1st Order Failure Model for Area Array CSP Devices with Pb-Free Solder

Nathan Blattau, Joelle Arnold, Gerd Fischer, Craig Hillman
DfR Solutions
5110 Roanoke Place, Suite 101
College Park, MD 20740
nblattau@dfrsolutions.com

EXECUTIVE SUMMARY

As some of the reliability issues and cost associated with tin silver copper solders become more apparent, alternative pb-free solder formulations are being considered. Of particular interest are those that feature little or no silver. However, the thermo-mechanical reliability of these solders is not well known because the main focus has been on improving the mechanical shock/drop performance of the solder interconnects. This study presents preliminary thermal cycling data for a tin nickel copper soldered area array chip scale package. This data is then used to develop a 1st order analytical model to make thermal mechanical fatigue life predictions. The model uses basic distance to neutral point and continuous attach type equations to predict the strain energy dissipated by the solder joint. The energy dissipation is used to make fatigue predictions.

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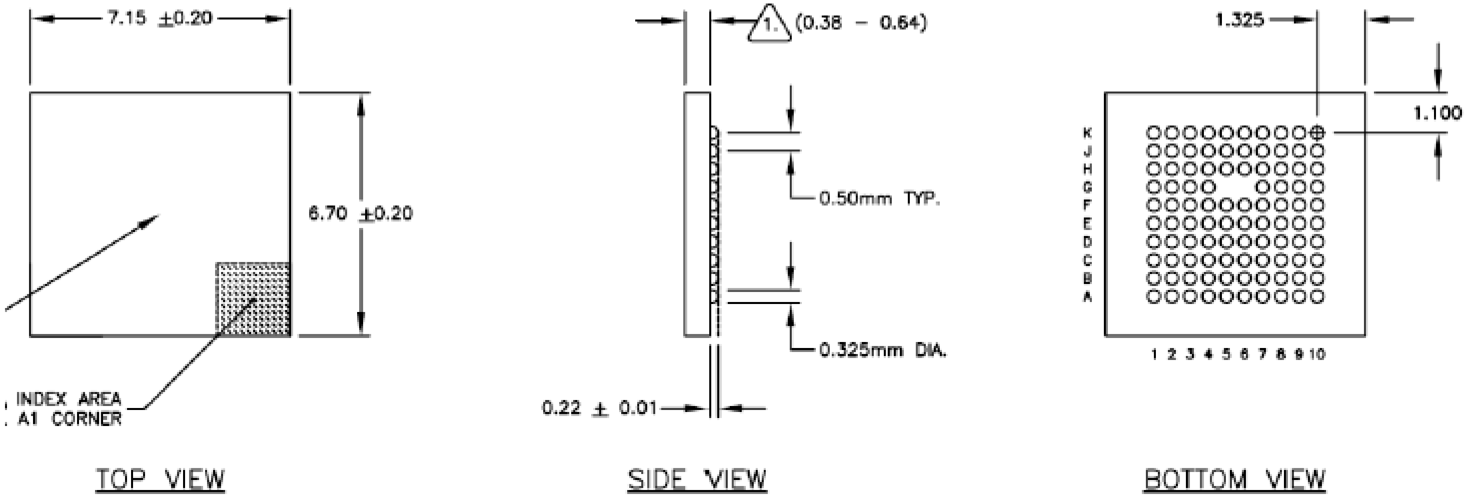
Introduction

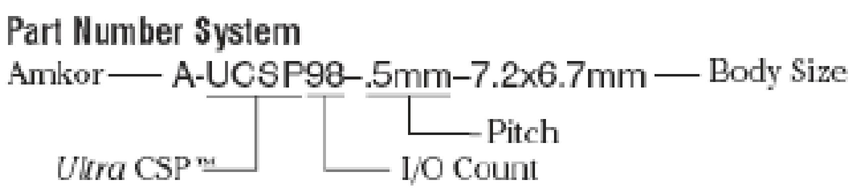
- Thermal cycling results for 98 I/O CSP soldered with SN100C solder
- 1st order model to predict the thermal cycling behavior of SN100C soldered CSP device

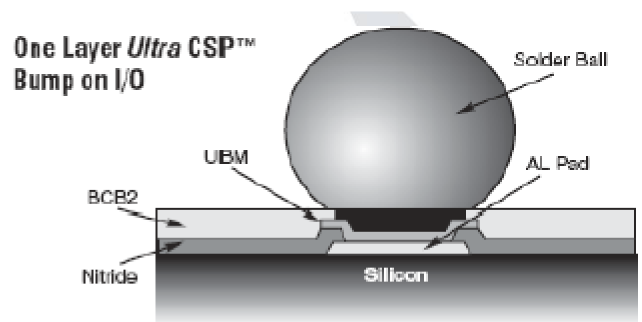
Components and Test Vehicles

CSP : 7.2mm x 6.7mm, 0.5mm pitch (98 I/O)

The bump alloy was matched to the solder alloy

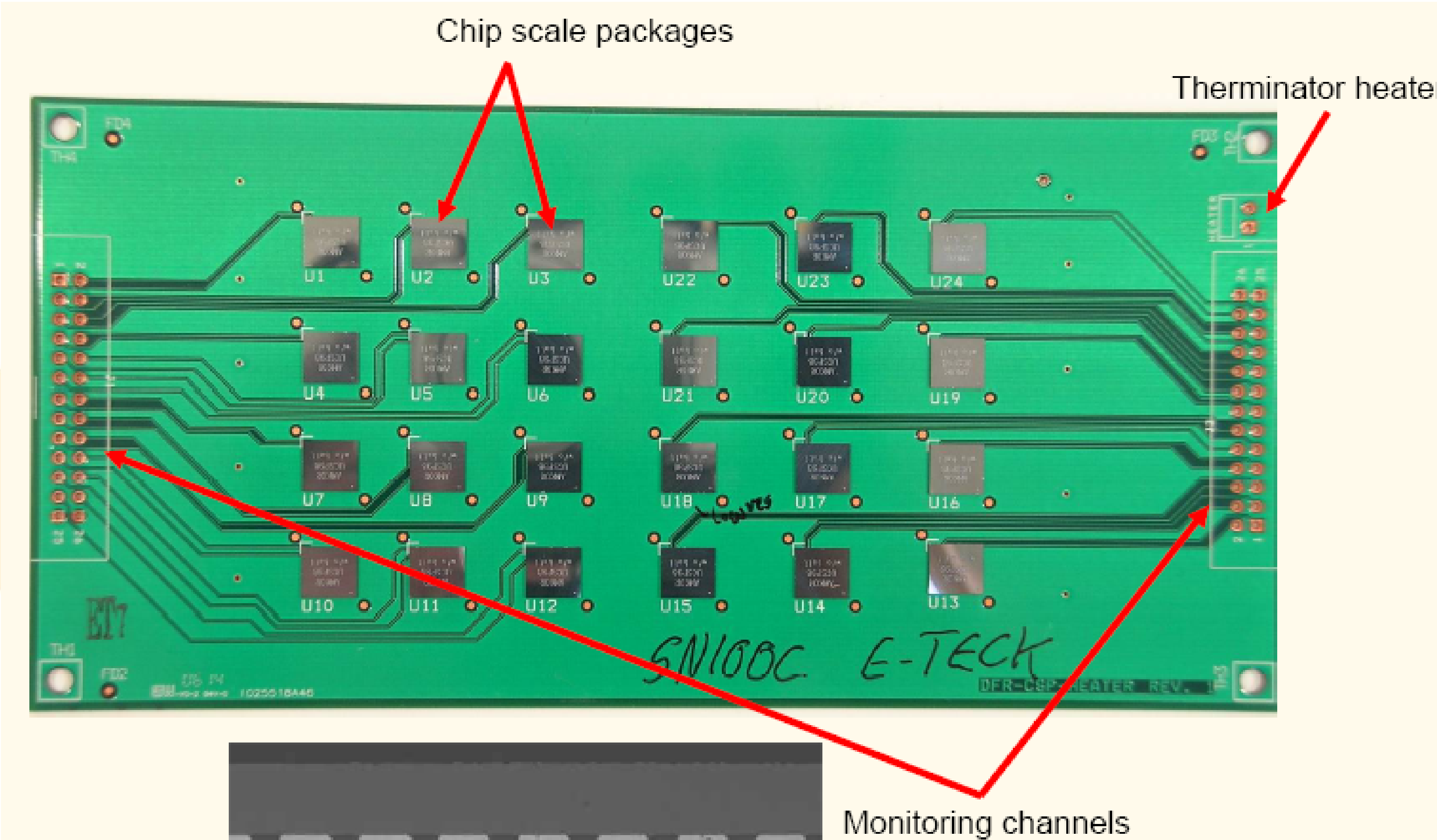


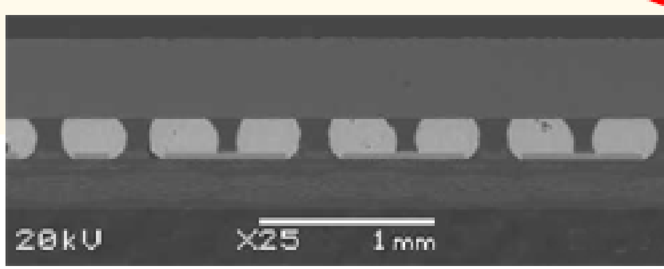




Components and Test Vehicles

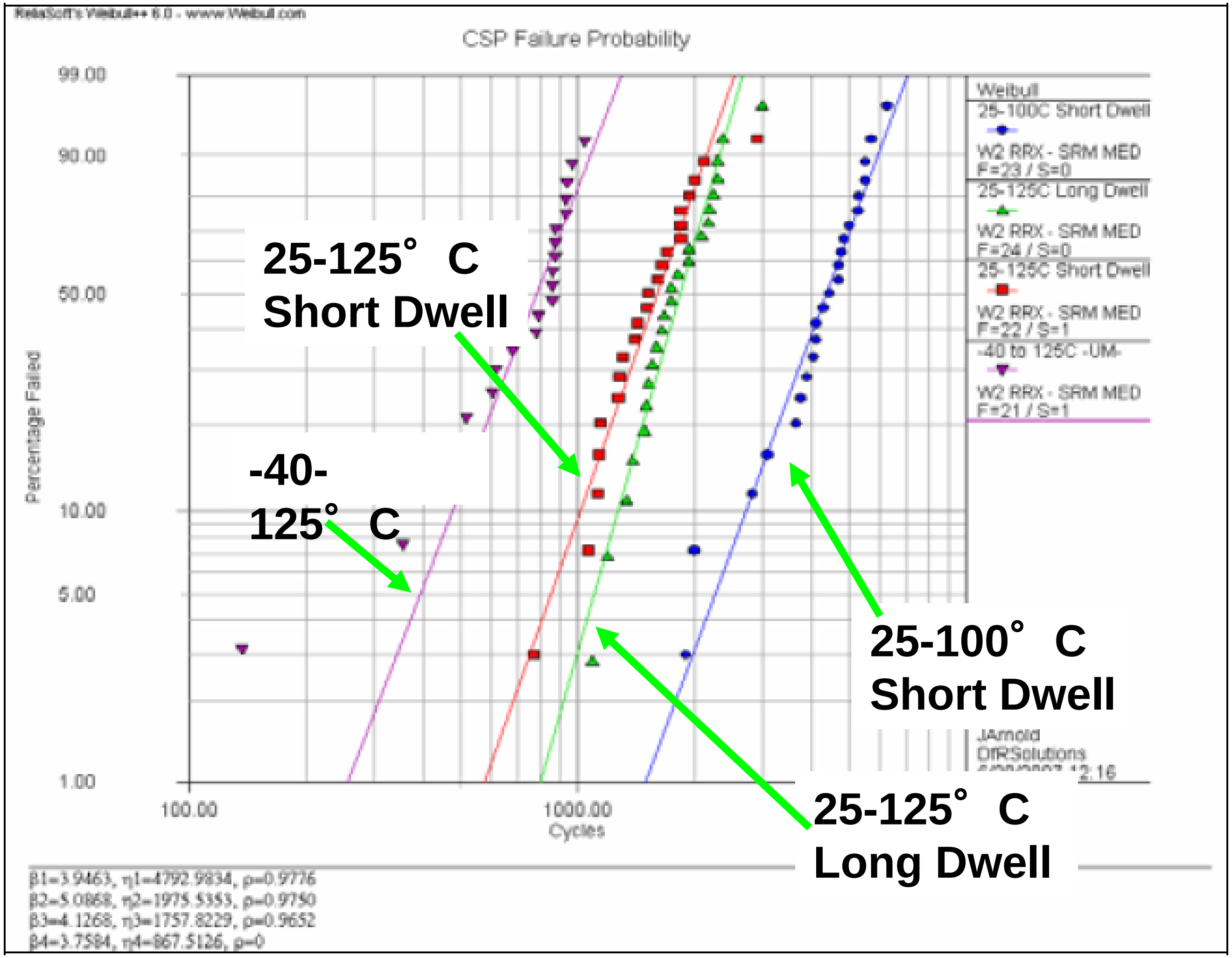
CSP Assembly





Test Methods and Results

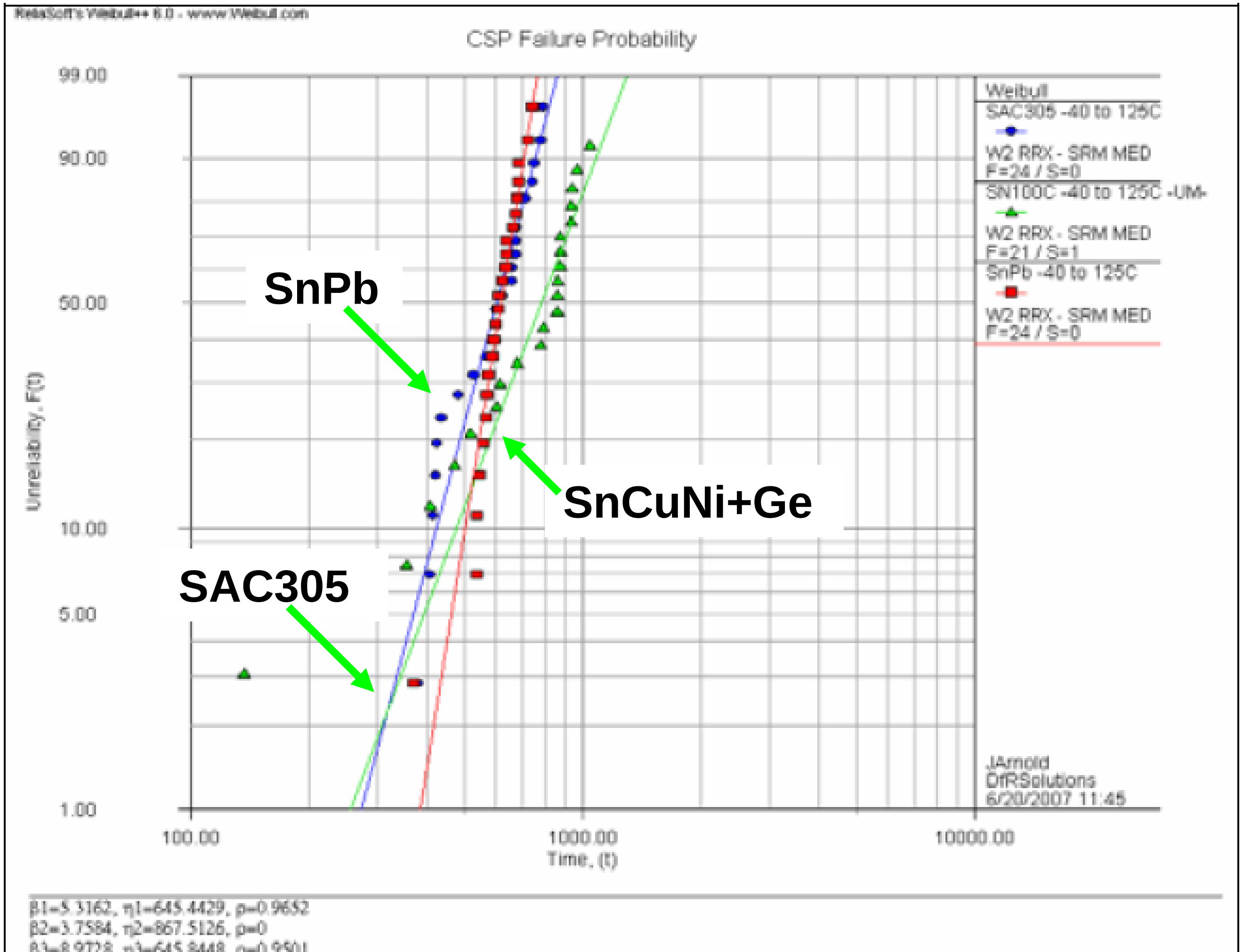
Thermal Cycling



CSP- Ni-modified Sn-0.7Cu

Test Methods and Results

Thermal Cycling



CSP- -40 – 125° C

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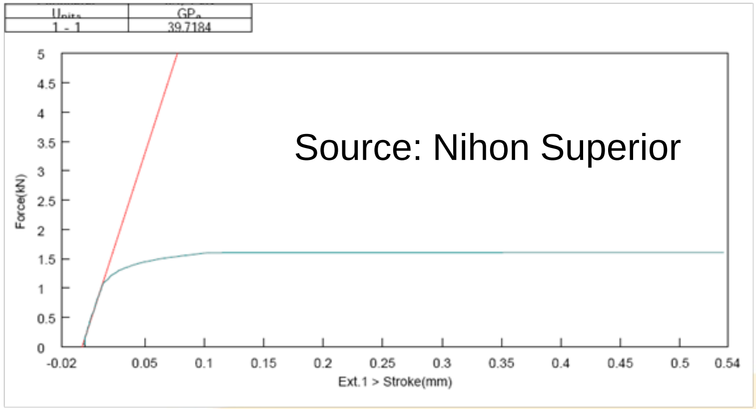
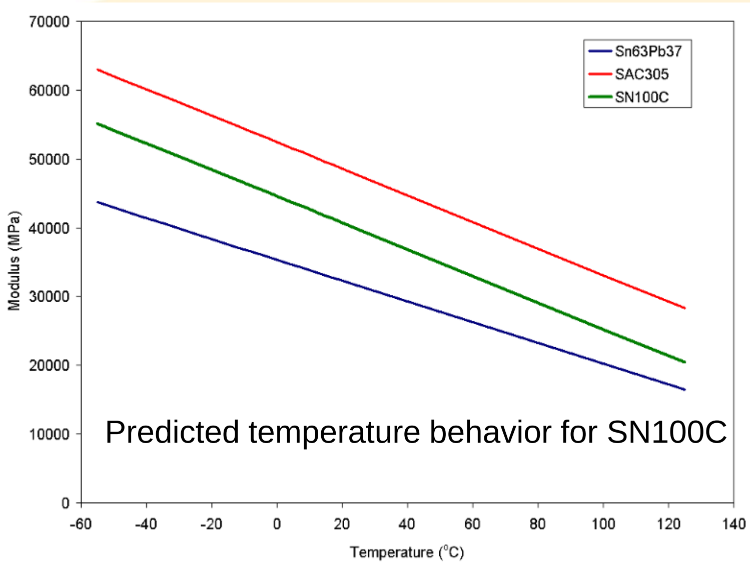
Elastic Modulus of SN100C





SN100C is about 25% stiffer than SnPb

Modulus comparison @ room temperature

Solder	Modulus (MPa)	Ratio to SnPb
SN100C	39720	1.25
Sn63Pb37	31590 [1]	1
SAC305	47575 [1]	1.51

1. R. Darveaux, K. Banerji. “Constitutive Relations for Tin-Based Solder Joints”. IEEE Transactions on Components, Hybrids and Manufacturing Technology, 1992, Vol 15, No. 6, Page(s): 1013-1024.

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Model Development

- Calculation for Stress and Strain
- Stress Calculation
  Equations developed by Jiang
  Z. Q. Jiang, Y. Huang, and A. Chandra, “Thermal stresses in layered electronic assemblies,” ASME J. Electron. Packag., vol. 119, pp. 1127–1132, 1997.
- Strain Calculation (DNP), basically:

$$\Delta\gamma = C\frac{L_D}{h_s}\Delta\alpha\Delta T$$

  Engelmaier, W., "Chap. 17: Solder Attachment Reliability, Accelerated Testing, and Result Evaluation" in *Solder Joint Reliability - Theory and Applications*, edited by Lau, J. H., Van Nostrand Reinhold, New York, 1991, pp. 545-587.
- Determine the strain energy dissipated and calculate the cycles to failure

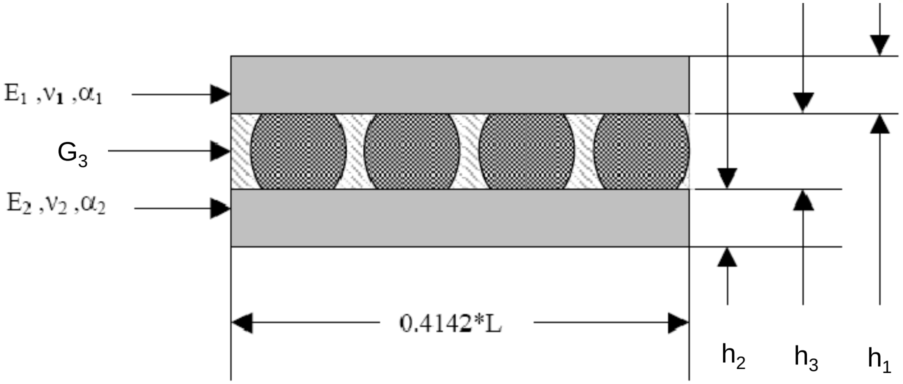
1st Order Model for CSP

- Shear Stress Calculation, Jiang

$$f_s(x) = \frac{G_3 \alpha'_{21} \Delta T}{\gamma h_3} e^{\gamma(x-L)}$$

where G_3 is the shear modulus of the adhesive; $\gamma = 2\sqrt{G_3(\lambda_1+\lambda_2)/h_3}$, $\lambda_i = (1-\nu_i)/E_i h_i$, and $\alpha'_{21} = (1+\nu_2)\alpha_2 - (1+\nu_1)\alpha_1$

- Top and bottom layers modeled as beams, solder is assumed to be a compliant elastic layer



Calculations, cont.

- Solder layer
  - Stiffness is reduced by the area ratio of the package area to solder cross-sectional area (solder diameter, number of I/O)

$$G_3 = \frac{G_s A_s}{A_p}$$

A_s total area of the solder joints
A_p total area of the package
G_s shear modulus of the solder at the solder joint mean temperature

Failure Prediction

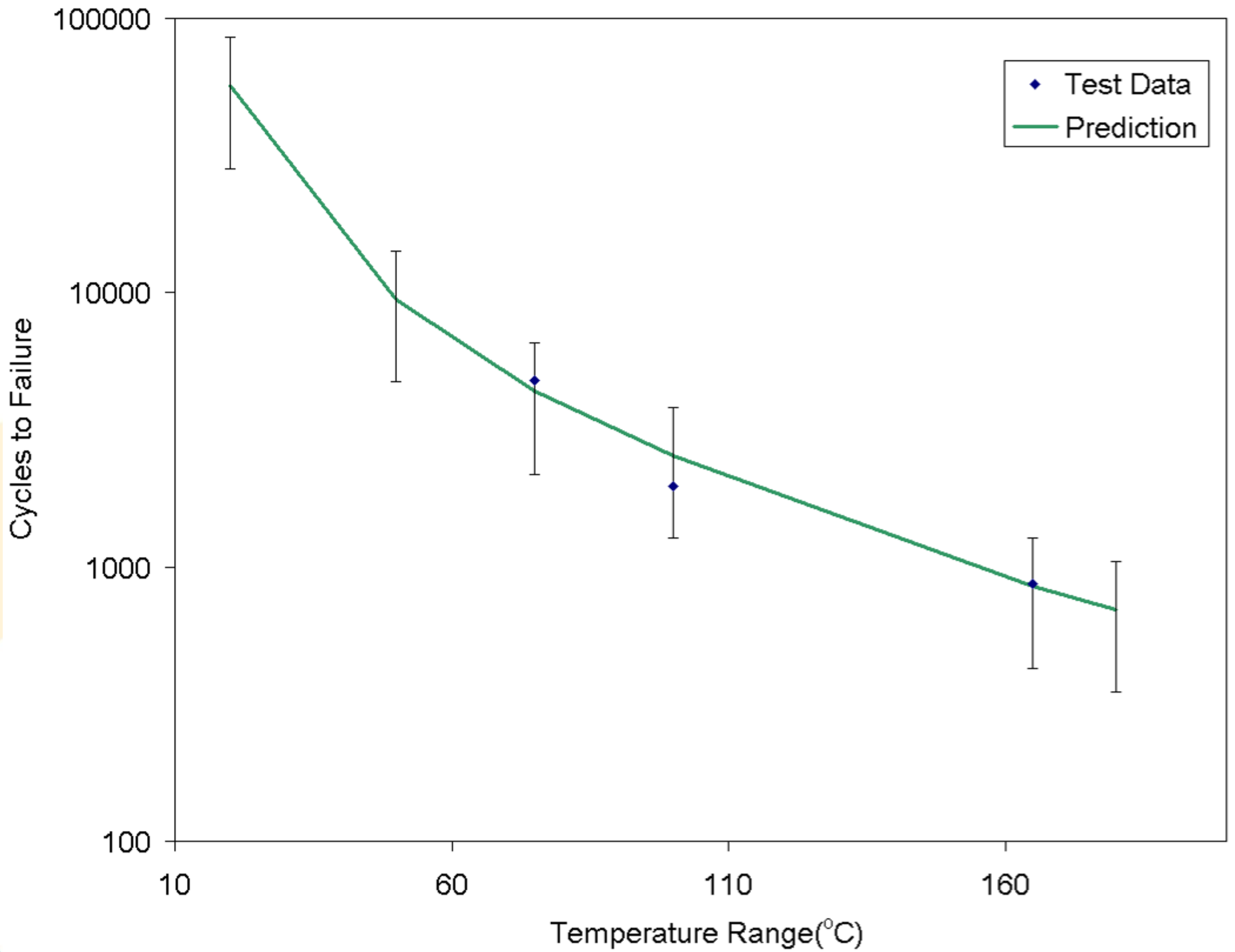
- Temperature range effects included by using the temperature dependent shear modulus
- Insufficient data for including dwell effects, no significant difference noted during experiments (long dwell verse shorts dwell)
- Strain energy dissipated during a temperature computed using:

$$w_{acc} \cong \frac{1}{2}\Delta\gamma \cdot \tau$$

- Cycles to failure computed using:

$$N_f = \left(0.0015 w_{acc}\right)^{-1}$$

Comparison to Experimental Results



Conclusion

- Effects of dwell on SN100 fatigue life appear to be less than that with SAC305 solder
- Simple prediction model utilizing DNP strains and continuous attach stress calculations
- Life prediction calculations fit the experimental results