Are You Cool Enough for Low Temperature Solders?

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Agenda

- Low Temperature Solder Alloys (Lead-Free)
  - Sn/Bi57/X (138-140 °C) and Sn/BiX/+X (138-174 °C)
  - Alloy Ingredients and Phase Diagrams
  - Microstructure Properties
- Applications for Low Temp Alloys
- Assembly Process
  - Reflow Profiles
  - Soldering SAC305 BGAs with Low Temp Solders
  - Hand Soldering, Rework & Other Processes
- Concerns
- Advantages & Disadvantages of Low Temp Alloys
- Summary and Questions

Low Temperature Solders

What is Low Temperature?

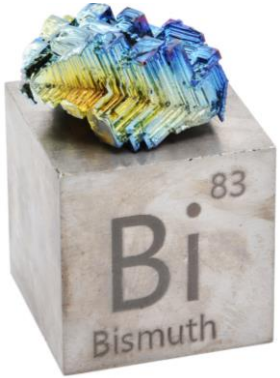
- Commonly defined as having a peak reflow temperature < 200 °C
- SAC305 has a peak reflow ~245 °C
- Sn/Pb37 has a peak reflow ~215 °C

Low Temperature Solder Alloys

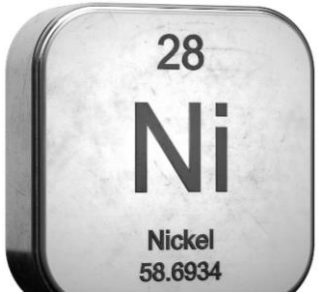
Solder Alloy	Composition (% wt)	Melting Range (°C)
Sn/Pb	Sn63/Pb37 or Sn62/Pb36/Ag2	179 - 183
SAC305	Sn96.5/Ag3.0/Cu0.5	217 - 220
Tin-Bismuth	Sn/Bi58 or Sn/Bi/Ag0.4-1.0	138 - 140
Proprietary Alloy 1	Sn/Bi/X	138 - 151
Proprietary Alloy 2	Sn/Bi/X	Peak reflow < 150
Proprietary Alloy 3	Sn/Bi37/X	139 - 174
Sn/Bi40	Sn60/Bi40	138 - 170
Sn/In52	Sn48/In52	118
Sn34/Bi46/Pb20	Sn34/Bi46/Pb20	96

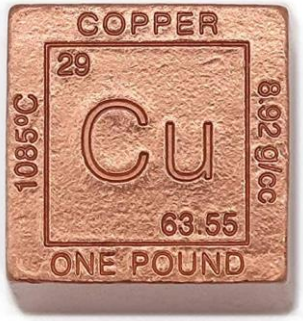
Alloy Ingredients

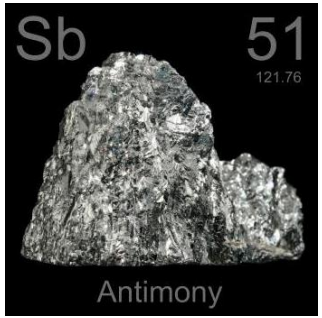
M.P. Reducers



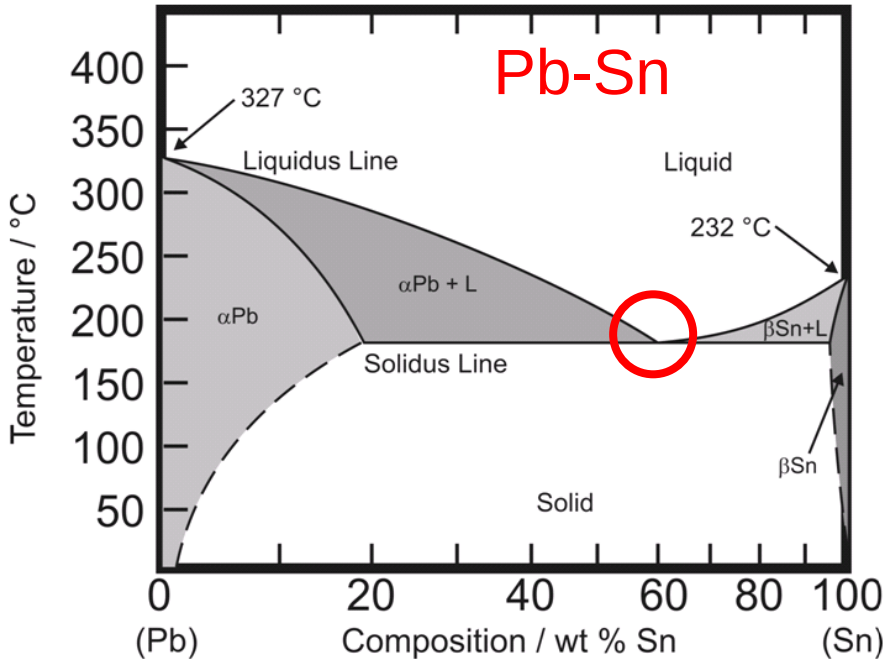
Strengtheners



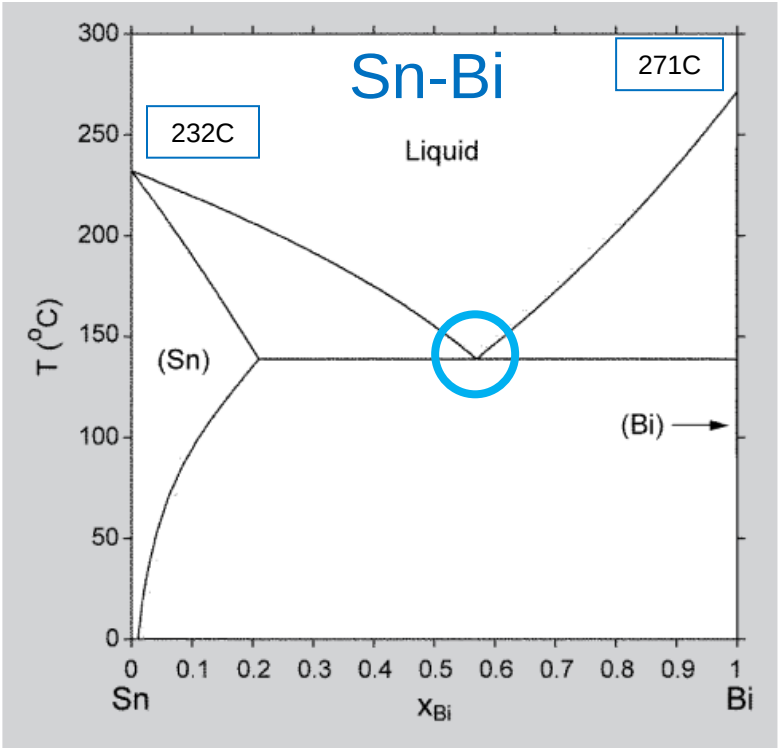




Phase Diagrams

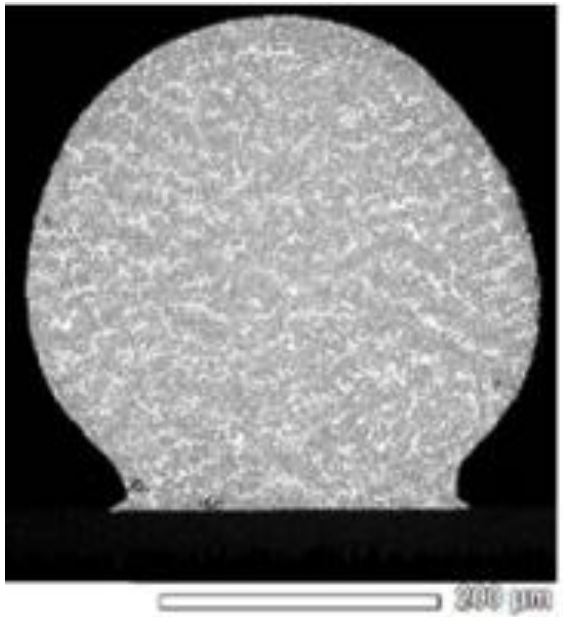


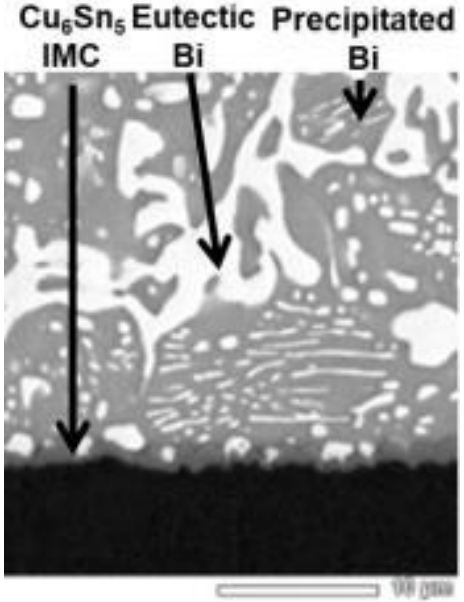
Eutectic m.p. 183C



Eutectic m.p. 138C

Solder Microstructure - Bi

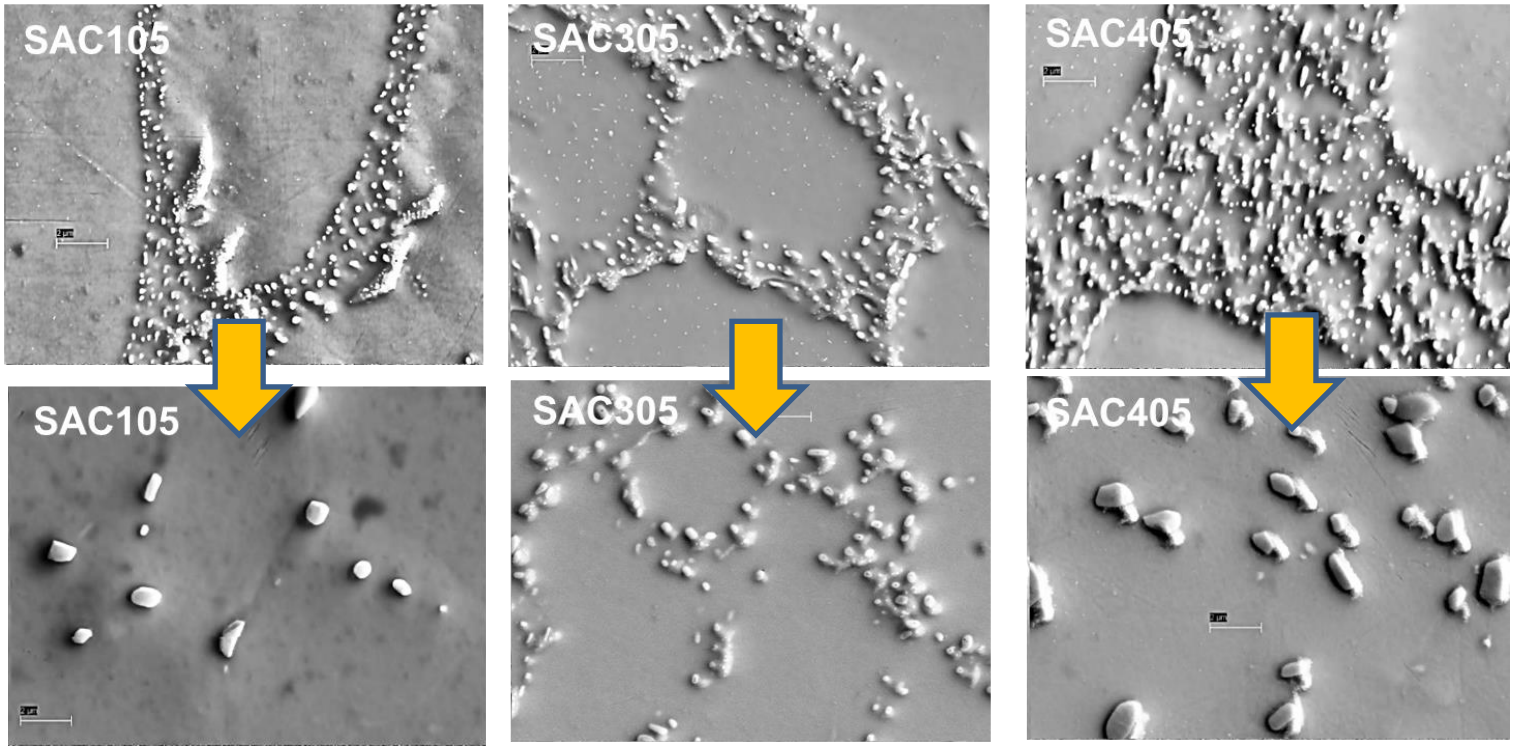




Microstructure of reflowed Sn/Bi37/X

*SMTAI 2019. Sweatman, “OPTIMIZING SOLDER ALLOY COMPOSITION FOR LOW TEMPERATURE ASSEMBLY”

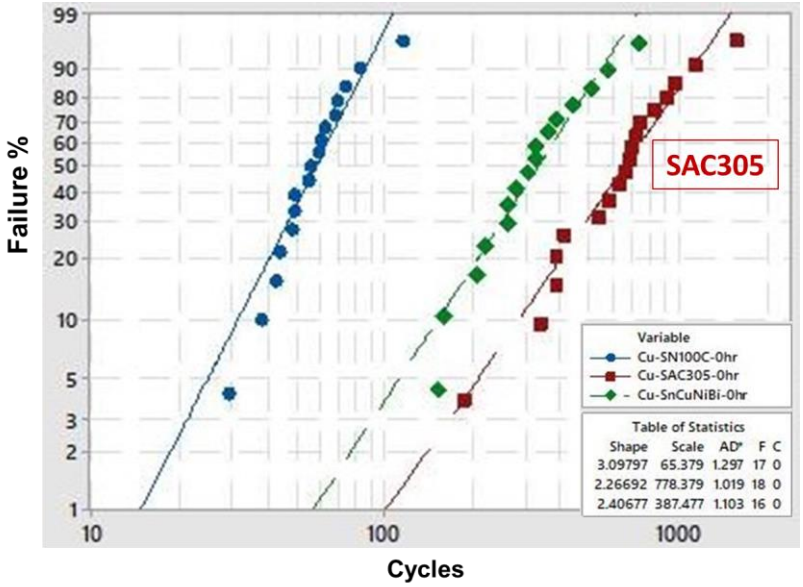
Solder Microstructure - Ag



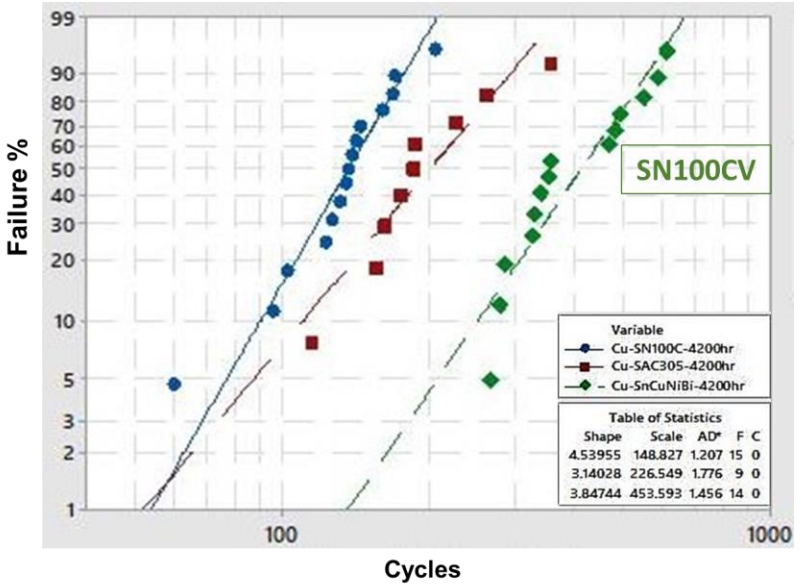
After 2520hrs @125C

Ag_3Sn particles coarsen

Solder Microstructure - Ag



Cu Substrate
As Soldered



Cu Substrate
4200 hrs 125C

Applications

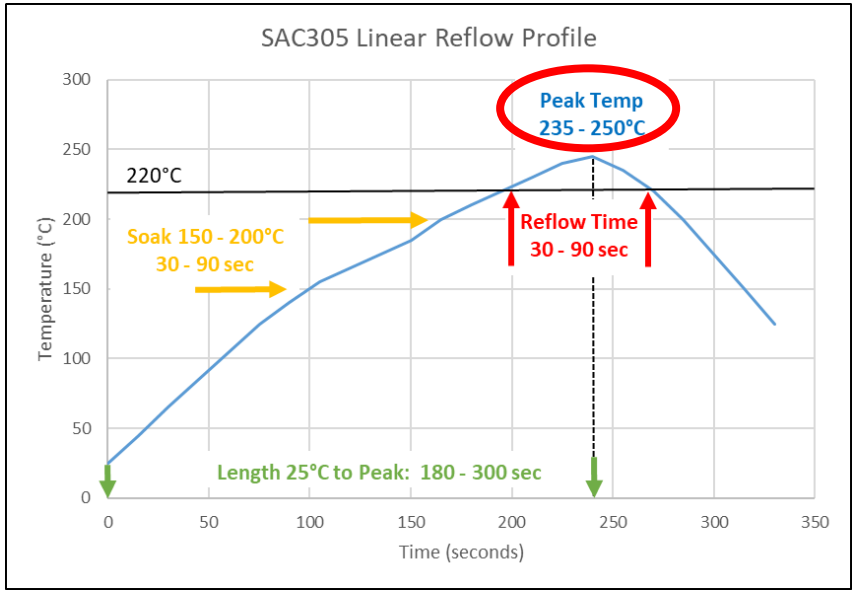
Applications for Low Temp Solders

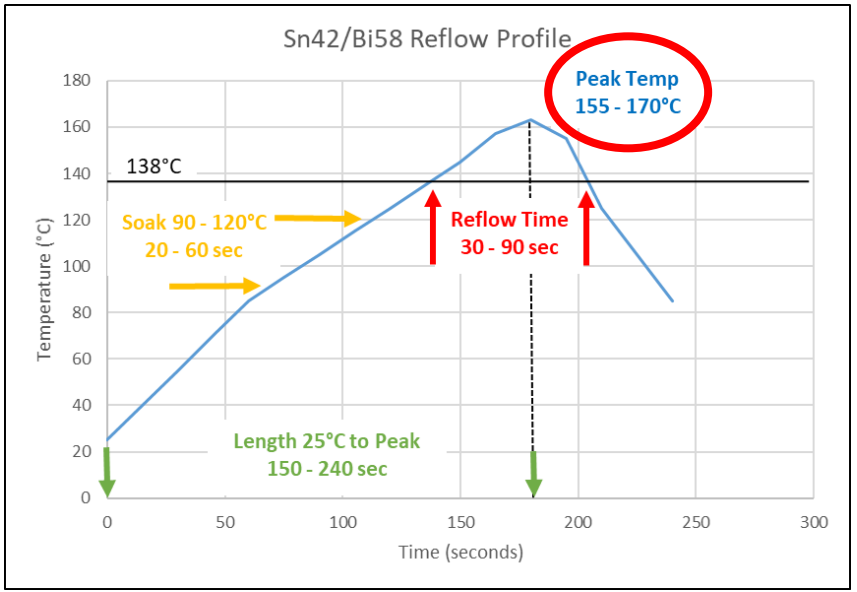
Applications for Low Temp Solders

- Operating temp max < 130°C
- Low potential for drop shock & vibration
  - Underfill & encapsulation help but add $$
  - Difficulty of reworking BGAs & BTCs
- Class 1 and 2 Products with “Short” expected life

Assembly Process

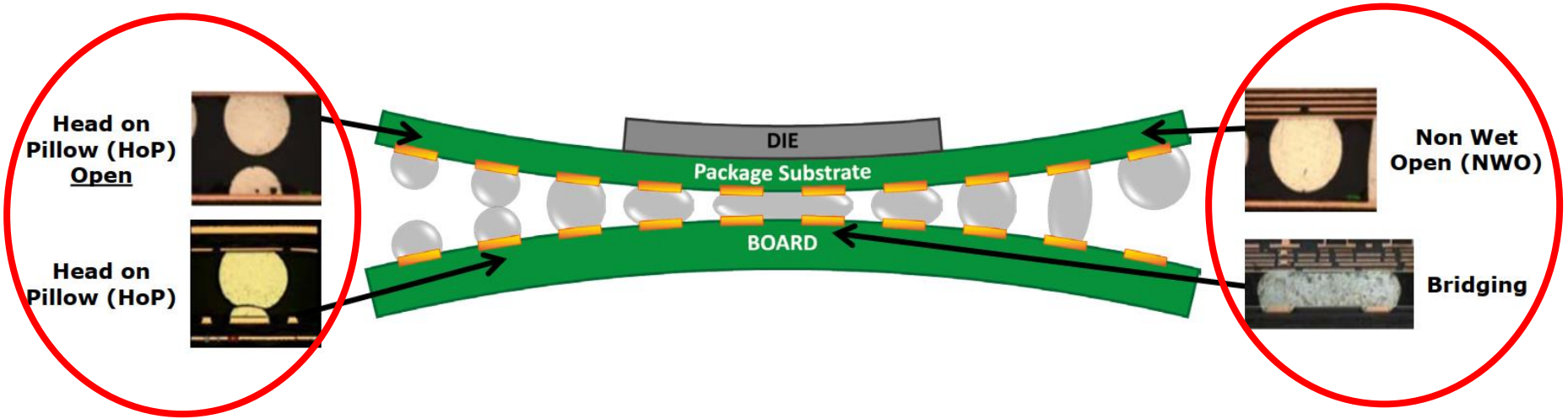
Assembly Process - Reflow





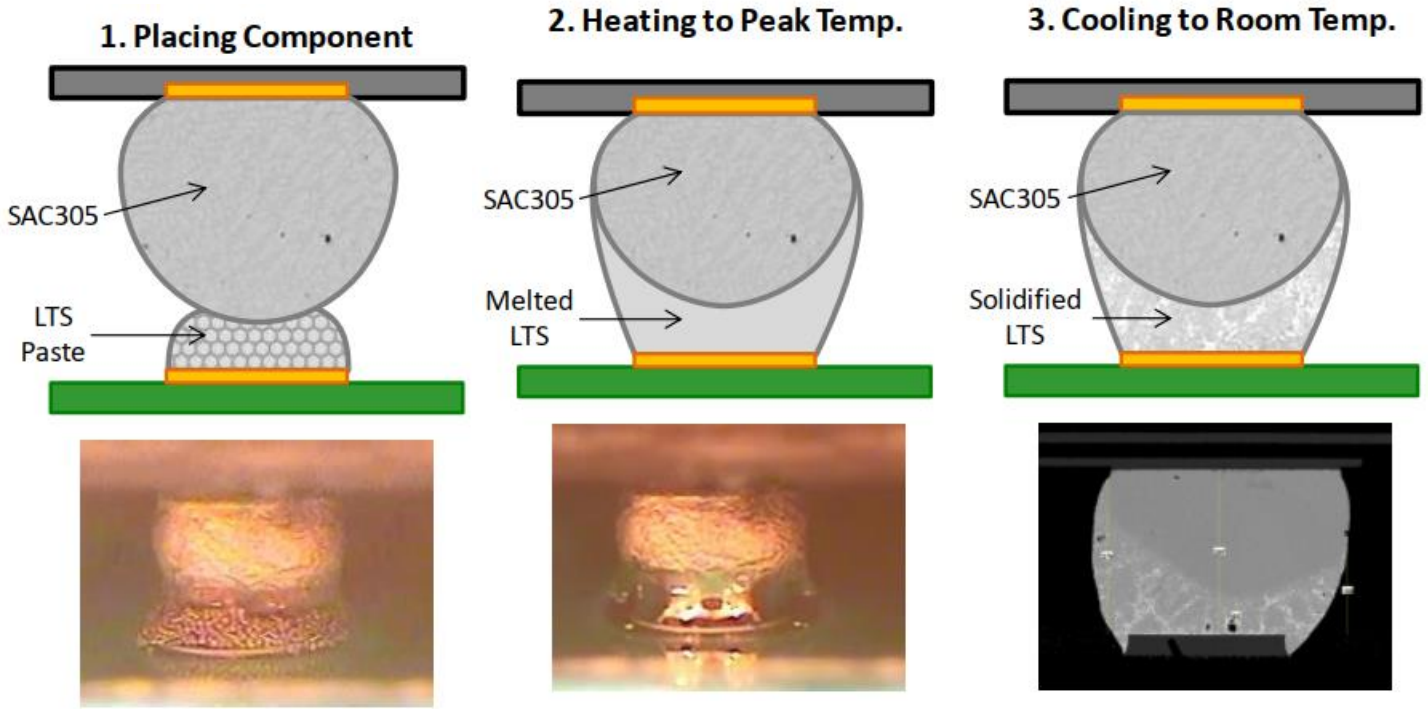
Peak temperature 80C cooler, and time in the oven 60 seconds shorter.

Assembly Process – HoP & NWO



*IPC APEX 2019. Tseng, “New Generation, Low-Temperature Lead-Free Solder for SMT Assembly”

Mixed Metal BGA & LT Solder Paste



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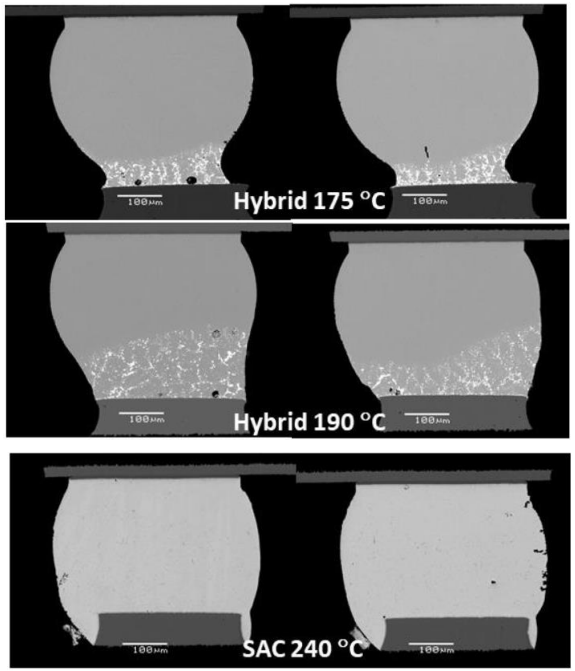
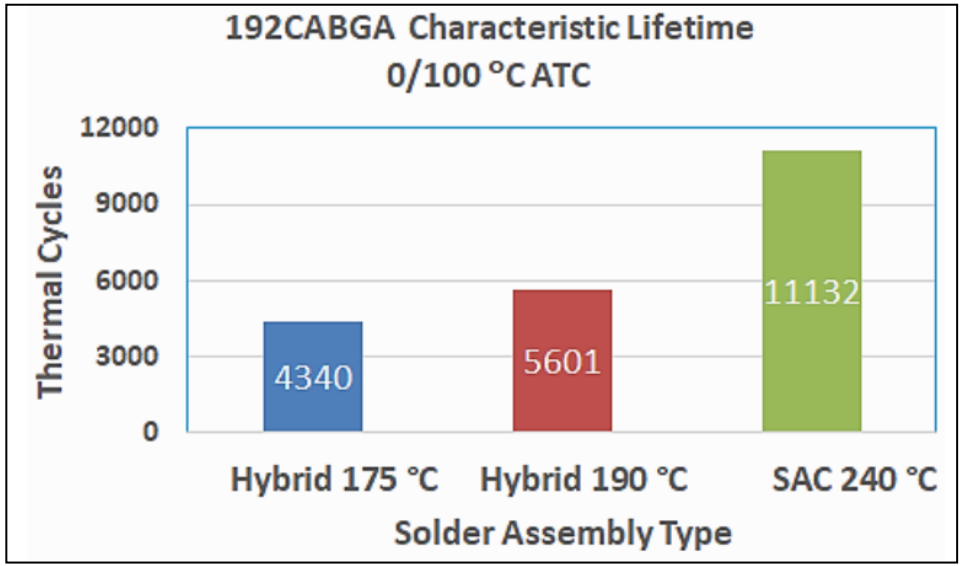


~13% Mixing

~30% Mixing

100% Mixing



*SMTAI 2021. Coyle, “The Effect of Peak Reflow Temperature on Thermal Cycling Performance and Failure Mode of Low Temperature Hybrid Solder Joints”

Hand Soldering & Rework

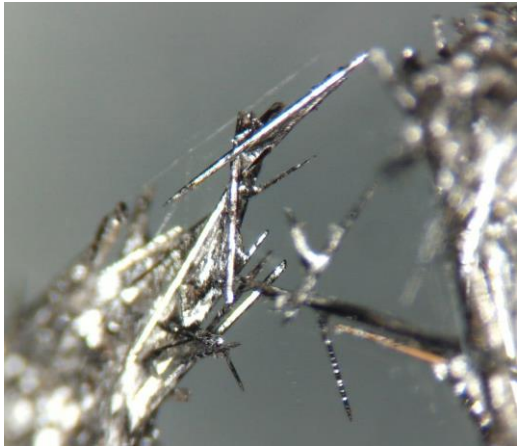
- Hand Soldering
  - LTS joint requires less heat
    - Iron temp 290°C vs. 390°C
  - Sn/Bi57/Ag available as solid wire
    - Limited sources of flux core
  - Other alloys of wire not available
  - Fluxes for this?

Hand Soldering & Rework

- Rework
  - LTS BGA rework at 190-200°C
  - Mixing LTS joints with SAC305 wire
  - Rework SAC305 BGA with nearby LTS
    - Local printing of LTS paste & possible preforms
  - LTS oxides & wetting?

Selective Soldering

- LTS usable but challenging
- High levels of additives may cause dross $(Cu,Ni)_6Sn_5$ “needles”
- Clogged nozzles from oxidation and dross
- Nitrogen use is key

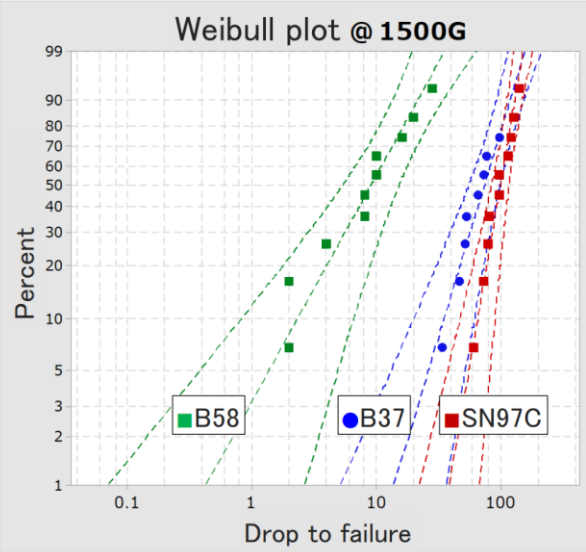


*IPC APEX 2022. Diepstraten, “Solder Alloy Contribution to Robust Selective Soldering Process”

Concerns

Concerns – SnBi Brittleness

- Poor mechanical shock & fatigue
  - Reducing Bi & additives improve this



Drop to failure

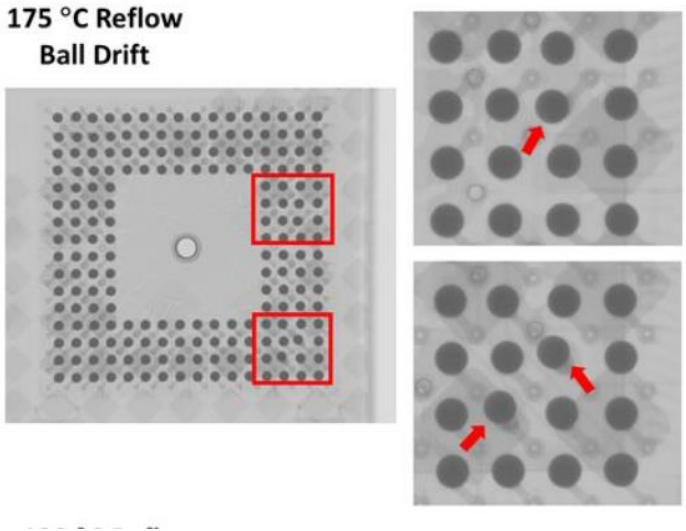
Alloy	N=1～10									
Sn/Bi58	2	2	4	8	8	10	10	16	20	28
Sn/Bi37/X	34	46	52	53	66	73	78	99	12[illegible]	137
SAC305	60	73	80	81	97	99	114	120	129	141

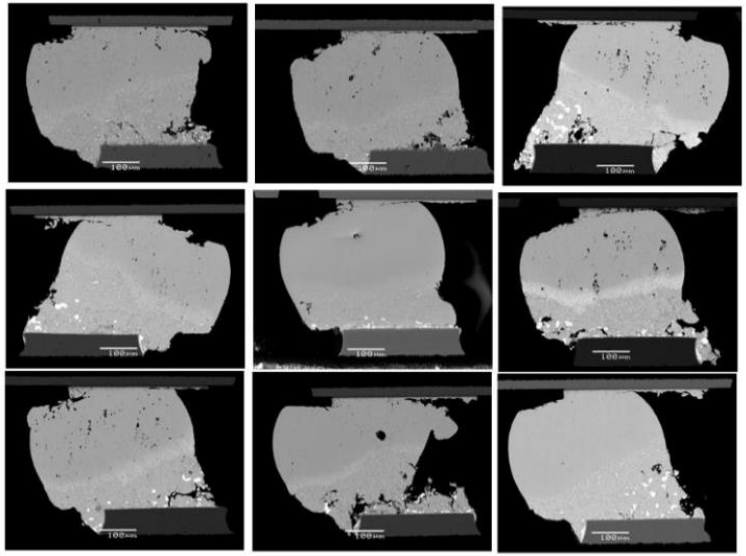
Characteristic life

Alloy	Characteristic life ※Weibull、63.2%
Sn/Bi58	11.9
Sn/Bi37/X	86.5
SAC305	109.1

Concerns – Hybrid SAC305 & LTS Ball Drift

- Ball drift seen during thermal cycling





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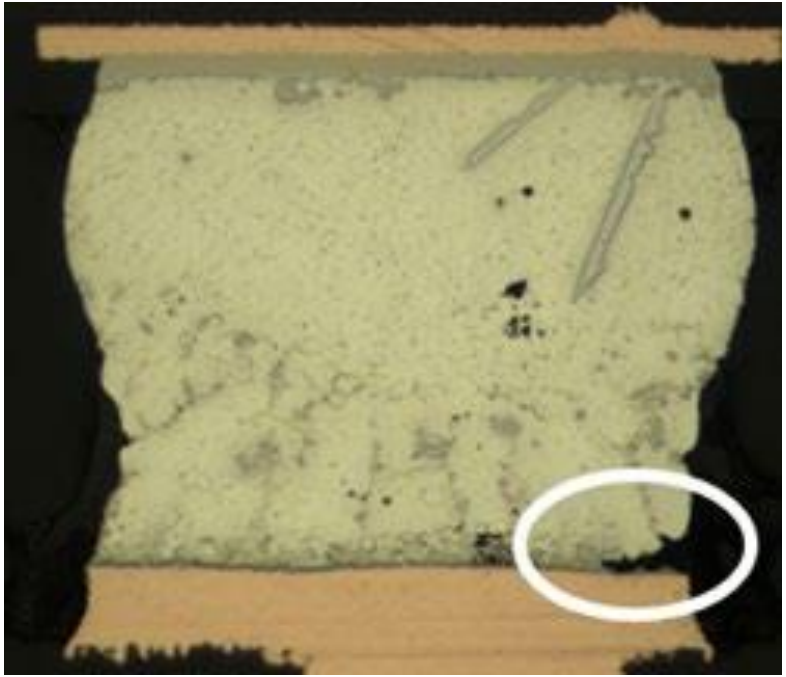
Concerns – Hybrid SAC305 & LTS Hot Tear



- Caused by warpage + slow wetting on the PCB pad
- Smaller BGA's
- Related to Non wet opens (NWO)
- Increased paste volume & reduced peak temp help

*SMTAI 2019. Harris, "ROOT CAUSE AND SOLUTION TO MITIGATE THE HOT TEAR DEFECT MODE IN HYBRID SAC-LOW TEMPERATURE SOLDER JOINTS"

Advantages & Disadvantages

Advantages of Low Temp Solder

- Energy savings
- Less thermal damage
- Lower warpage of boards & components
  - Less HiP/HoP and NWO
- Use of temperature sensitive devices
- Eliminate re-melting of 1st SMT

Disadvantages of Low Temp Solder

- Sn/Bi58 solders can be brittle
  - Sn/Bi + X additives increase ductility
- Sn/Bi solders expand during freezing
- Sn/Bi + Pb mixture very low melting (96°C)
- Sn/In solders can be costly
  - Indium ~ $110 / lb. Bismuth ~ $4 / lb.
- Rework SAC305 BGA with nearby Sn/Bi

Summary

Summary

- Sn/Bi/X solders have reliability approaching SAC305
- Cost savings from energy usage & improved yields
- Concerns about rework & hand soldering
- Concerns about hybrid SAC305 & LTS solder joints

Thank You!

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