Temperature Cycling of Coreless Ball Grid Arrays

DfR Solutions Open House

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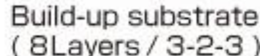
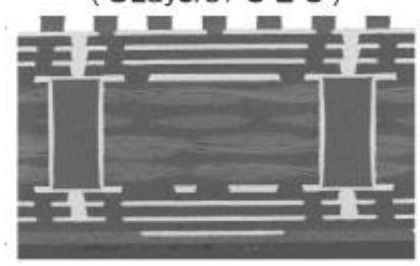
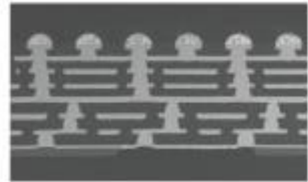
Introduction

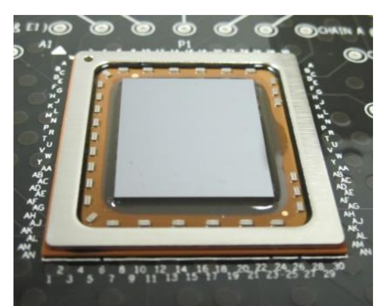
- Standard packages have a laminate core
  - Thickness 200-800µm
  - Various E-glass options
- Coreless packages
  - Only "build-up" layers exist
  - Typically more prone to warpage during assembly
  - Typically have a higher CTE than standard packages
- In this study:
  - Large BGA package with a large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





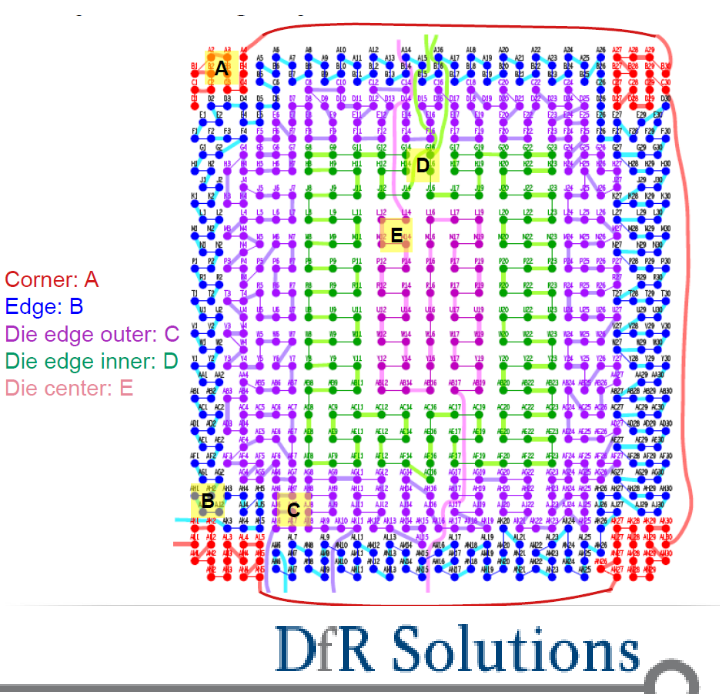
Coreless substrate
(8Layers)





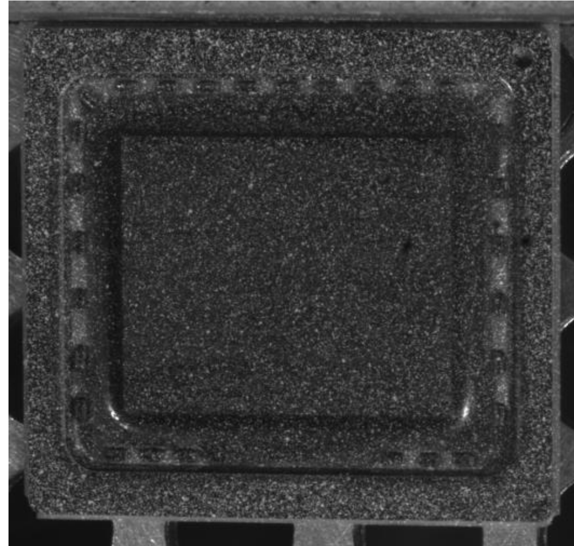
Experimental Procedure

- Coreless BGA Package
  - Footprint: 25 by 27 mm, Total thickness: 1.54 mm
  - Silicon die details: 13.8 by 16.5 mm, Thickness: 750µm
  - 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



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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 ~80µm

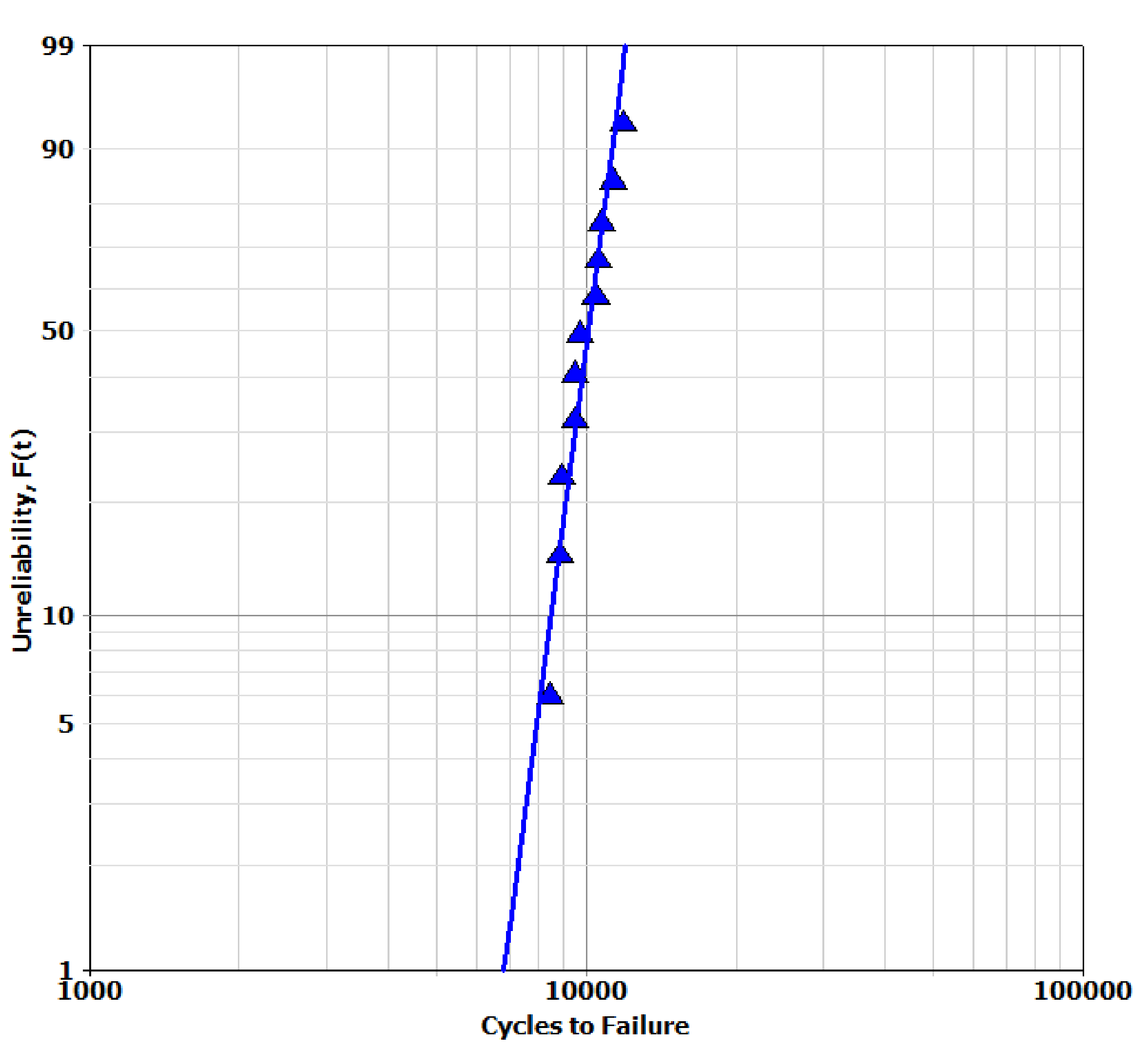
Individual Weibull Plots

- Green: with edge bonding
  - Shape parameter, β = 8.9575
  - Characteristic Life η = 10,924 cycles
- Blue: without edge bonding
  - Shape parameter, β = 15.369
  - Characteristic Life η = 9,777 cycles
- Edge bonding does not affect the results

99
90
50
10
Unreliability, F(t)
1000
10000
100000
Cycles to Failure

Combined Weibull Plot

- Overall Weibull parameters
  - Shape parameter, β = 10.8304
  - Characteristic life η = 10,425 cycles
- Why is this happening?
- DIC results?



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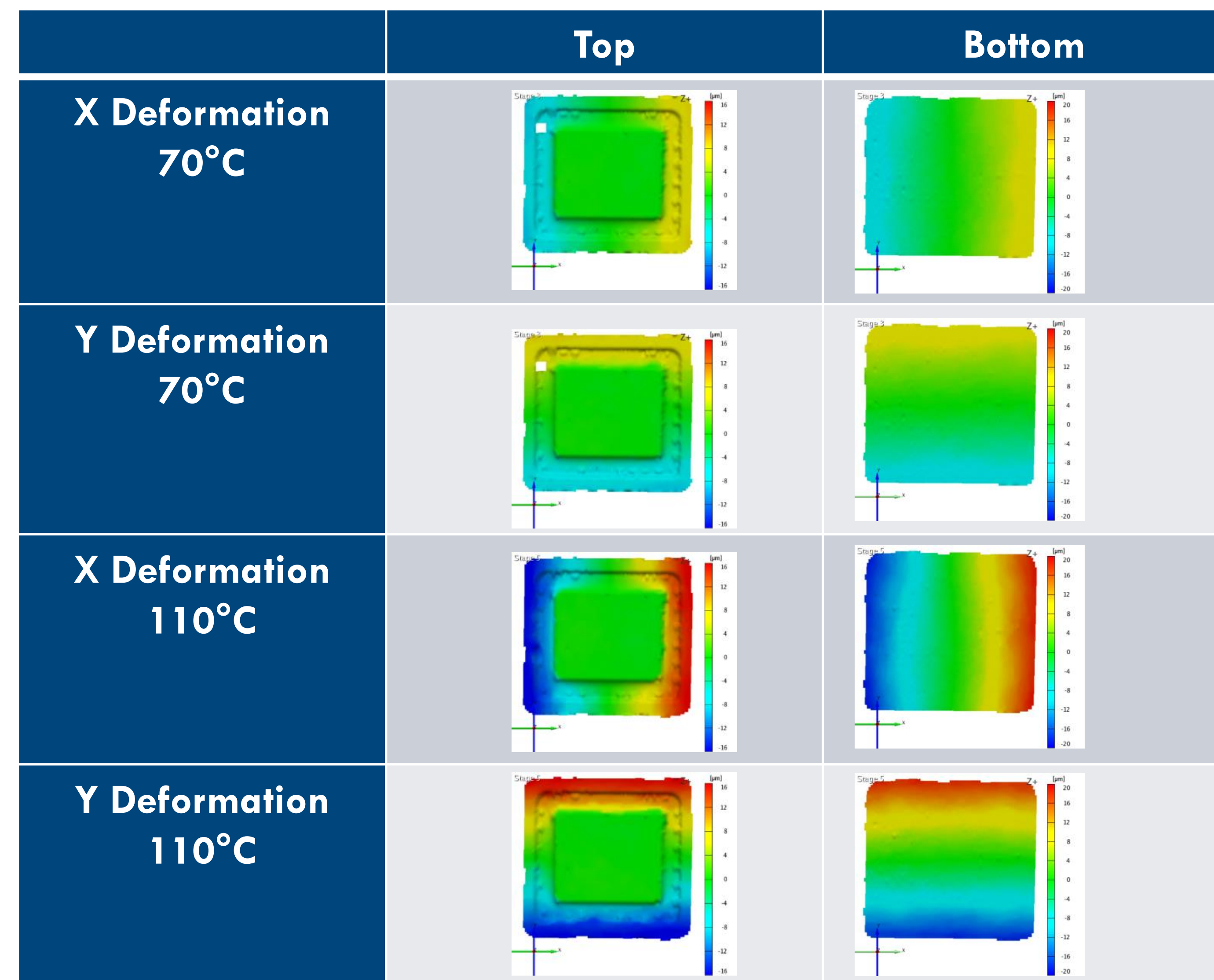
DIC Results



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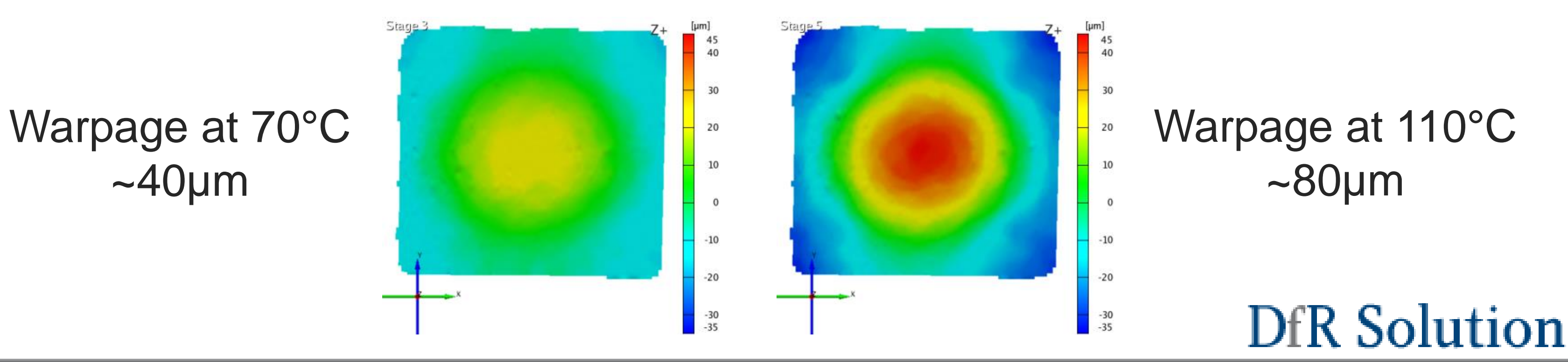
Package Deformation

- 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?



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 80µm

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