Durafuse™ LT

An Industry Leader in Low Temperature solder

Low Temperature Solder

Industry Drivers

- Reduce cost in component, substrate, and soldering temperature
- Heat sensitivity of some components and flex polymers
- Reduce Thermal Warpage
  - Component miniaturization (Intel driven)
  - Multilayer board warpage (Server applications)
- Eliminate Wave Soldering Process
- Step Soldering
  - RF Shield Attachment
  - Rework Applications
  - Avoid Solder Squeezeout

Warpage as a Function of Temperature

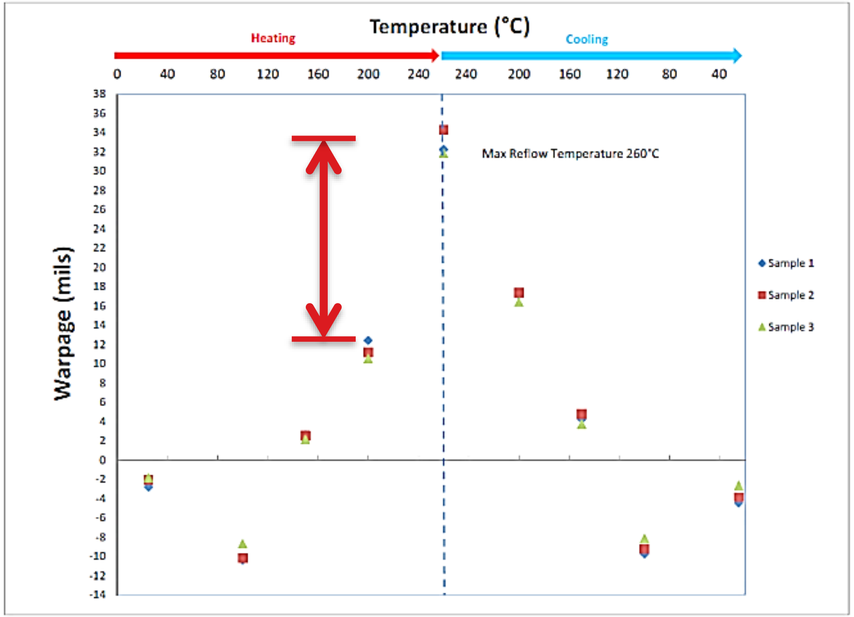
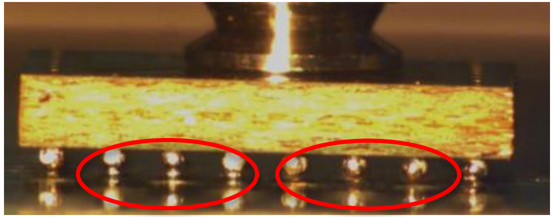


Figure 4: Warpage as a function of temperature during simulated reflow.

Universal Instruments
Advanced Process Laboratory
Process Support / Failure Analysis

Thermal warpage is impacted by increasing component complexity, decreasing ball pitch, substrate material, size, and package thickness



HIP/HOP

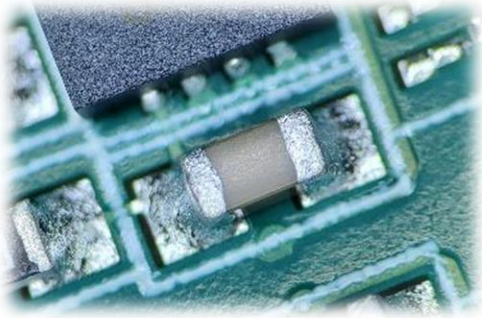
Solder to Pad Separation

Although highly component specific, a temperature change to 200°C can result in a dramatic warpage reduction

Low Temp 3 Prong Support

Durafuse™ LT ★	*The* ***next level of Drop Test reliability*** *with our novel low temperature mixed alloy system*
Bismuth+	*Doped bismuth alloy bringing increased TCT reliability and security to your low temperature process*
Classic Solutions	*Bismuth and indium solutions backed by decades of experience, ideal for traditional applications*

Durafuse™ LT



Advantages:

Reflow below 210˚C

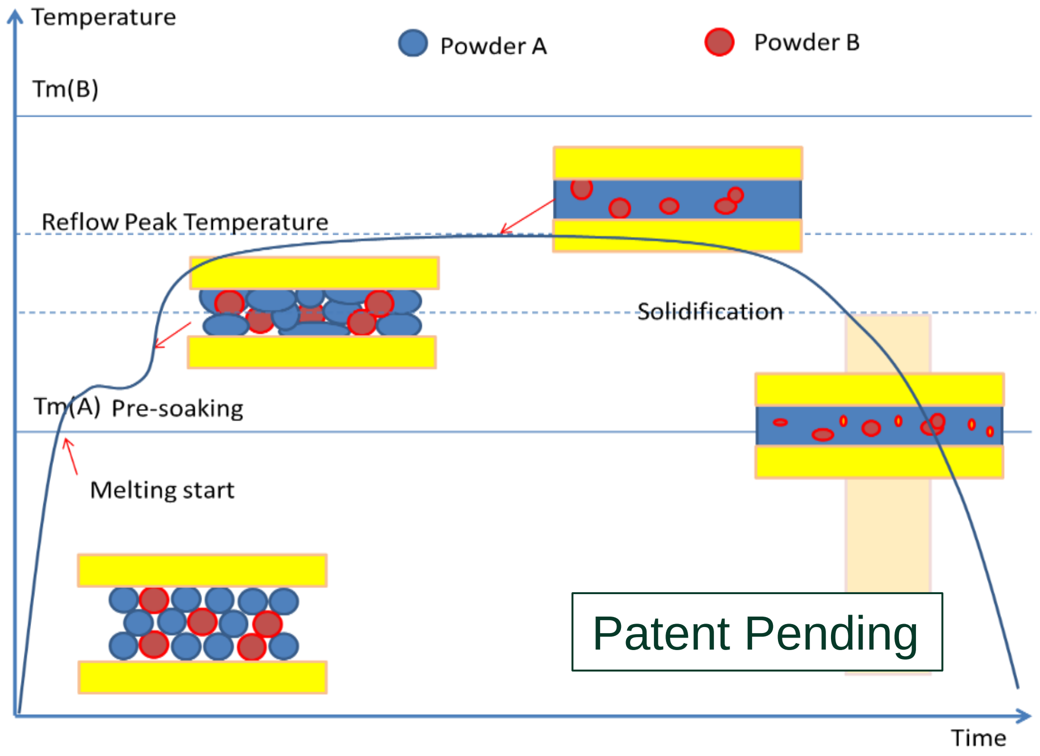
Melting temperature >180˚C

Excellent drop shock - comparable to SAC

Good mechanical shear strength up to 150~165˚C

Good thermal & electrical conductivity

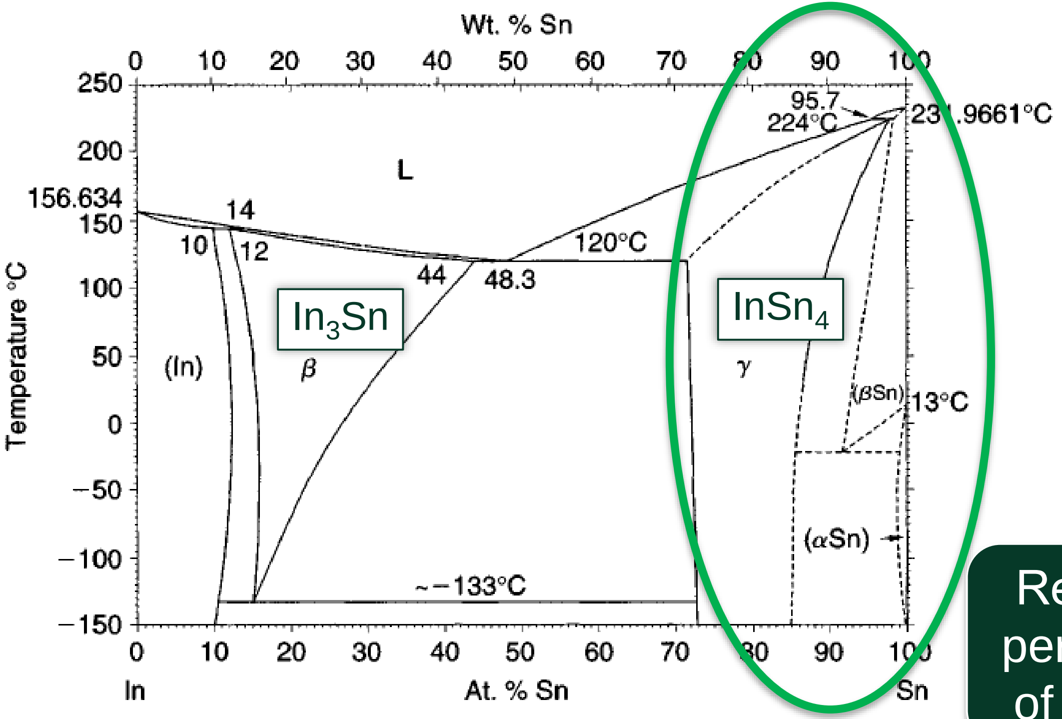
Design of *Durafuse™ LT* Patent Pending



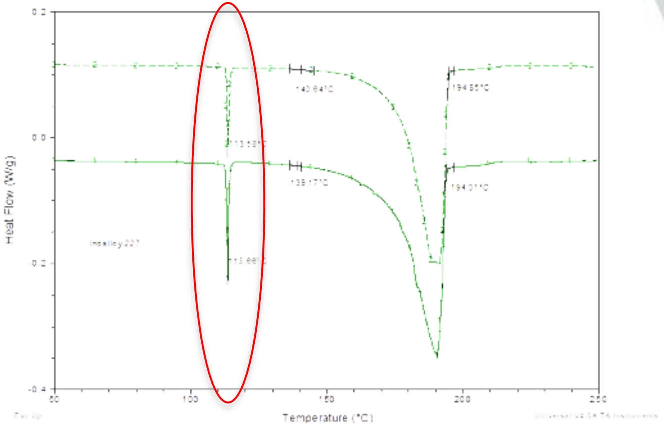
Low Temperature Drop Shock Solution

Durafuse™ LT for drop shock contains an low melting indium based alloy which initiates joint fusion, while the high melting SAC alloy provides enhanced strength and durability

Unique Melt Characteristics

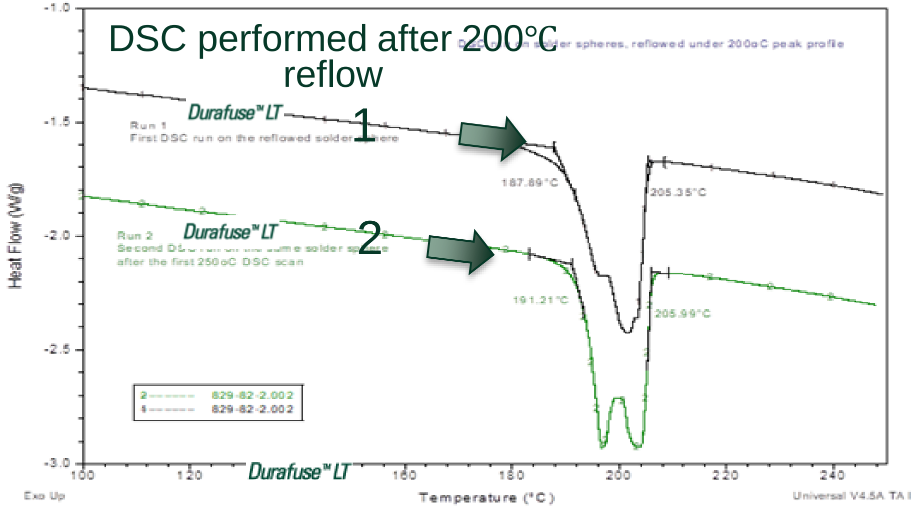


High indium (≥20%) content alloy low melting peak (DSC)



Reflowed Durafuse™ LT contains a low percentage of indium, avoiding formation of low melting In-Sn or InSn$_4$-In eutectic

Post Reflow Melt Characteristics

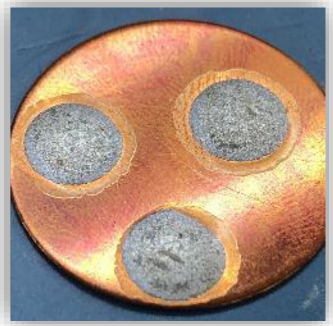


DSC performed after 200℃ reflow

DSC: <u>Melt,</u> <u>Remelt</u>

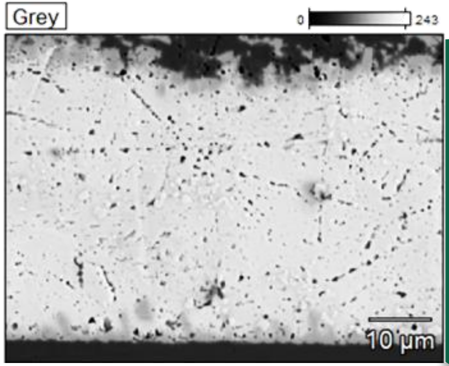
Post Reflow Solidus 188 ℃
Second DSC Solidus 191 ℃
Post Reflow Liquidus 206 ℃

Roughened surface demonstrates mixed crystal formation with partially diffused Sn

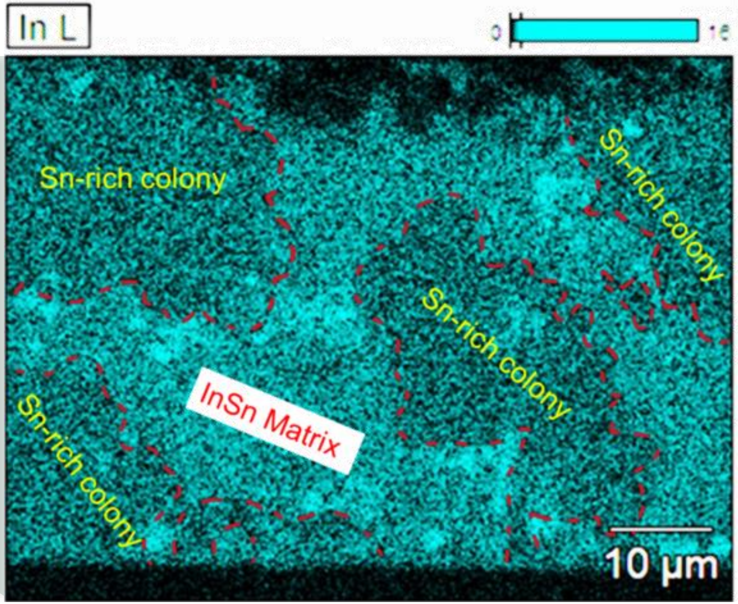


During reflow Durafuse™ LT introduces more Sn into the liquid phase to increase joint melting temperature and eliminate the low melting peak typically found with In/Sn solders

Joint Microstructure

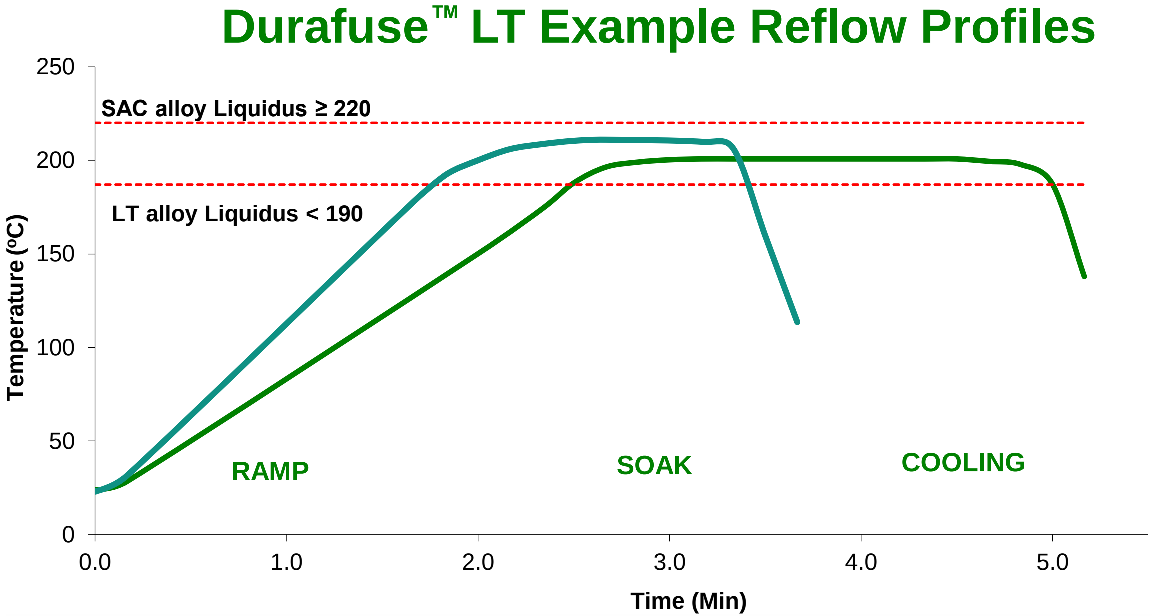


Despite Sn-rich colonies causing crystal structure variation and roughened solder joint appearance, SEM analysis shows no distinct interfaces between compositions



After reflow the “darker” Sn-rich colonies are embedded in InSn matrix

Reflow



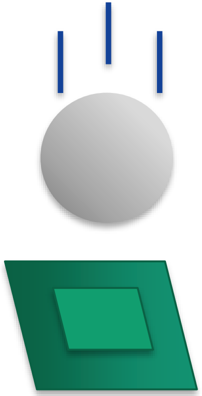
A plateau region between low and high-temperature alloy liquidus temperatures facilitates alloy integration.

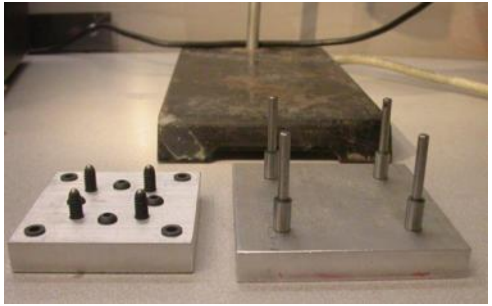
Peak reflow temperatures from 200-210℃

Durafuse™ LT is designed for use with Indium 5.7LT-1. The flux has a high thermal tolerance and is compatible with a linear ramp rate of 0.5-2°C/s

Drop Shock Methodology

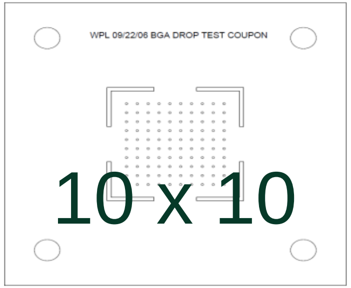
Indium Corporation uses a ball drop - type test to determine drop shock reliability

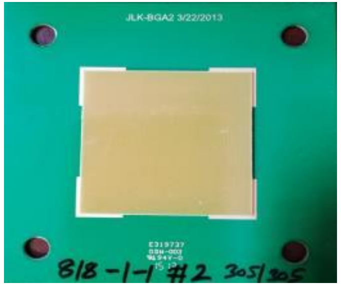


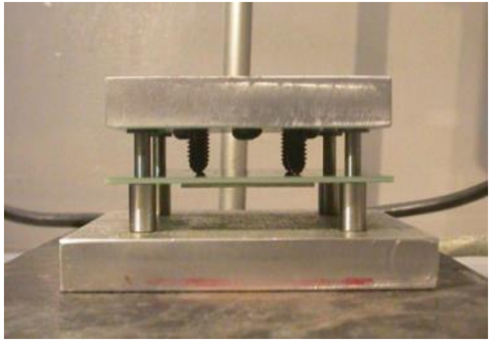


Drop Test BGA

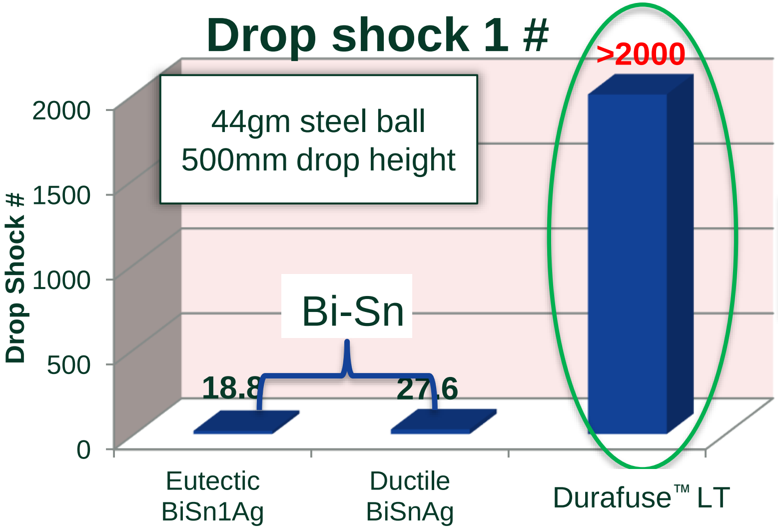
10x10 grid
Diameter 0.6MM
Pitch 4.5MM

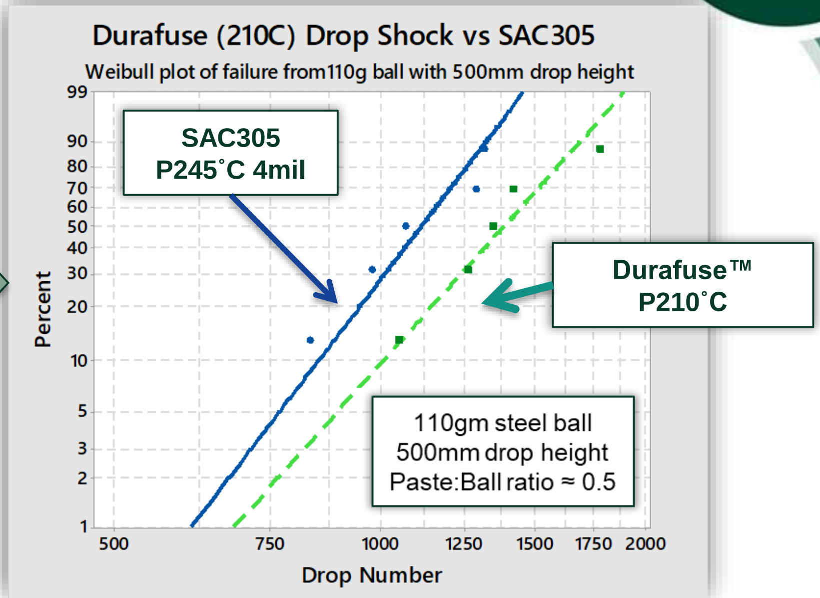






Drop Shock Testing



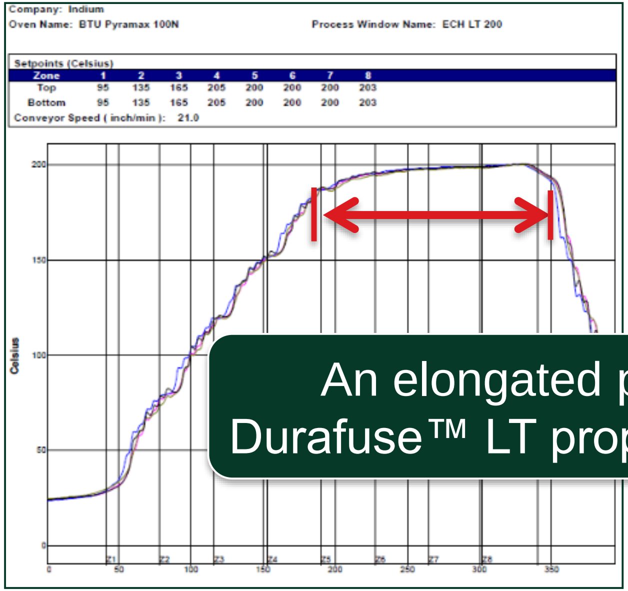


Durafuse™ LT (200°C peak reflow) drop shock resistance is over two orders of magnitude higher than Bi-Sn (170°C peak reflow)

Durafuse™ LT (210℃ reflow) drop shock **surpassed SAC305**

Reflow Profile Optimization

Peak Temp: 200˚C
Time @ Peak: 120 seconds



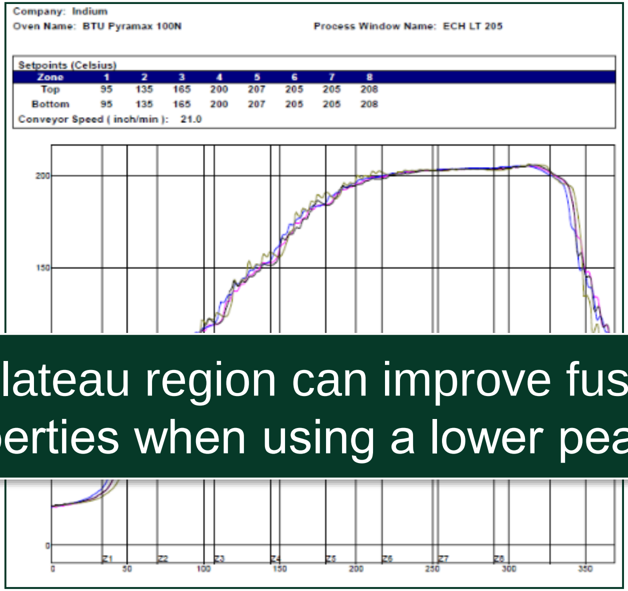
Company: Indium
Oven Name: BTU Pyramax 100N
Process Window Name: ECH LT 200

Setpoints (Celsius)

Zone	1	2	3	4	5	6	7	8
Top	95	135	165	205	200	200	200	203
Bottom	95	135	165	205	200	200	200	203

Conveyor Speed (inch/min): 21.0

Peak Temp: 205˚C
Time @ Peak: 100 seconds



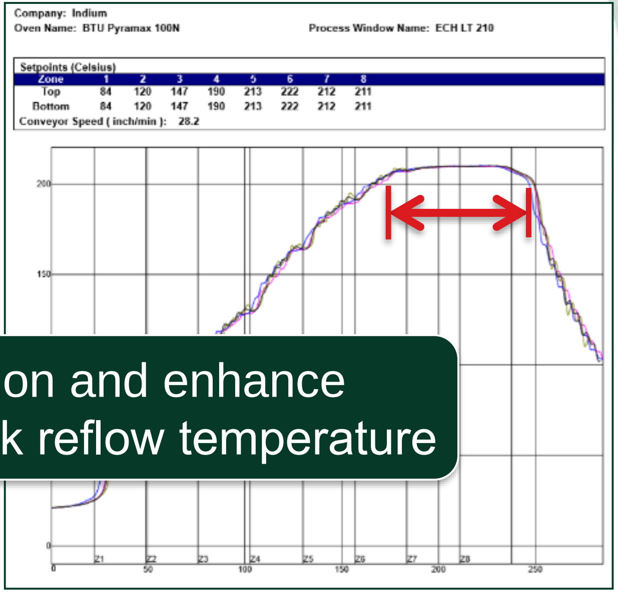
Company: Indium
Oven Name: BTU Pyramax 100N
Process Window Name: ECH LT 205

Setpoints (Celsius)

Zone	1	2	3	4	5	6	7	8
Top	95	135	165	200	207	205	205	208
Bottom	95	135	165	200	207	205	205	208

Conveyor Speed (inch/min): 21.0

Peak Temp: 210˚C
Time @ Peak: 60-70 seconds



Company: Indium
Oven Name: BTU Pyramax 100N
Process Window Name: ECH LT 210

Setpoints (Celsius)

Zone	1	2	3	4	5	6	7	8
Top	84	120	147	190	213	222	212	211
Bottom	84	120	147	190	213	222	212	211

Conveyor Speed (inch/min): 28.2

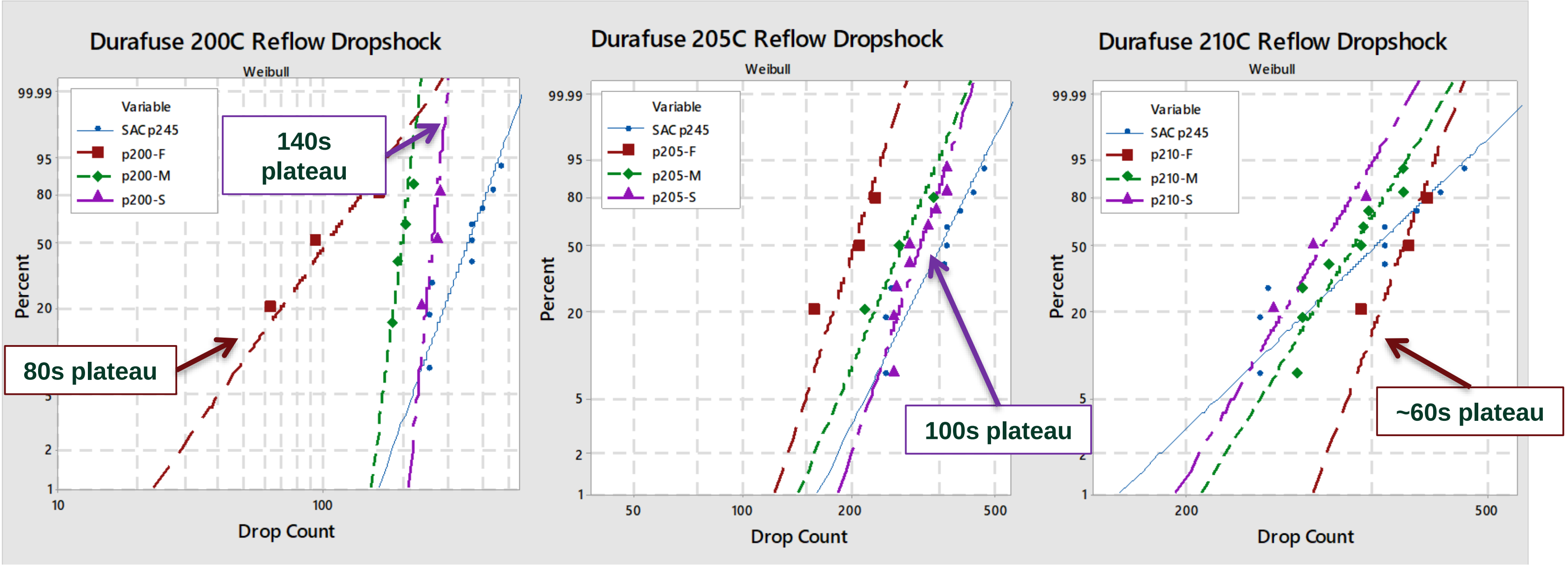
An elongated plateau region can improve fusion and enhance Durafuse™ LT properties when using a lower peak reflow temperature

Fusion Time vs Drop-shock

Depending on peak temperature, time at peak can be used to optimize for drop-shock resilience

Reflow oven belt rate

Fast Medium Slow



140s plateau

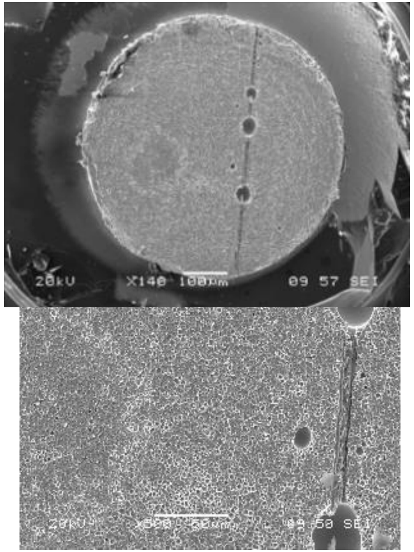
80s plateau

100s plateau

~60s plateau

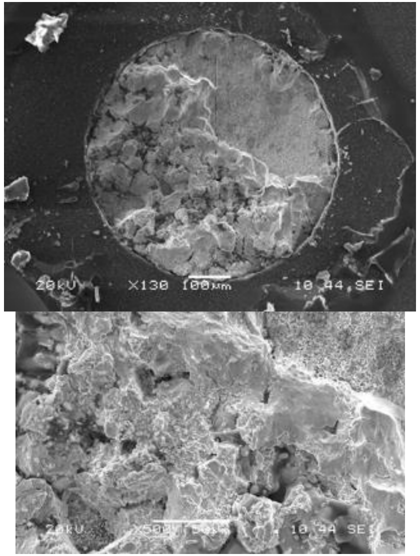
Drop Shock Failure Mode

SAC305



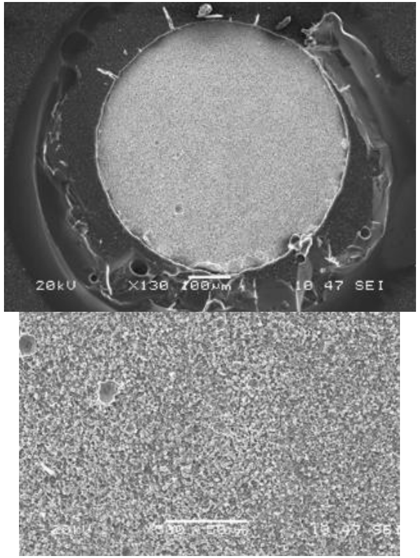
Ruptures within the IMC interface

Durafuse™ LT P200



Solder failure close to PCB side. Grainy surface is exposed. Exposed particles are smooth

Durafuse™ LT P210



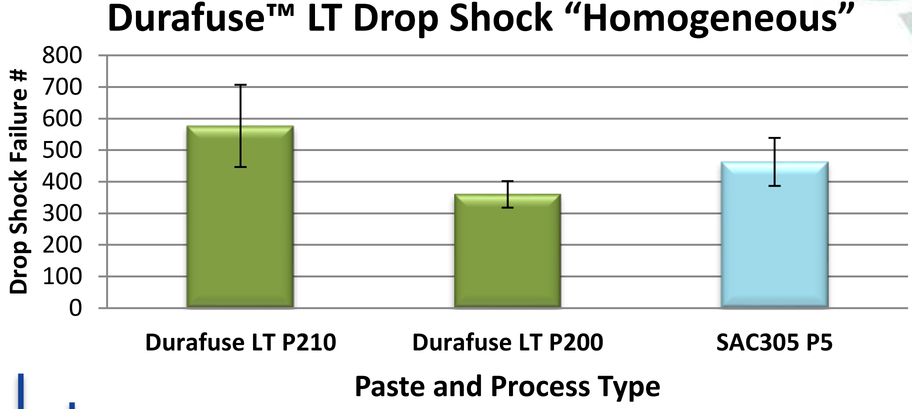
Fails between solder and IMC. Cu_6Sn_5 IMC is exposed. Similar to SAC305.

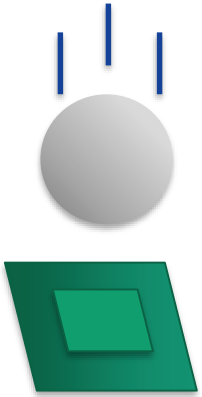
Drop Shock

Durafuse™ LT Solder Paste Only (LGA)

Durafuse™ LT can provide high drop shock performance in a wide array of applications

Performance remains consistent between applications with and without SAC solder balls



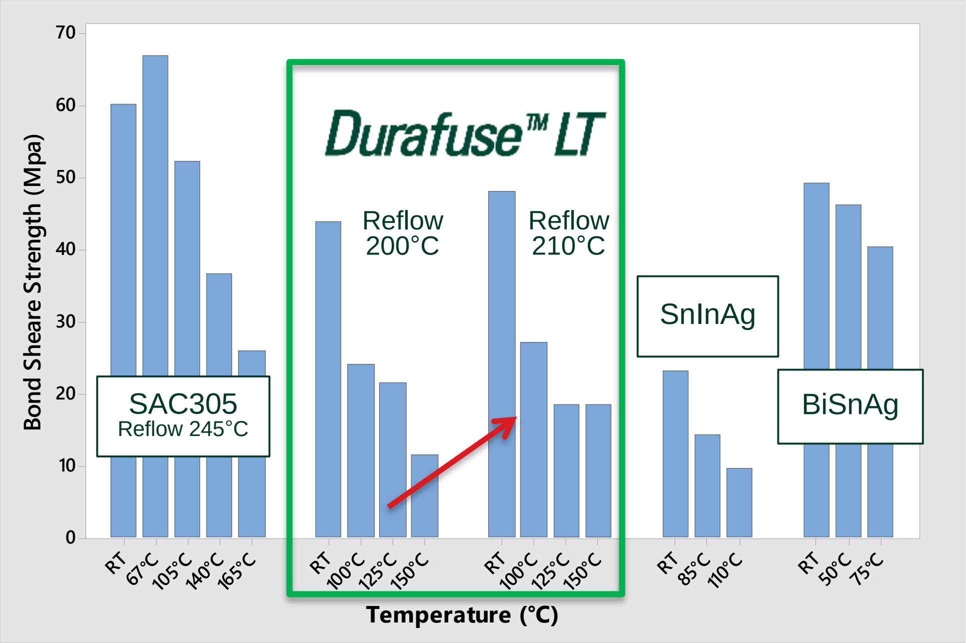


10x10 grid
Pitch 4.5MM

The Durafuse™ LT data above shows paste-only performance. The components used for testing are the same type and dimension as those in previous tests, but with the solder balls removed to turn the BGA into an LGA.

HT Bond Shear Strength

Durafuse™ LT



**Oven belt speed remained unchanged*

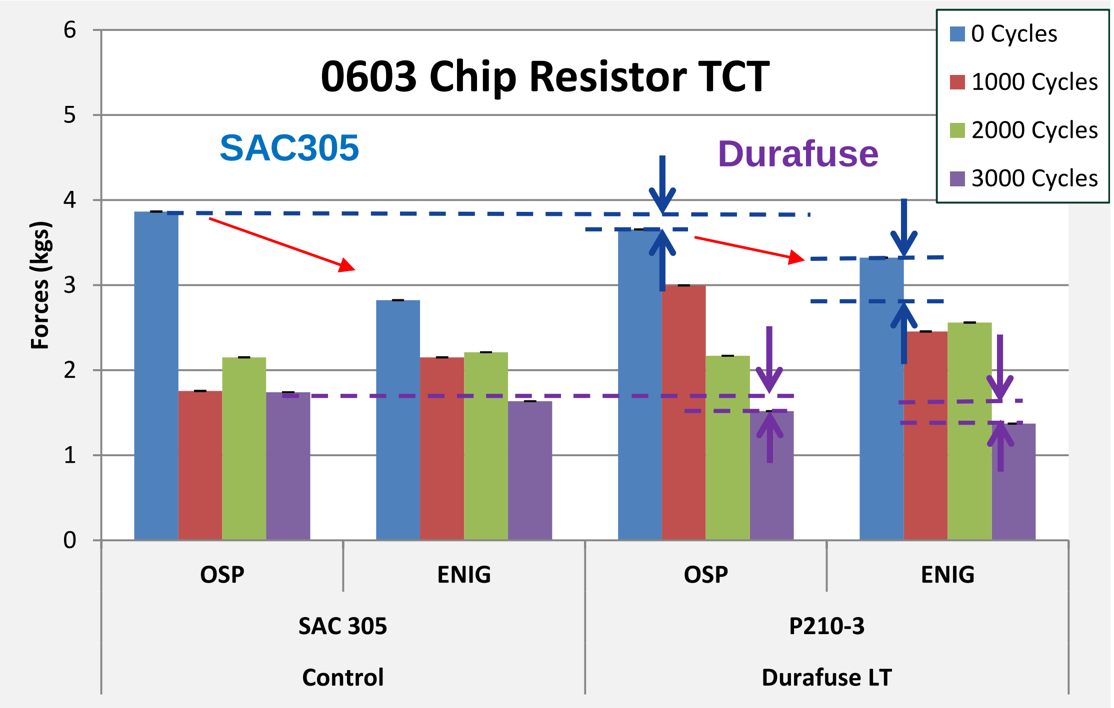
Twice the shear strength of indium based low temperature alloys

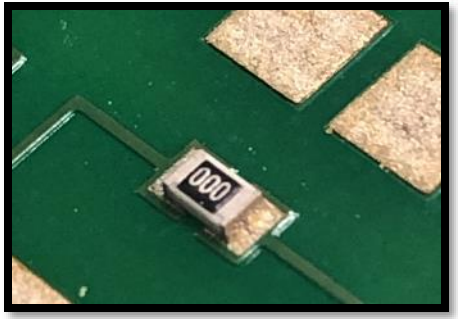
Maintains shear strength at temperatures beyond bismuth and indium alloy capability

Bond shear strength can be enhanced by using a peak reflow temperature of 210°C

Thermal Cycling

0603 Chip Resistors -40/+125 ℃ Shear Strength





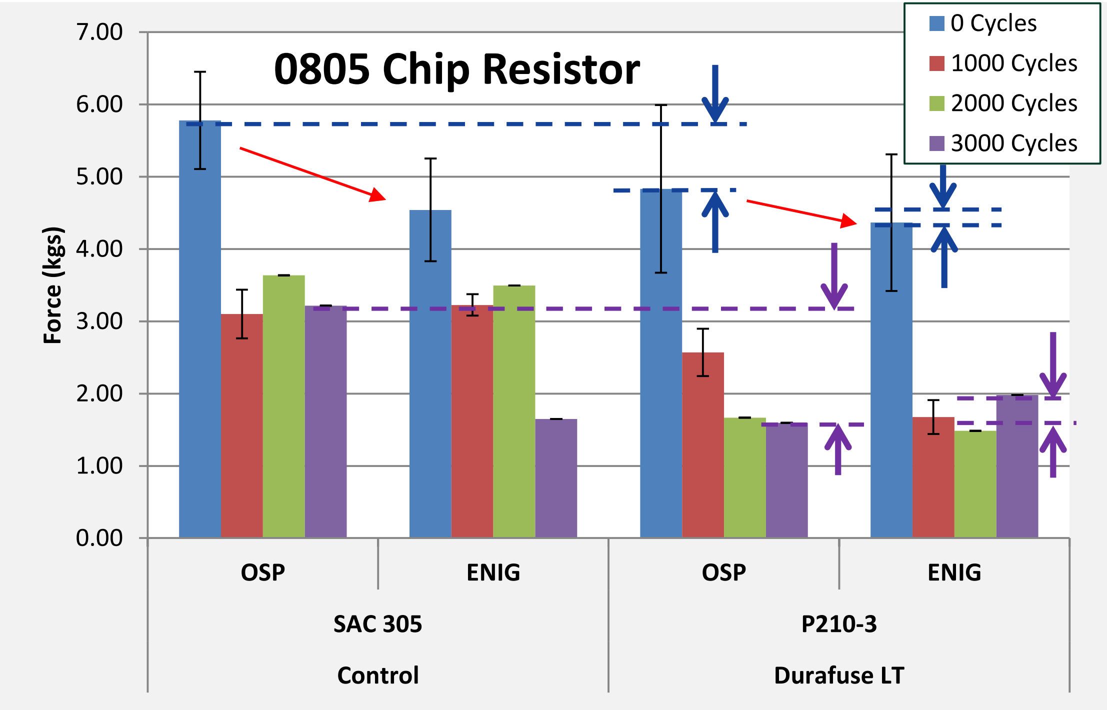
After reflow, SAC is slightly ***stronger*** than or ***comparable*** to DF.

After 3000 cycles, the relative strength of SAC and DF is ***constant***.

OSP has stronger joint than ENIG after reflow

Thermal Cycling

0805 Chip Resistors -40/+125 ℃ Shear Strength



TCT -40/+125℃ with 10min dwell times for 3000 cycles

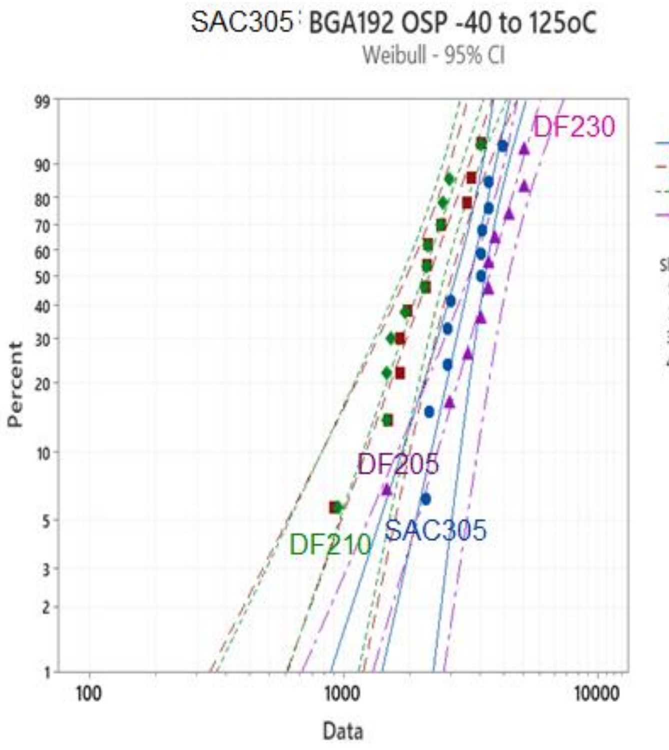
On ***OSP*** SAC has greater shear strength than DR and after 3000 cycles retains that margin

DF is ***comparable*** to than SAC305 for ***ENIG***.

OSP has stronger joints than ENIG after reflow

Thermal Cycling

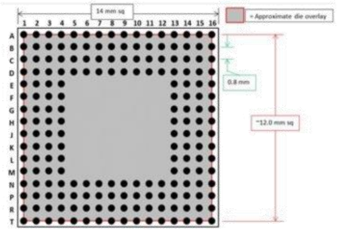
BGA192 -40/+125 ℃ Electrical Failure



Shape	Scale	N	AD	P
5.291	3372	11	0.535	0.164
3.291	2417	12	0.323	>0.250
3.455	2277	12	0.265	>0.250
4.042	4067	10	0.252	>0.250

Test Conditions

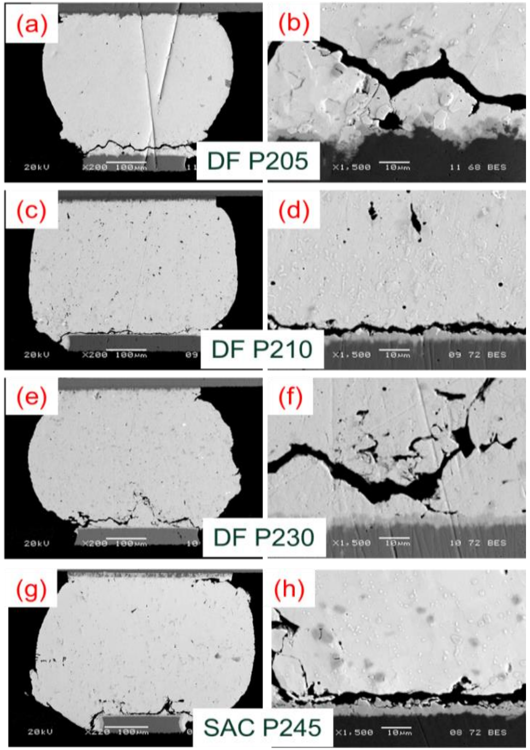
- 14x14mm BGA package
- 12x12mm die
- 0.8mm ball pitch
- 0.46mm ball diameter
- 0.38mm NSMD chip pad diameter
- OSP surface finish
- 127um stencil thickness
- 45min cycle 10min dwell



	Characteristic Life (cycles)
SAC305 P245	3372
Durafuse™ LT P205-S	2417
Durafuse™ LT P210-S	2277
Durafuse™ LT P230	4067

BGA TCT Failure Mechanism

OSP



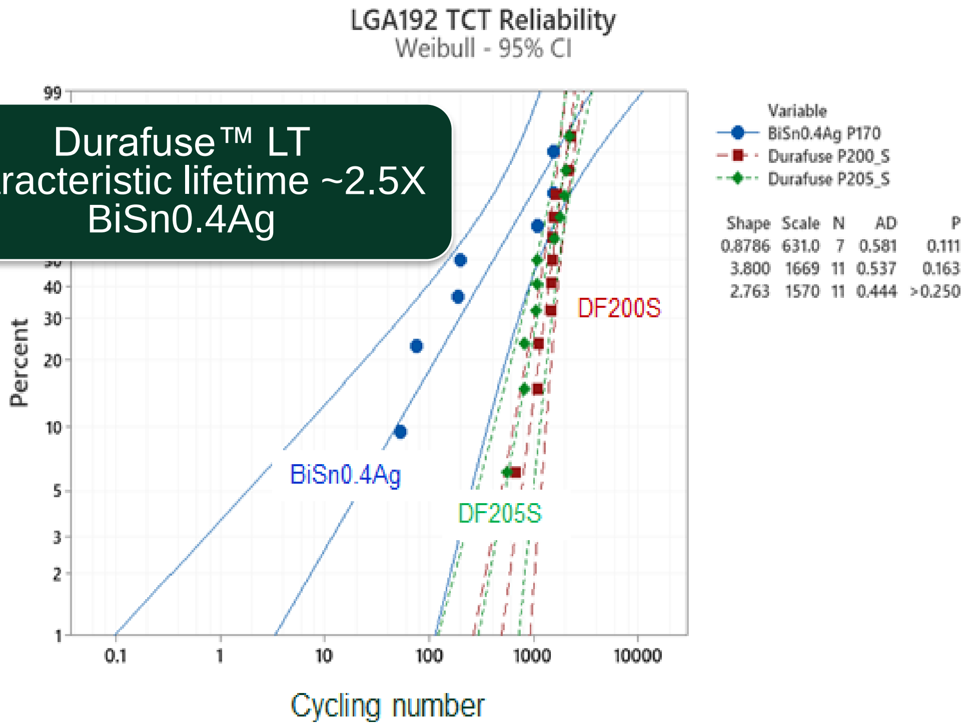
TCT Failure Analysis

- Failure mechanisms typical of thermal fatigue
- Corner joints failed first during TCT
- Most joints cracked near solder/pad interface
- Mixed cracking
  - Along solder and Cu_6Sn_5 IMC boundary and within solder bulk

Elongated plateau at peak temperature enabled spherical joints for all profiles, demonstrating good joint formation

Thermal Cycling

LGA192 -40/+125 ℃ Electrical Failure



Shape	Scale	N	AD	P
0.8786	631.0	7	0.581	0.111
3.800	1669	11	0.537	0.163
2.763	1570	11	0.444	>0.250

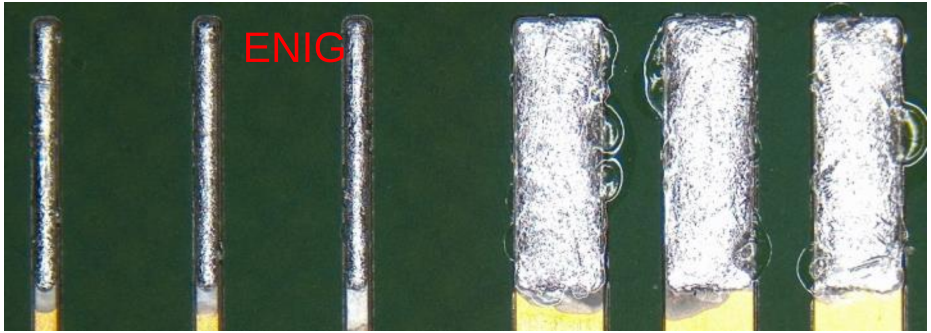
Durafuse™ LT characteristic lifetime ~2.5X BiSn0.4Ag

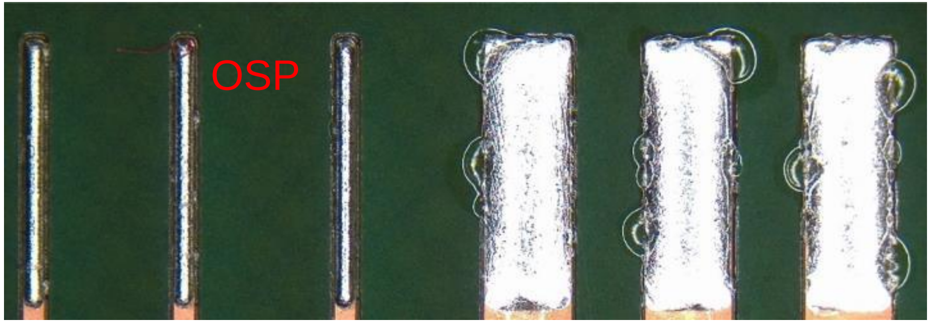
Test Conditions

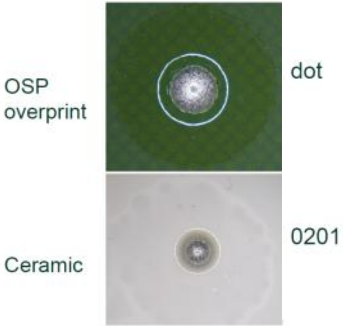
- 14x14mm LGA package
- 12x12mm die
- 0.8mm pad pitch
- 0.38mm chip pad diameter
- ENIG surface finish
- 127um stencil thickness
- 45min cycle 10min dwell

Alloy	Characteristic LIfetime
Durafuse™LT 200 ℃ reflow	1669
Durafuse™LT 205 ℃ reflow	1570
BiSn0.4Ag	631

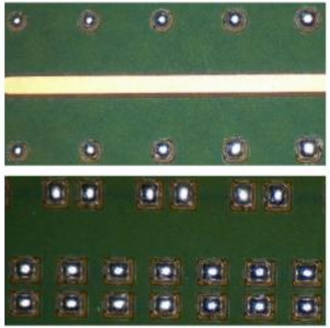
Wetting & Coalescence







Solder Ball



Graping

Excellent wetting graping and solder ball performance on ENIG and OSP surfaces

Mechanical Properties

Durafuse LT (Strain rate: 0.01 s^{-1})		
Elastic Modulus	Gpa	53.6
Yield Strength	Mpa	53
Tensile Strength	Mpa	72
Elongation to Fracture	%	22.71
Specific Heat (@25 ℃)	J/g K	0.1157

Methodology

Bulk Material Behavior

Anisotropic

Elastic Plastic

Strain Rate Dependent

Characteristic Geometry

Matched Microstructure:
- Grain Size (~single crystal)
- Intermetallics

Durafuse™ LT Print Testing

Print testing
Continuous Print Test (20 boards)
Response to Pause

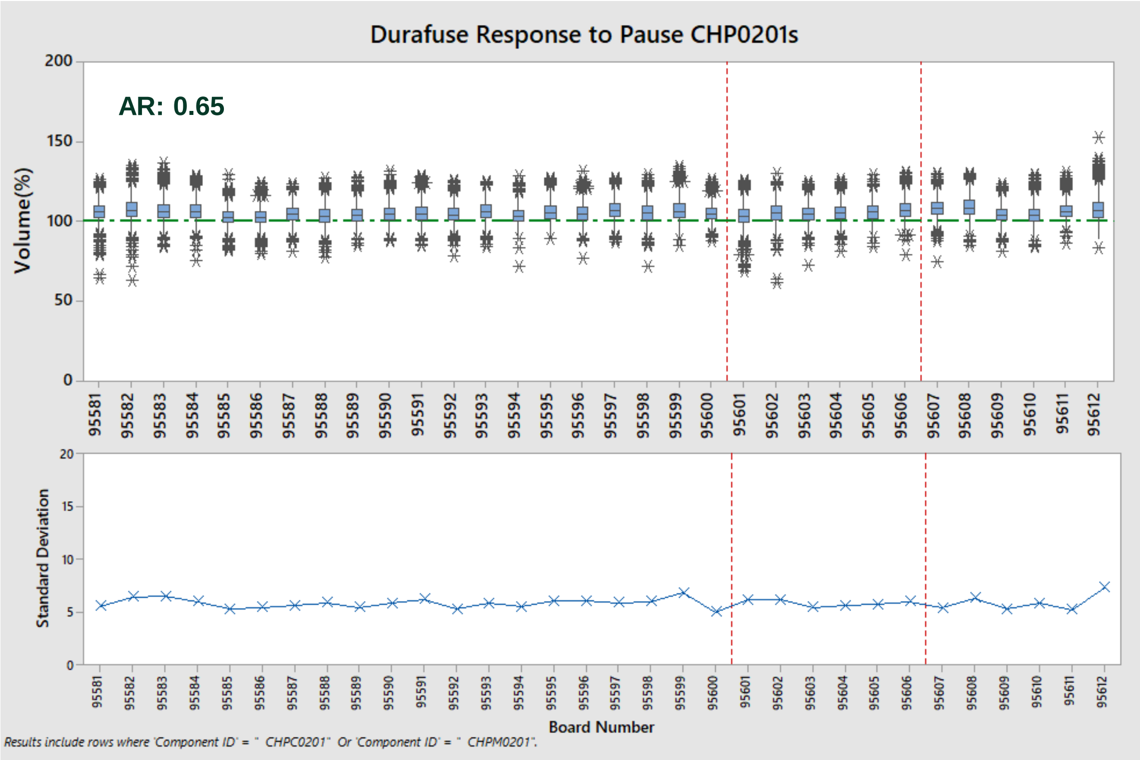
Response to Pause Procedure
Continuous Print 20 boards
Wipe Stencil
Pause 1hr
Wipe Stencil
Print 6 boards
Wipe Stencil
Print 6 boards

Print Settings

- Type 4 powder in 5.7LT-1
- Pressure 8.6Kg
- Speed 50mm/s
- 4mil stencil

Response To Pause

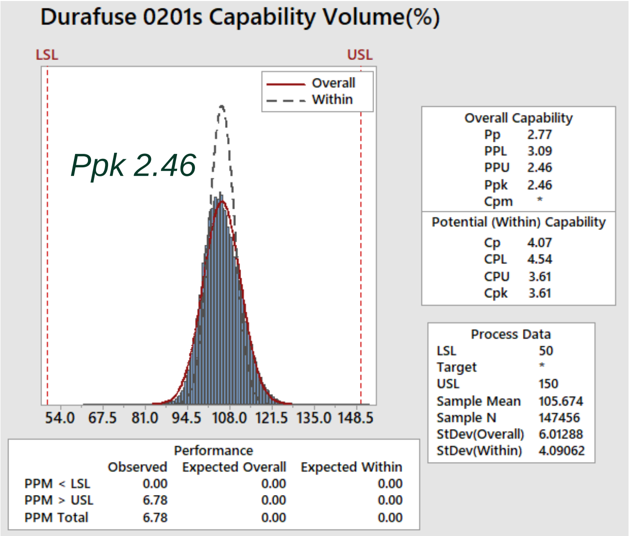
Component: 0201 Chip Resistors



Durafuse Response to Pause CHP0201s

AR: 0.65

Results include rows where 'Component ID' = " CHPC0201" Or 'Component ID' = " CHPM0201".



Durafuse 0201s Capability Volume(%)

Ppk 2.46

Overall Capability	
Pp	2.77
PPL	3.09
PPU	2.46
Ppk	2.46
Cpm	*
Potential (Within) Capability	
Cp	4.07
CPL	4.54
CPU	3.61
Cpk	3.61

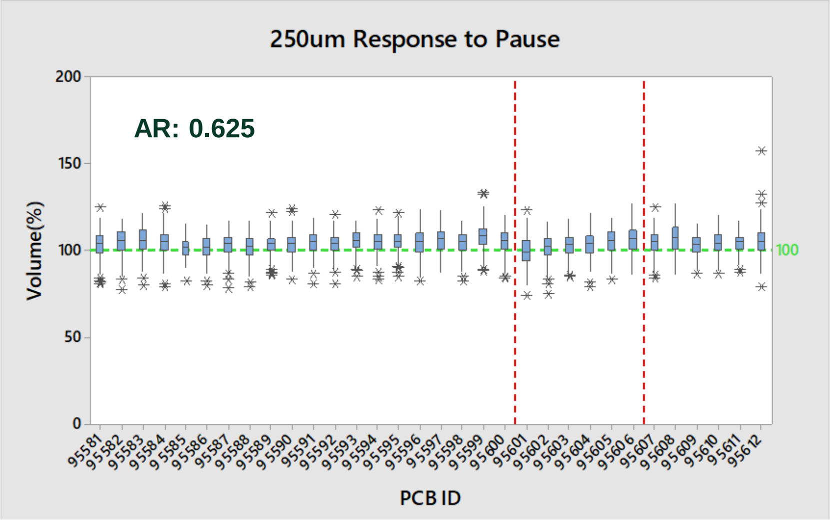
Process Data	
LSL	50
Target	*
USL	150
Sample Mean	105.674
Sample N	147456
StDev(Overall)	6.01288
StDev(Within)	4.09062

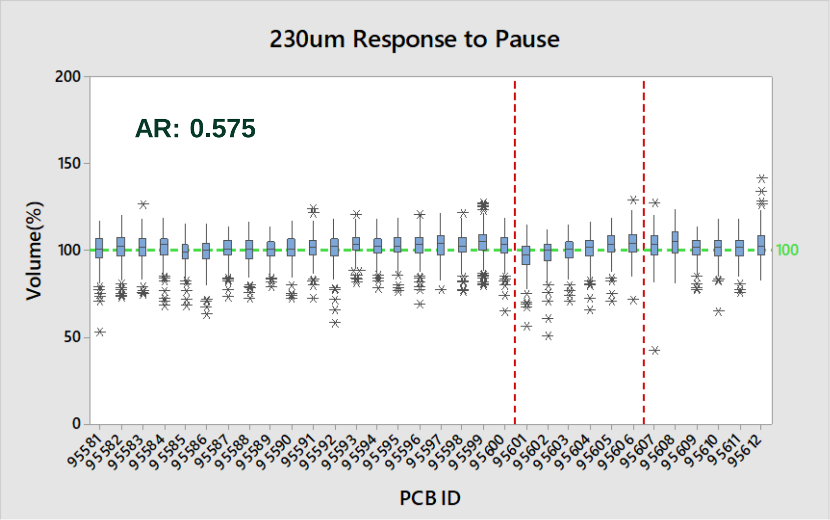
Performance

	Observed	Expected Overall	Expected Within
PPM < LSL	0.00	0.00	0.00
PPM > USL	6.78	0.00	0.00
PPM Total	6.78	0.00	0.00

**High transfer efficiency & low variation*
**Outstanding continuous printing*
**Excellent response to pause*

Paste RTP vs Aperture Size

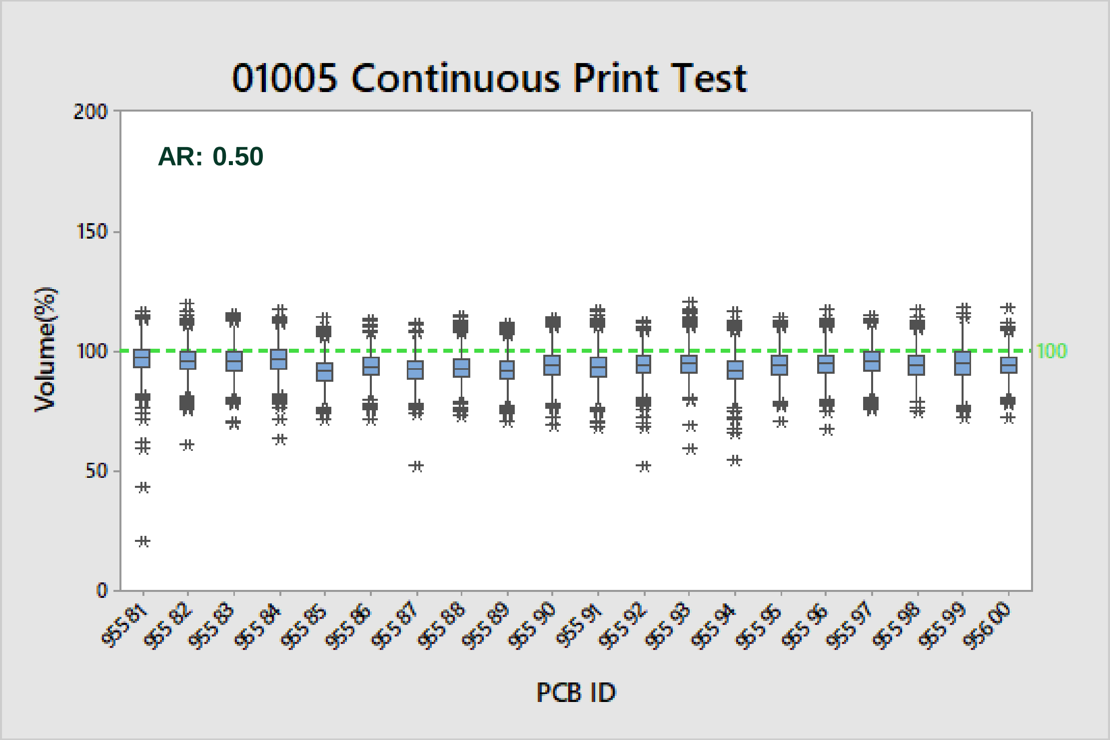




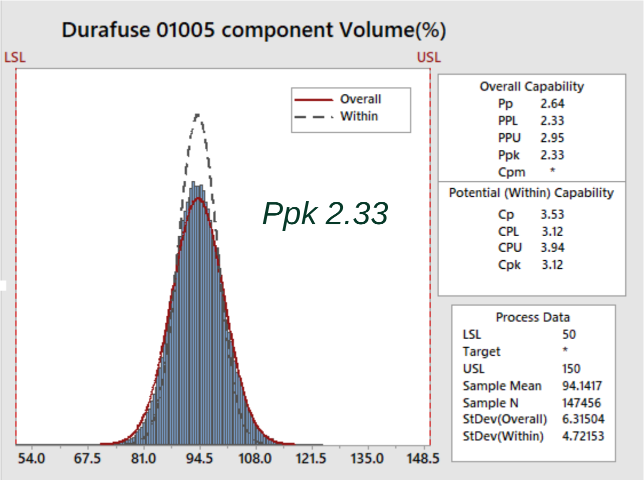
Durafuse™ LT retained good response to pause performance after transitioning from 0.635 area ratio to 0.575 area ratio apertures

**Aperture shape: Square*
**Both solder mask defined and non-solder mask defined components*

01005 Continuous Print Test



Although Durafuse™ LT T4 powder performed exceptionally well, T5-MC powders are generally recommended for printing 01005s



Overall Capability	
Pp	2.64
PPL	2.33
PPU	2.95
Ppk	2.33
Cpm	*

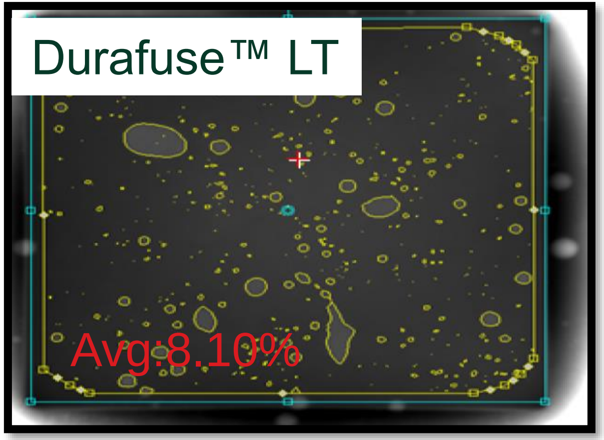
Potential (Within) Capability	
Cp	3.53
CPL	3.12
CPU	3.94
Cpk	3.12

Process Data	
LSL	50
Target	*
USL	150
Sample Mean	94.1417
Sample N	147456
StDev(Overall)	6.31504
StDev(Within)	4.72153

Durafuse™ LT Voiding

Cu/Cu assembly

Sample No	Total Void %	Largest Void %
1	12.61	1.24
2	6.10	0.94
3	6.97	0.55
4	11.76	0.89
5	7.09	2.07
6	4.08	0.63
7	8.06	0.72
8	8.15	1.35
Avg	**8.10%**	
Std	**2.83%**	



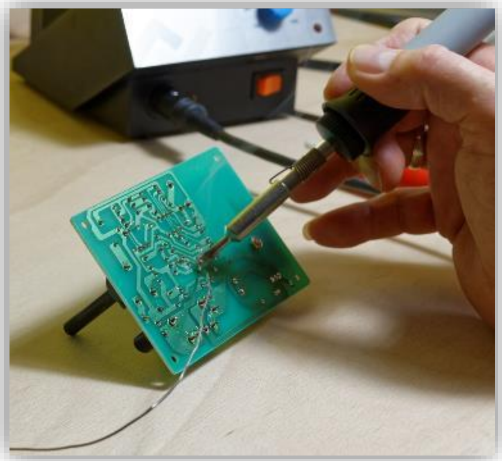
Voiding X-ray prepared using a Cu/Cu assembly and Durafuse™ LT

Rework

Rework is a necessary consideration for many SMT processes

Rework reattachment options

- Durafuse™ LT
  - Dispensable paste
  - Same reflow as printed Durafuse™ LT
- SAC305
  - Localized heating avoids damage to sensitive components
- Indalloy®254
  - Available as wire, liquidus 205℃
- Indalloy®227
  - Available as wire, liquidus 187℃



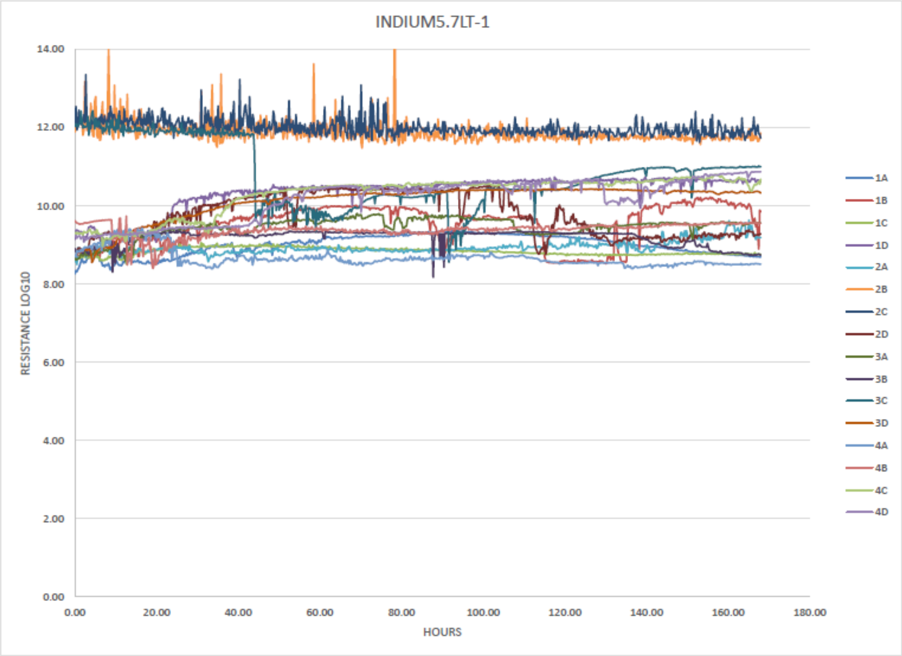
On Durafuse™ LT boards we recommend reaching above 206℃ for easiest component removal

Flux Reliability

3rd Party SIR testing IPC-TM-650 Test Method: 2.6.3.7

PASS

5.7LT-1 was designed for quality performance in low temperature applications



Durafuse™ LT

- **High drop-shock reliability**
  - Reflow profile optimizable
- Proven flux vehicle: Indium5.7LT-1
- T4 and T5-MC powder samples are available

Key Strengths:

Low Temperature reflow

- Reduce reflow temperature 40-50°C

High drop shock resilience

- Matches SAC305 capability
- Orders of magnitude superior to bismuth alloys

Shear Strength

- Joint shear strength retained even at elevated temperatures

Step-soldering enhancement

- Solidus above Bi-alloy reflow temperature
- Peak reflow temperature below SAC solidus

Thank You

Classic Low Temperature Solders

- **Bismuth Based**
  - Indalloy #281 (58Bi/42Sn) 138˚C
  - Indalloy #282 (57Bi/42Sn/1Ag) 139-140˚C
  - **Indalloy #283 (57.6Sn/42Sn/0.4Ag) 139-144˚C**
- **Indium Based**
  - Indalloy #1E (52In/48Sn) 118˚C
  - Indalloy #290 (97In/3Ag) 143˚C
  - Indalloy #4 (100In) 157˚C
  - **Indalloy #227 (77.2Sn/20In/2.8Ag) 175-187˚C**
  - Indalloy #254 (86.9Sn/10In/3.1Ag) 204-205˚C
- **Flux Vehicle:**
  - **Current Preferred Option: Indium5.7LT-1:** Offers better solder beading and solder balling performance that Indium5.7LT
  - **Other Options: Indium5.7LT & NC-SMQ80**

INDIUM CORPORATION

PRODUCT DATA SHEET

Low Temperature Solder

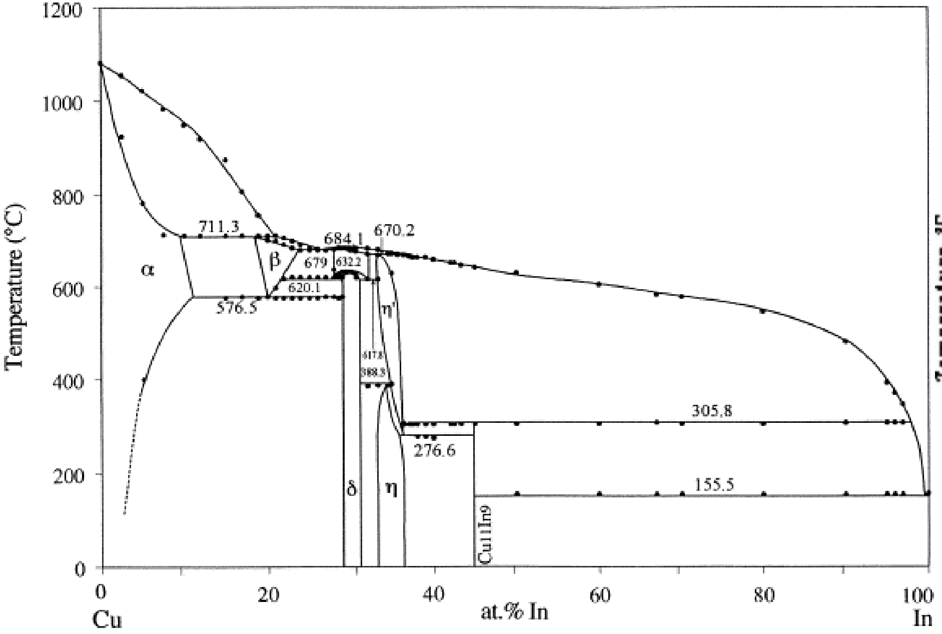
Introduction

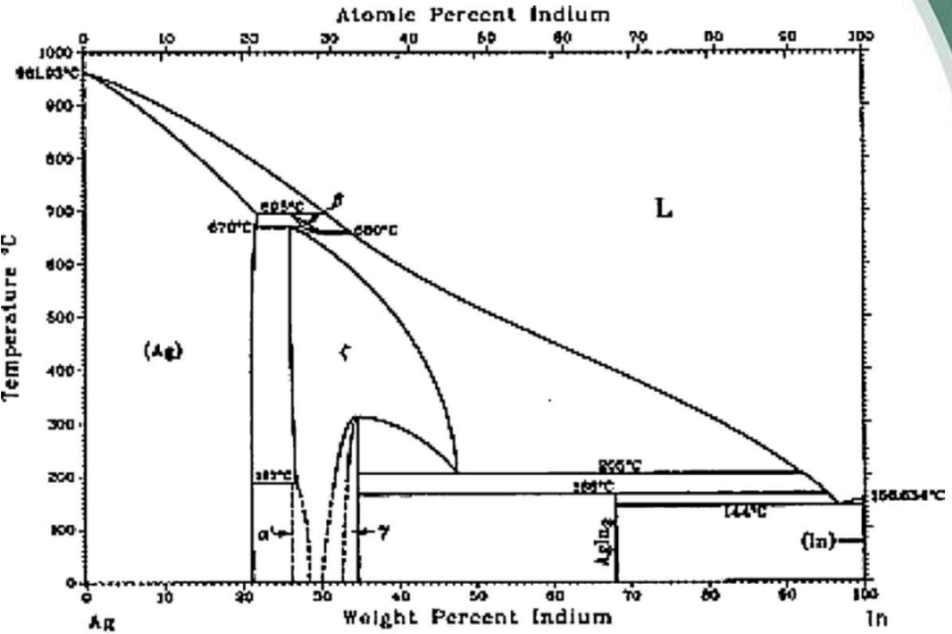
Indium-Containing Solder

Bismuth-Containing Solder

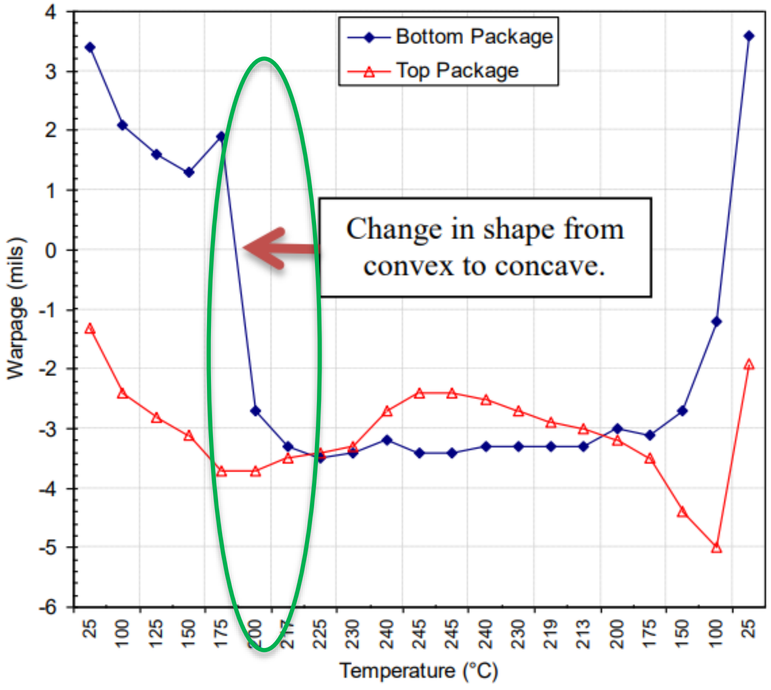
Solder Forms

Additional Phase Diagrams





Thermal Warpage



Change in shape from convex to concave.

Figure 4. Warpage of bottom PoP device is approximately 89microns (3.5mils)

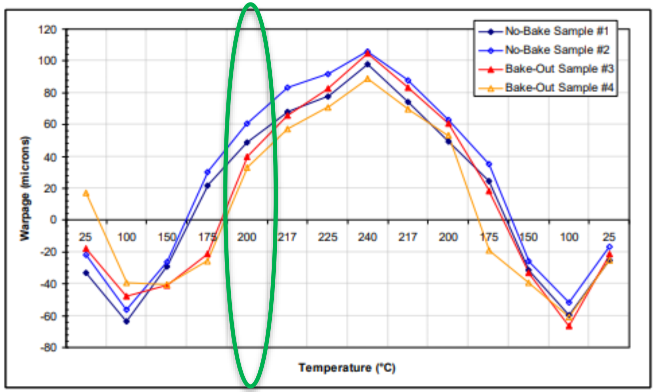


Figure 6. Maximum warpage was 100microns well below the allowable limit for a 1mm pitch device.

Dr. Anselm SMTAI 2014

"Most components warp suddenly when a T_g of a material is reached, when moisture evolves at 100°C or for any of a host of other reasons"