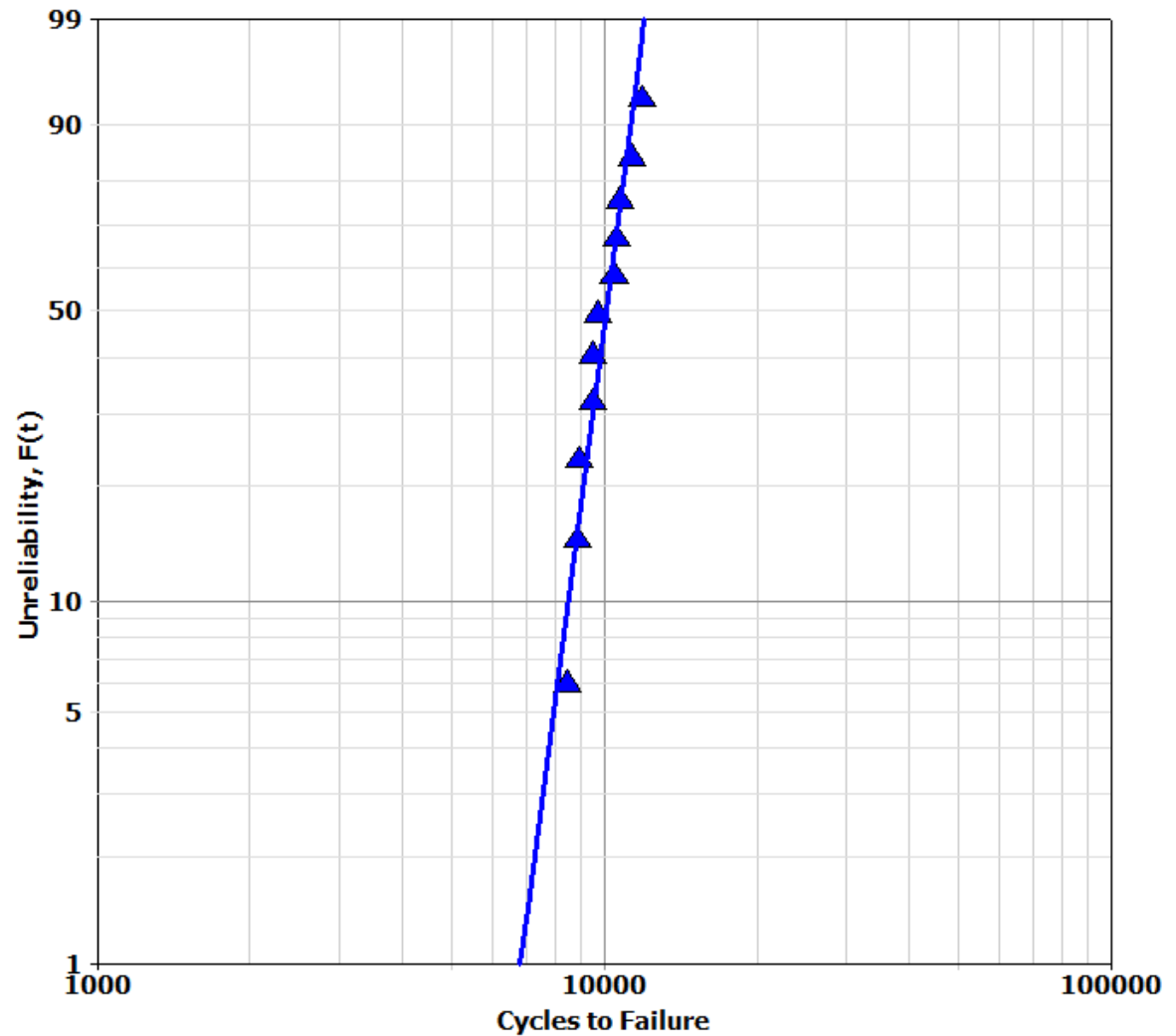
Individual Weibull Plots

- **Green: with edge bonding**
 - Shape parameter, $\beta = 8.9575$
 - Characteristic Life $\eta = 10,924$ cycles
- **Blue: without edge bonding**
 - Shape parameter, $\beta = 15.369$
 - Characteristic Life $\eta = 9,777$ cycles
- **Edge bonding does not affect the results**

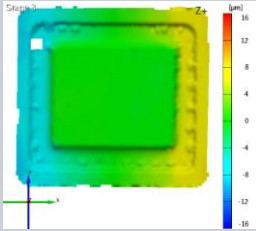
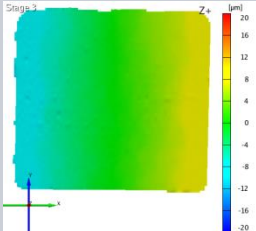
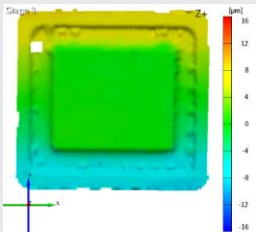
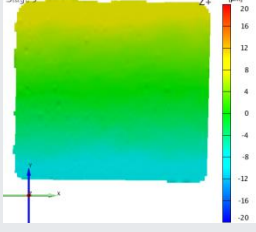
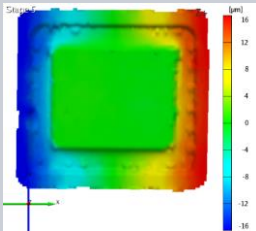
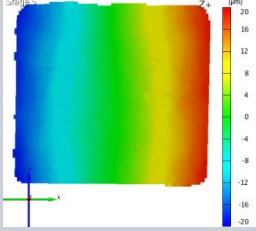
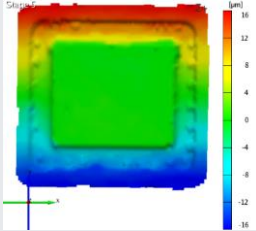
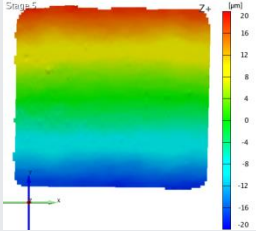


Combined Weibull Plot

- Overall Weibull parameters
 - Shape parameter, $\beta = 10.8304$
 - Characteristic life $\eta = 10,425$ cycles
- Why is this happening?
- DIC results?



DIC Results

	Top	Bottom
X Deformation 70°C	 DIC X Deformation 70°C Top view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the X-axis. The central hole is green (0 µm), and the displacement increases towards the edges, reaching approximately 16 µm at the corners. A color scale on the right ranges from -16 to 16 µm.	 DIC X Deformation 70°C Bottom view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the X-axis. The displacement is relatively uniform across the specimen, with a color scale on the right ranging from -20 to 20 µm.
Y Deformation 70°C	 DIC Y Deformation 70°C Top view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the Y-axis. The central hole is green (0 µm), and the displacement increases towards the edges, reaching approximately 16 µm at the corners. A color scale on the right ranges from -16 to 16 µm.	 DIC Y Deformation 70°C Bottom view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the Y-axis. The displacement is relatively uniform across the specimen, with a color scale on the right ranging from -20 to 20 µm.
X Deformation 110°C	 DIC X Deformation 110°C Top view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the X-axis. The displacement is higher than at 70°C, reaching approximately 16 µm at the corners. A color scale on the right ranges from -16 to 16 µm.	 DIC X Deformation 110°C Bottom view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the X-axis. The displacement is higher than at 70°C, reaching approximately 20 µm at the corners. A color scale on the right ranges from -20 to 20 µm.
Y Deformation 110°C	 DIC Y Deformation 110°C Top view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the Y-axis. The displacement is higher than at 70°C, reaching approximately 16 µm at the corners. A color scale on the right ranges from -16 to 16 µm.	 DIC Y Deformation 110°C Bottom view. The image shows a square specimen with a central square hole. The color map indicates displacement in micrometers (µm) along the Y-axis. The displacement is higher than at 70°C, reaching approximately 20 µm at the corners. A color scale on the right ranges from -20 to 20 µm.

Package Deformation

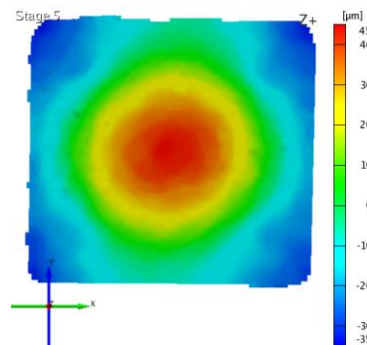
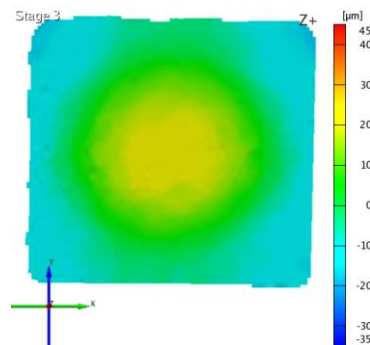
- **Top of package**
 - Driven by the presence of the die
 - Stiff die experiences little to no deformation
 - The majority of the deformation occurs in the substrate between the die edge and the substrate edge
 - Support the typical BGA device observations that solder balls at the die shadow fail fast
- **Bottom of package**
 - Relatively uniform deformation across both the x and y axes
 - The CTE values match the PCBs (15-17 ppm/°C)

CTE Results		
Side	X ppm/°C	Y ppm/°C
Top	13.5	15
Bottom	16	17.2

Effect of CTE

- CTE match between the bottom of package and the PCB
 - Samples survived more than 8,000 thermal cycles without failure.
 - Standard substrate BGA package does not last as long because the die stiffness has a greater impact on the bottom side CTE
- But coreless substrates have a propensity for warping during assembly
 - Stiffener ring prevents warpage during reflow
 - How effective is the stiffener ring?

Warpage at 70°C
~40µm



Warpage at 110°C
~80µm

Conclusions

- This particular coreless BGA package was very robust with regards to temperature cycling
- The source of this robustness was investigated using digital image correlation
- Coefficient of thermal expansion of the package bottom is very well matched to that of the printed circuit board
- Warpage of the package over the limited temperature range was around $80\mu\text{m}$