Voiding Mechanism and Control in Mixed Solder Alloy System

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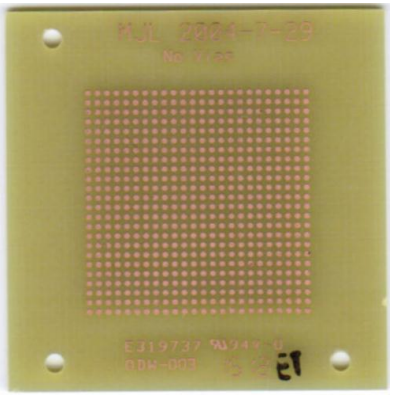
Introduction

- Transition to Pb-free soldering is incomplete for high reliability or high temperature applications
- For those not fully converted into Pb-free, mixed system is common due to lack of some Pb-containing components
- Mixed system encountered voiding problem, particularly for BGA applications
- Miniaturization aggravate vulnerability of device toward voiding
- Unravel voiding mechanism of mixed system critical for DFR for solder joints

Experimental

- Solder Materials
  - Ball Mounting Flux – Indium 446-AL water soluble flux
  - Solder Spheres (25 mils diam.)
    - Sn62, Sn63, SAC105, SAC305
  - Solder Pastes (type 3)
    - Sn62, Sn63, SAC105, SAC305

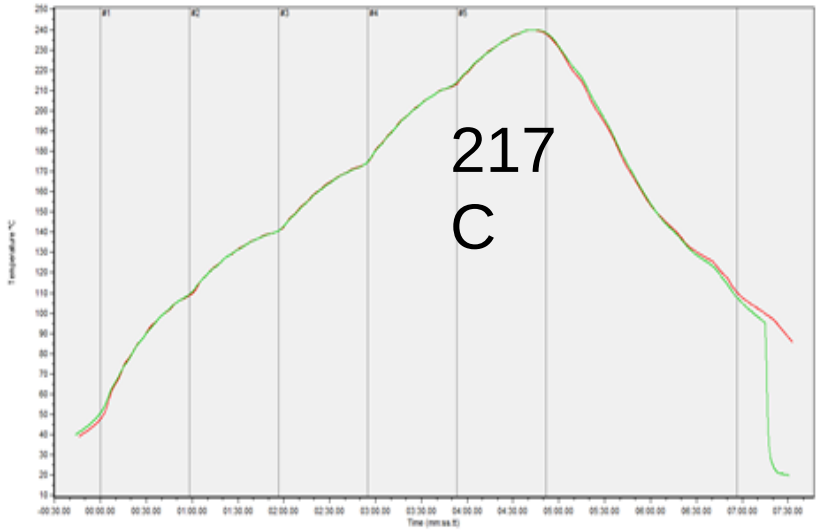
Experimental



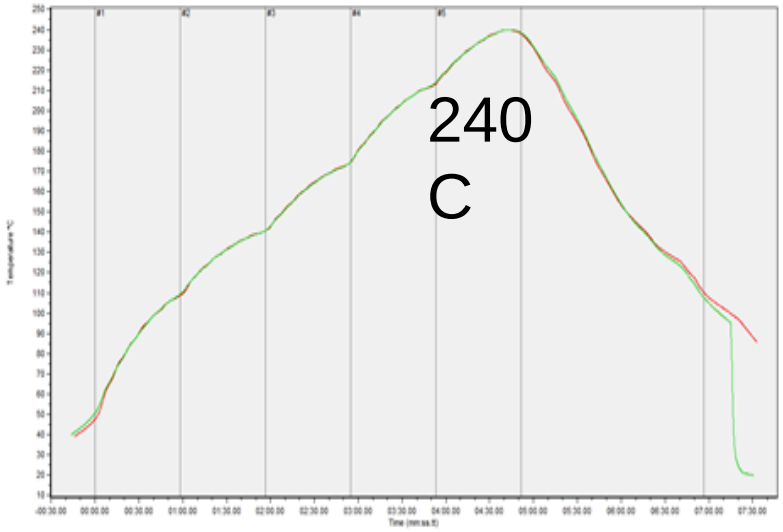
- BGA & BGA Assembly
  - Substrate
    - A 1.6” x 1.6” FR4 coupon with a centered 24 x 24 grid of OSP coated Cu pads used as simulated BGA substrate & for BGA assembly. Pad size was 25 mil with a 40 mil pitch
  - BGA ball mounting
    - Print flux, place ball, reflow at LT (217C peak) or HT (240C peak), water clean
  - BGA assembly
    - Print paste, place BGA, reflow at LT or HT under N2

Experimental

- Characterization
  - X-ray for voiding
  - Cross-section when needed
  - DSC for joint melting range
    - Print paste dot on ceramic coupon, place ball, reflow with LT or HT under N2, then run DSC up to 300°C.

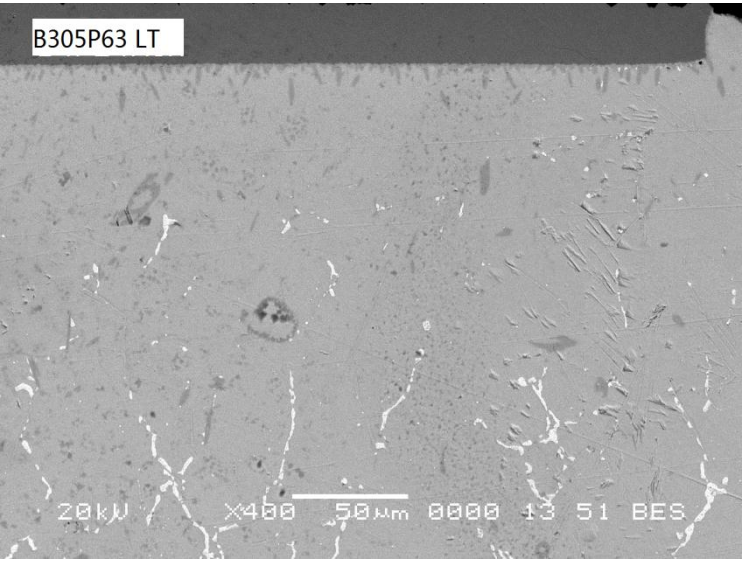


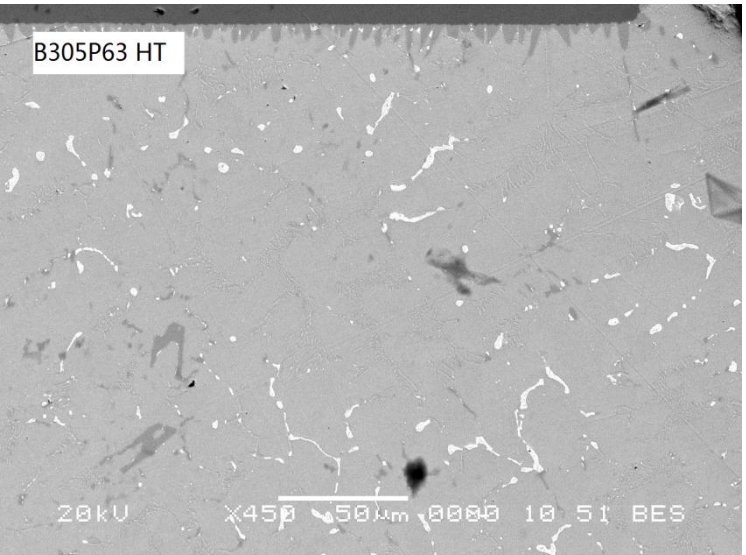
LT

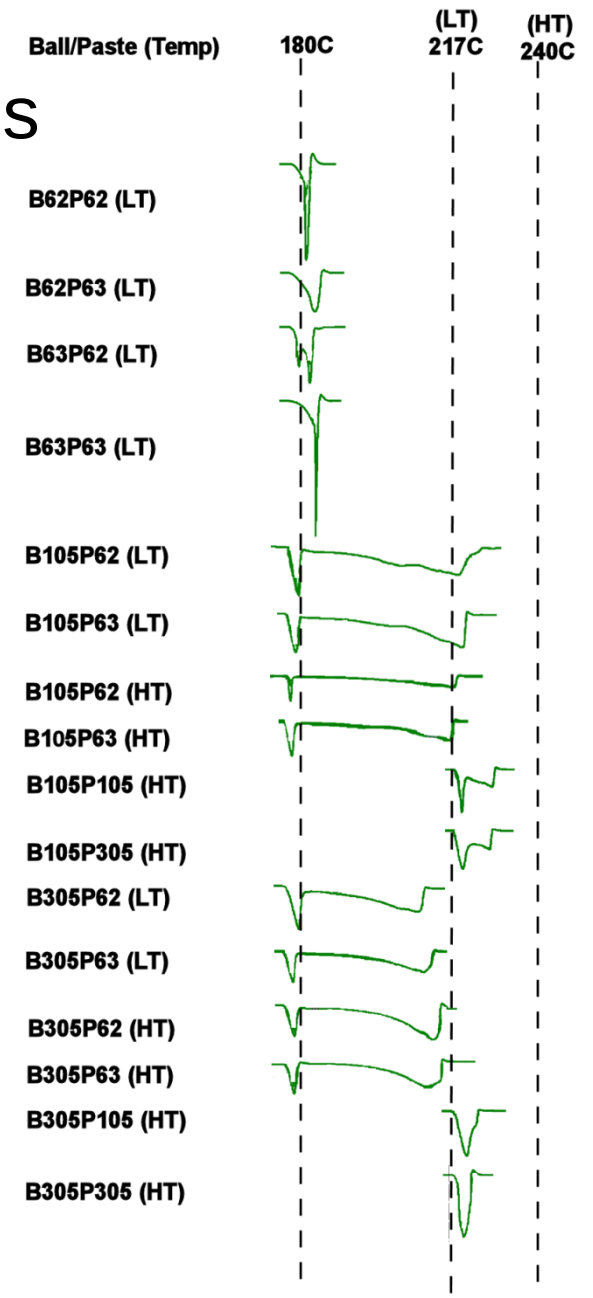


HT

DSC Results & Cross-Section Examples

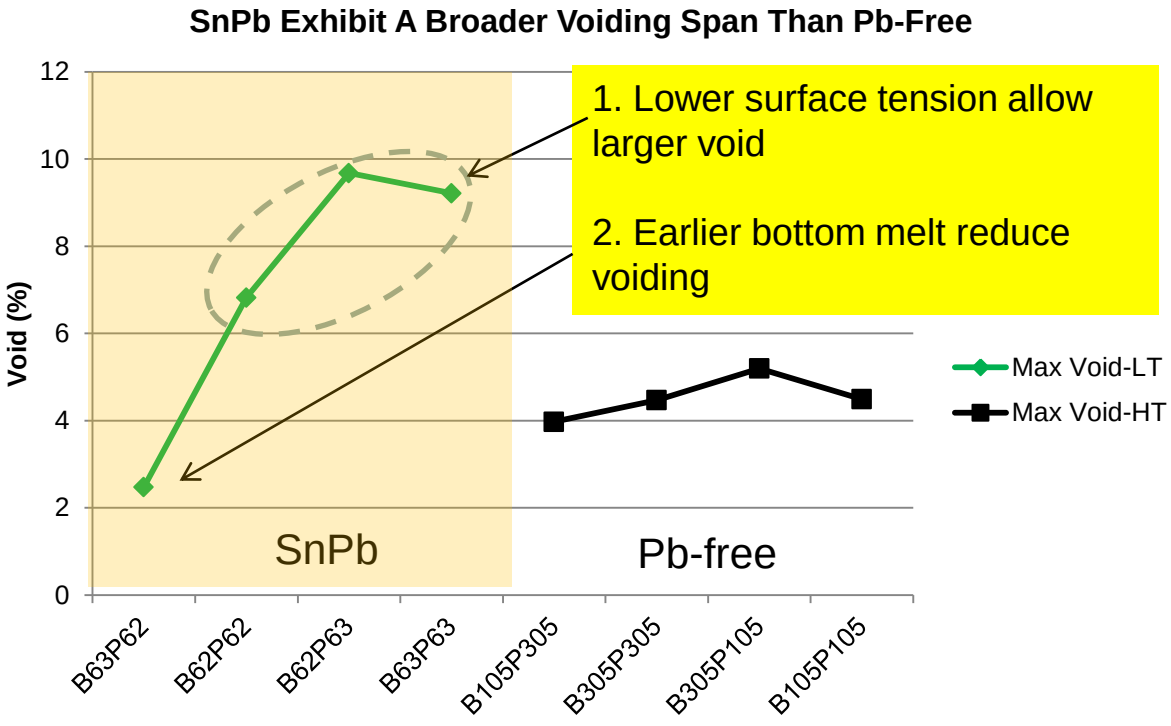






Low Surface Tension & Early Bottom Melt Cause Wide Span

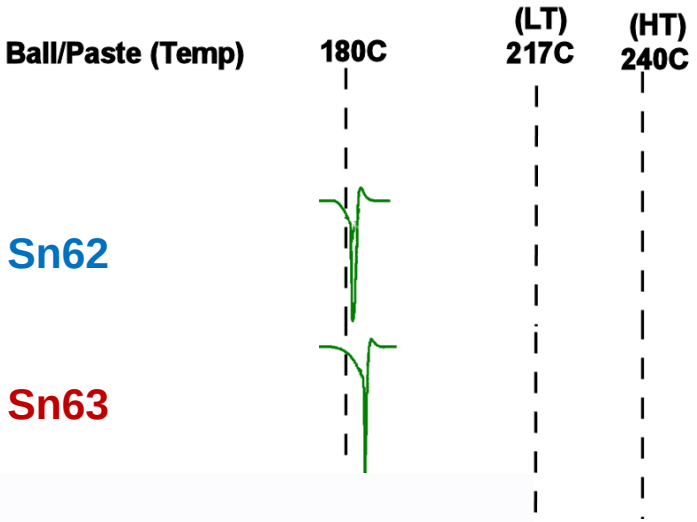
- SnPb wider span in voiding than Pb-free
- SnPb lower in surface tension (0.51N/m) than Pb-free (0.57N/m)
  - Under N2, no benefit on wetting
  - But, less restrictive force on confining entrapped volatiles, thus higher voiding
- Early bottom melt cause low voiding (see next slide)

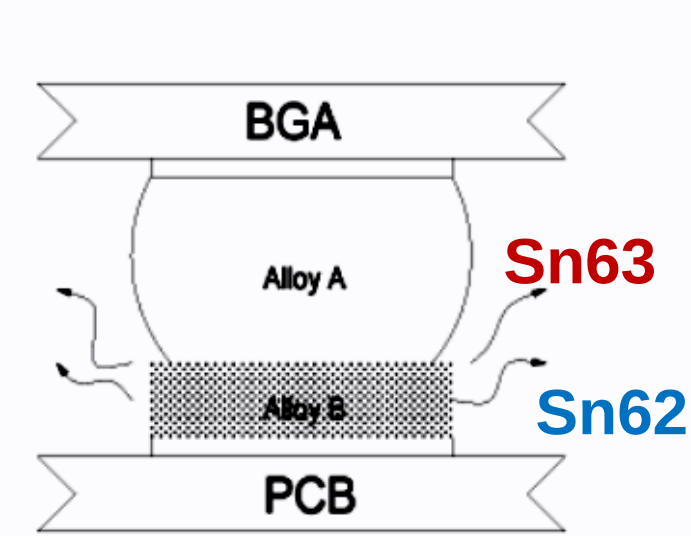


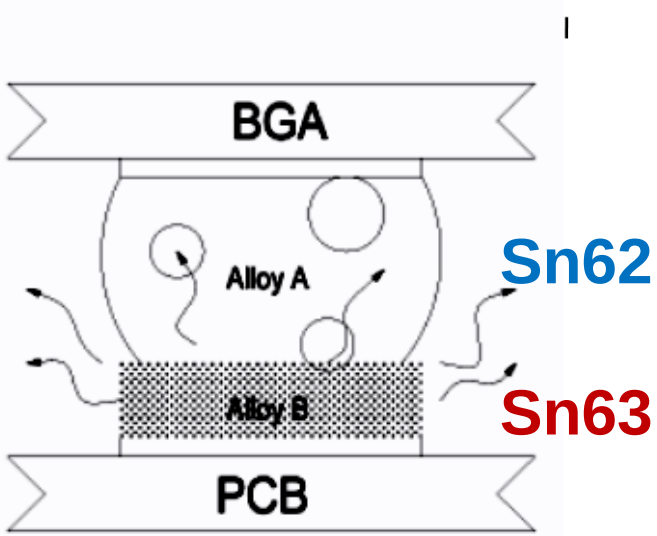
Sequence Factor

B63P62, Sn62 paste (177.9˚ C) melt 3.1˚ C earlier than Sn63 solder ball (180.8˚ C) – cause ultra-low voiding

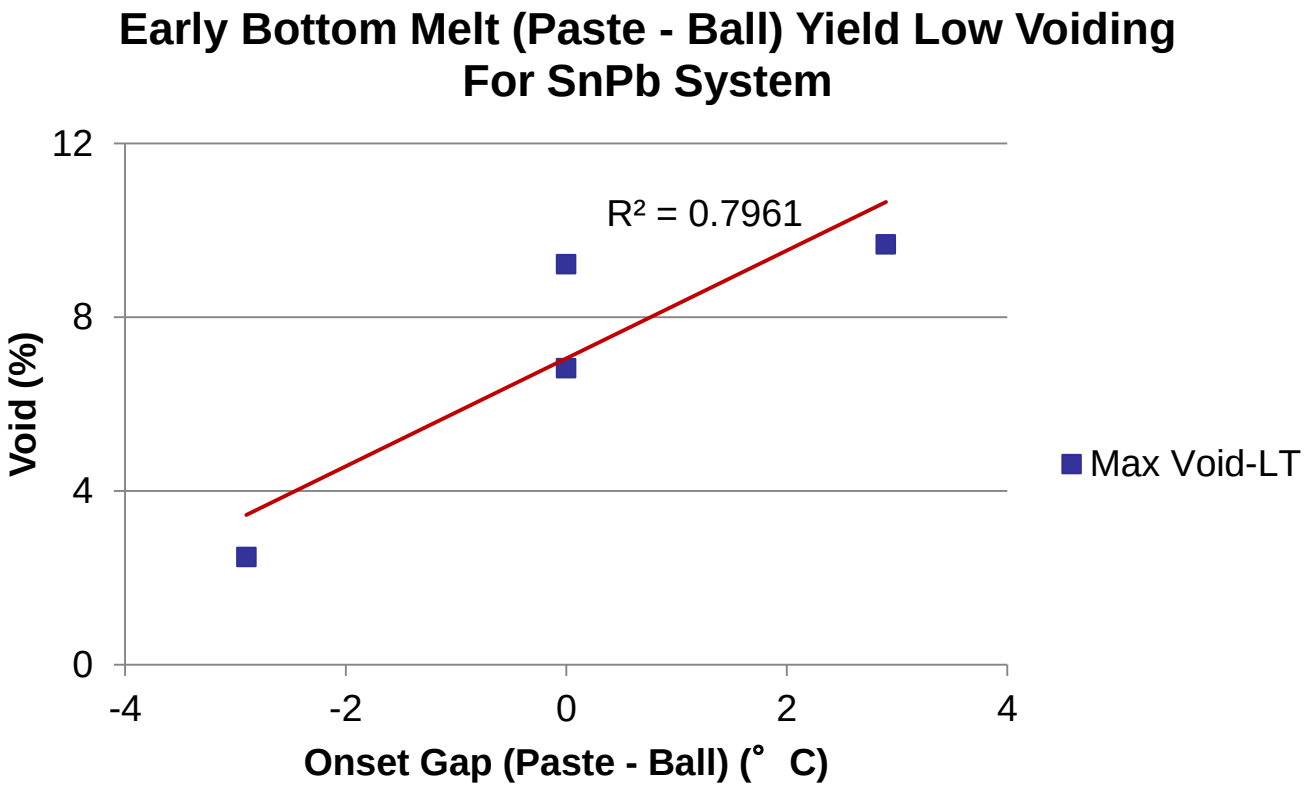
B62P63, highest voiding due to reversed sequence







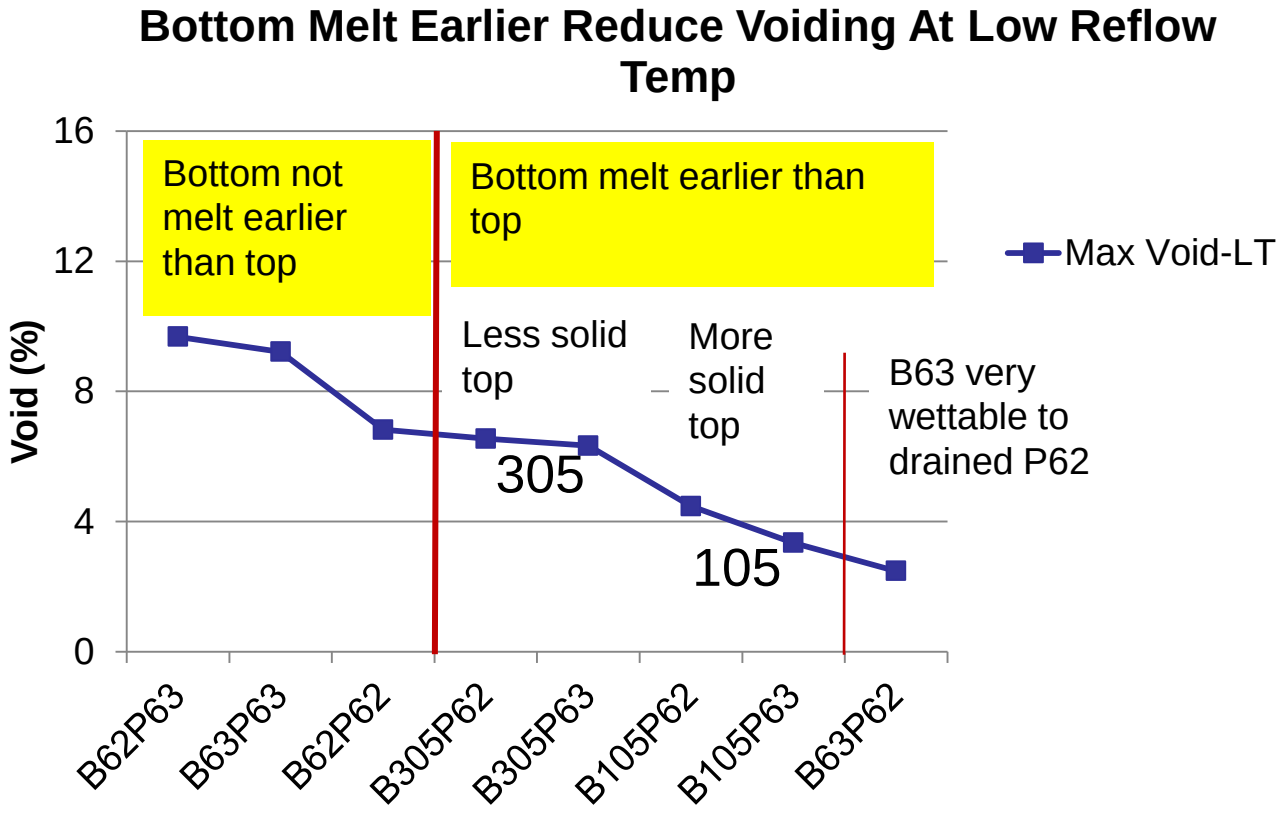
Sequence Factor Hold for SnPb



Bottom melt first

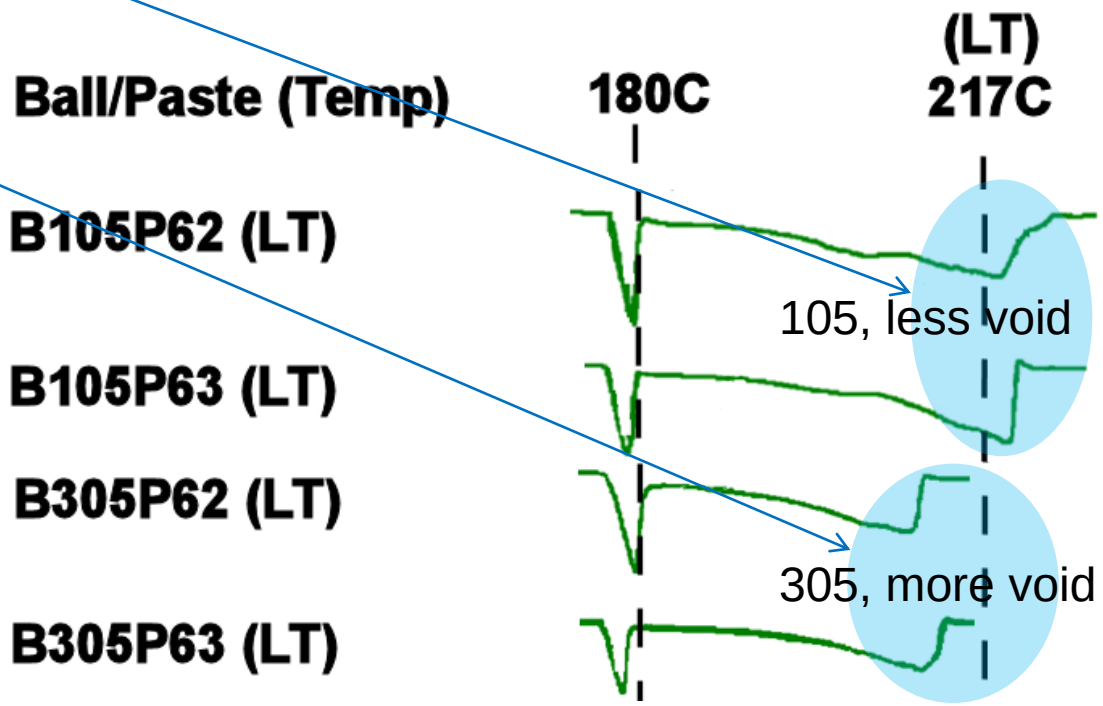
Sequence Factor Hold at LT

- Furthermore, also applicable to mixed alloy system with LT reflow



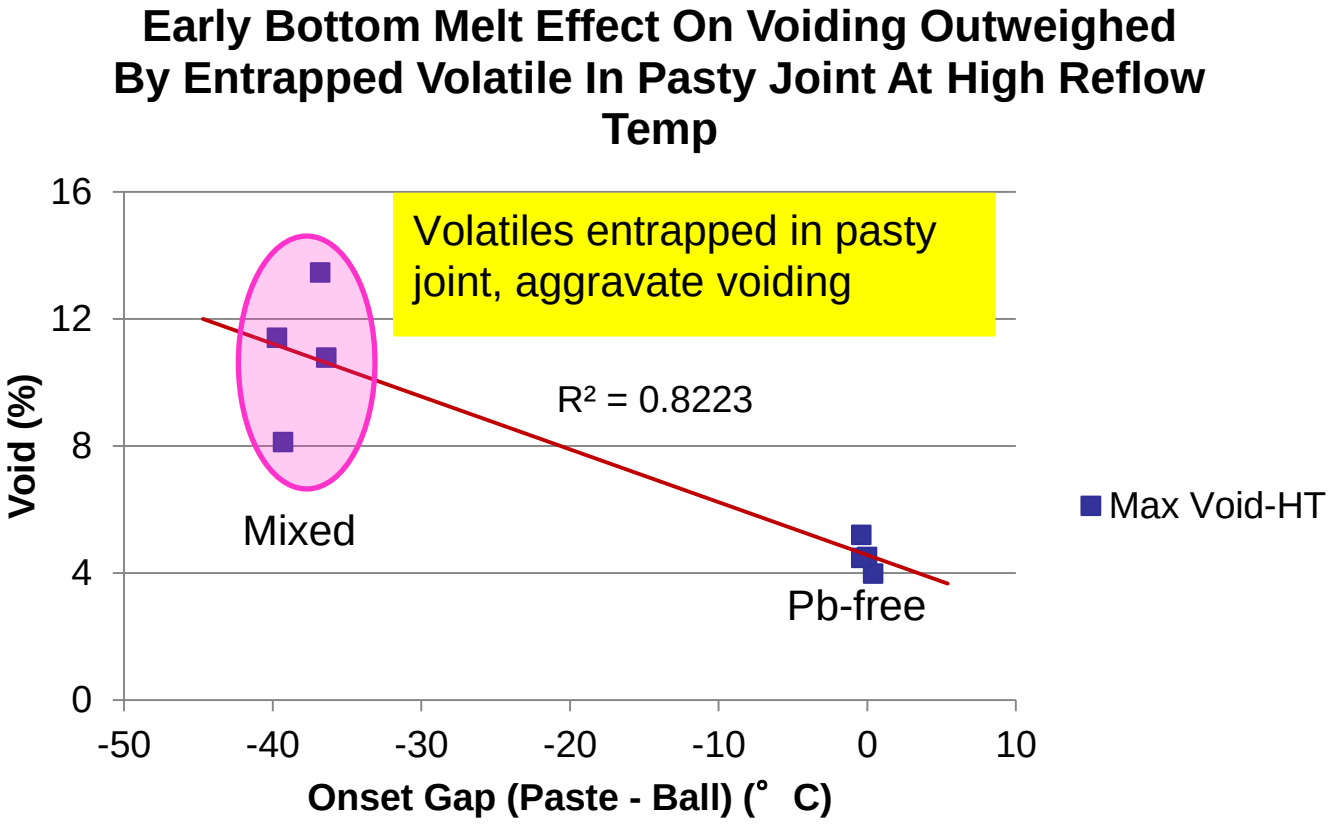
Solid Top Factor Contribute at LT for Mixed Systems

- At LT, Pb-free solder ball either not fully melted yet or barely completed melting. Solid top would not accommodate formation of voiding.



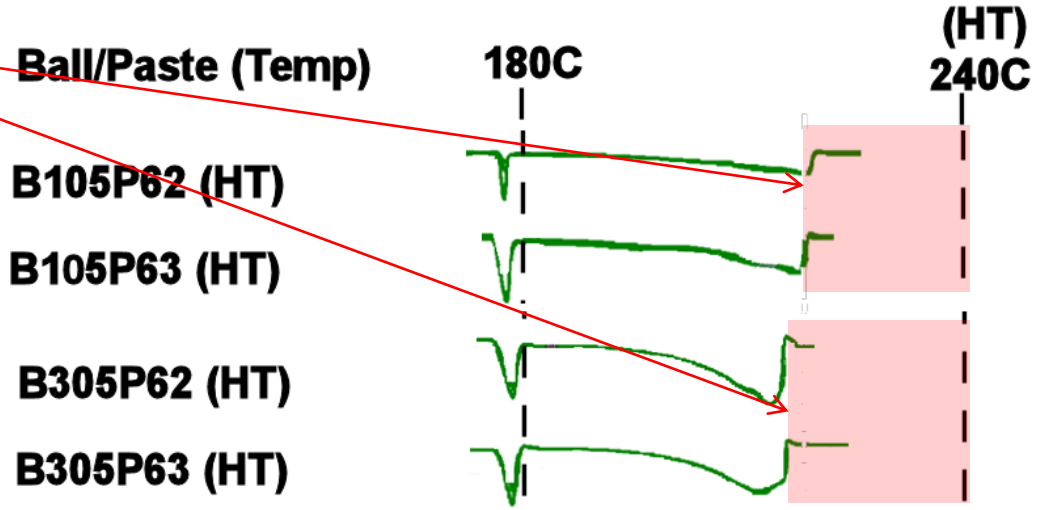
Sequence Factor Fall Apart at HT

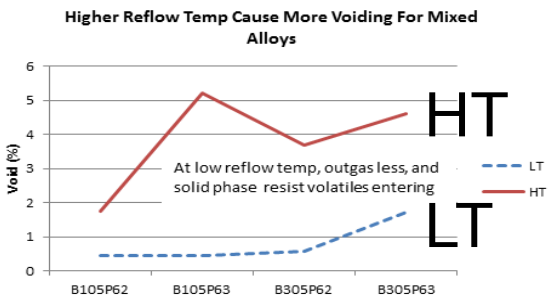
- When reflow at HT, early bottom melt (mixed system) more voiding than 0 gap (Pb-free). Why?



Solid Top Factor No Longer Help at HT for Mixed System

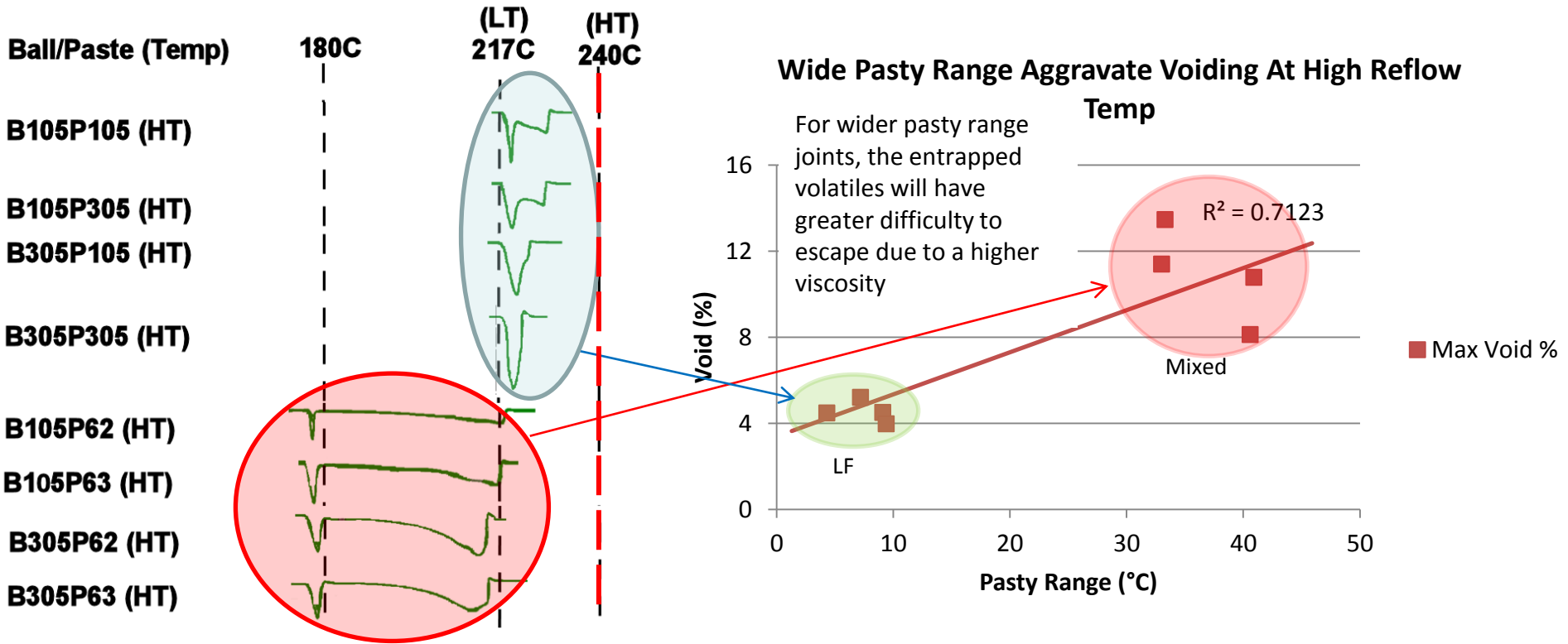
- At LT, Pb-free solder ball either not fully melted yet or barely completed melting. Solid top would not accommodate formation of voiding.
- At HT, all solid tops are well eliminated during reflow, and voiding can be developed due to entering of volatiles into liquid top.
- Explained voiding HT > LT for mixed





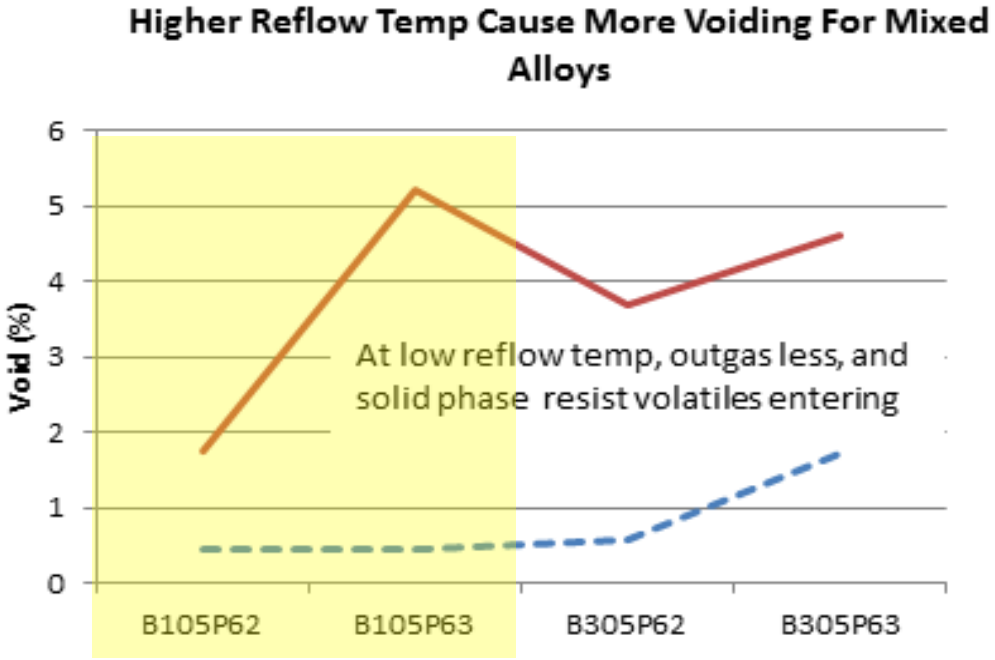
Pasty Range Factor Dictate at HT

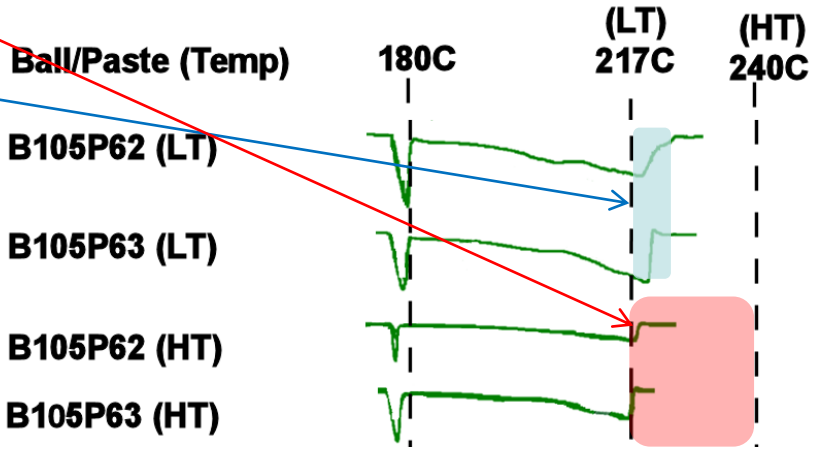
- Pb-free narrow pasty range, mixed wide pasty range at HT
- Pasty material viscous during heating, retain the volatiles easily and cause more voiding.



HT always shows a higher voiding than LT - Partially due to Solid Top Factor at LT

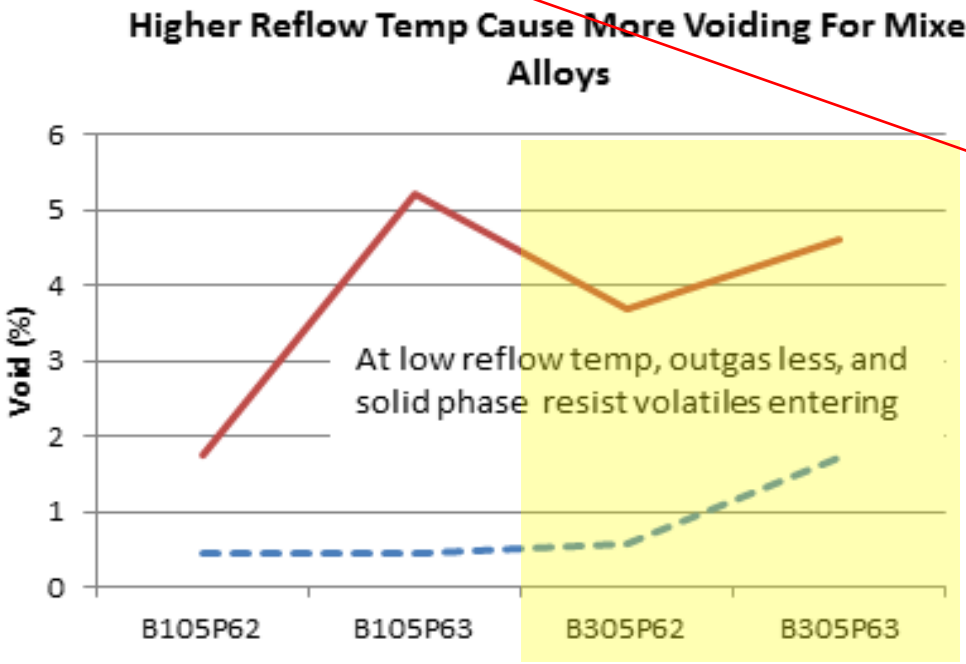
- B105P62 & B105P63 may be affected by solid top factor (with solid top at LT, no solid top at HT)

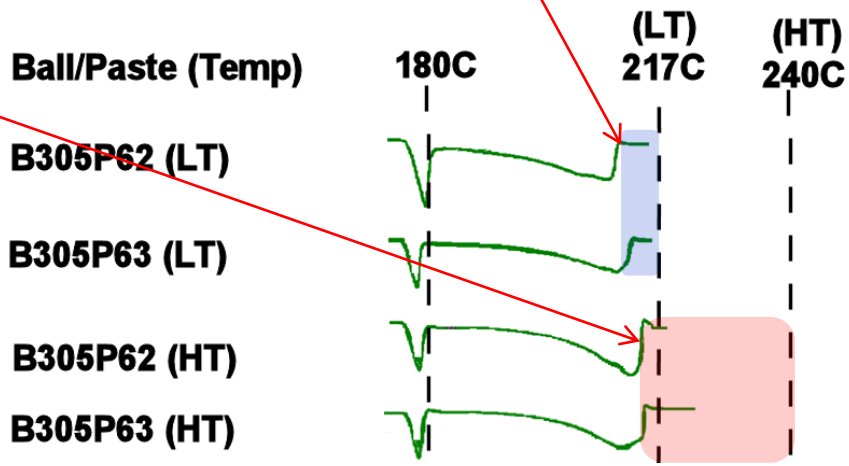




HT always shows a higher voiding than LT - Partially due to Overheating Factor

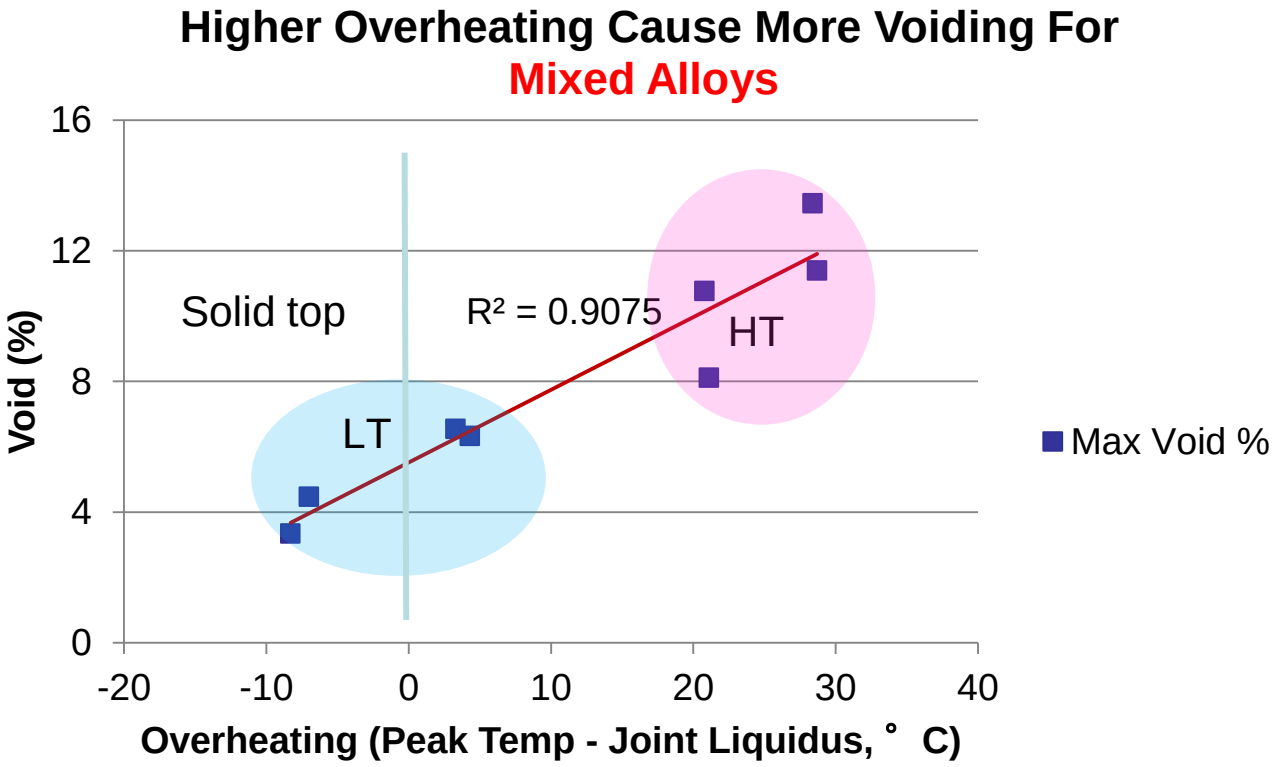
- B305P62 & B305P63
  - Neither LT nor HT has solid top
  - HT (overheating factor) cause more outgassing than LT, hence more voiding than LT.





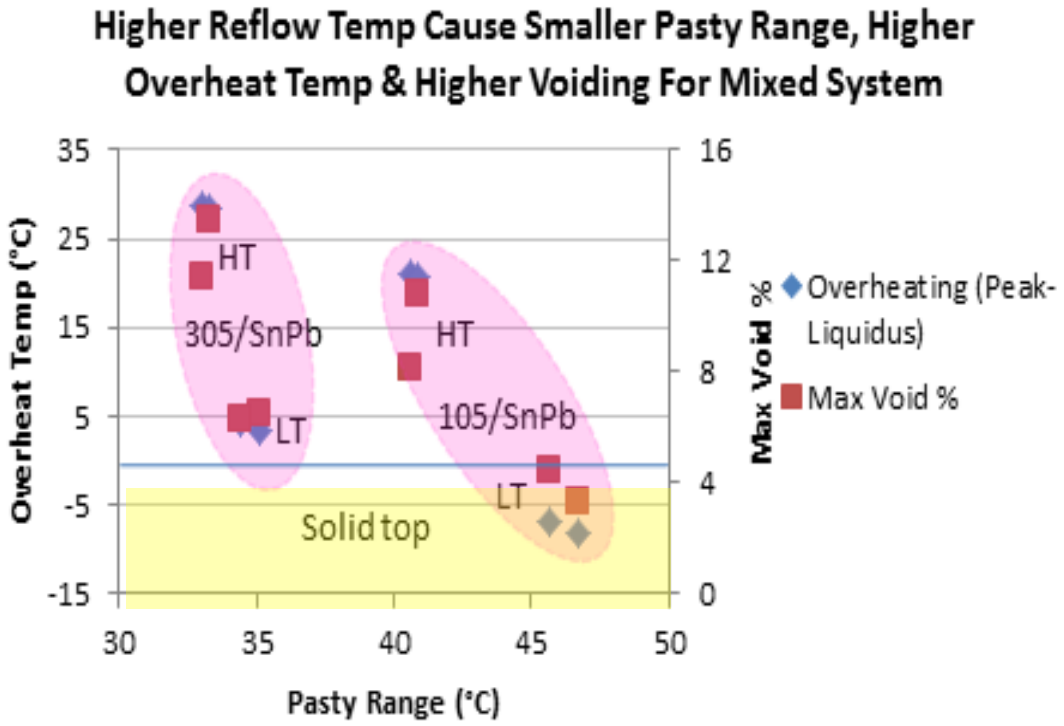
Overheating Factor Dictate For Mixed System!

- The high R-square value indicates that overheating is one very significant physical parameter in governing voiding



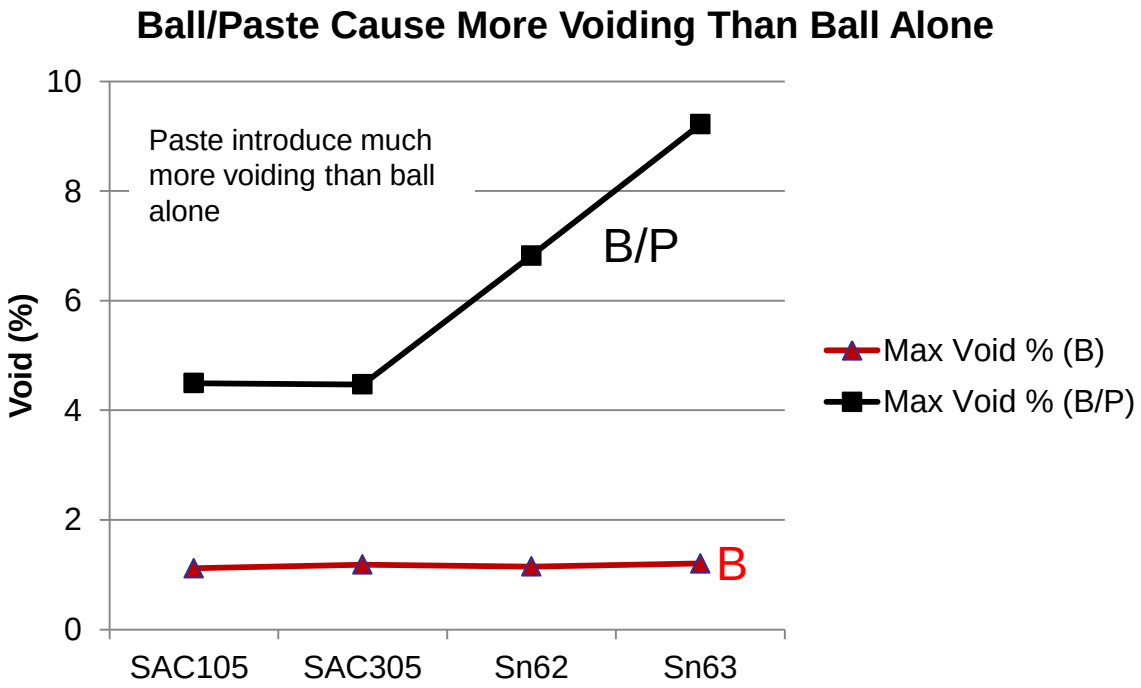
Overheating & Solid Top > Pasty Range Effect

- Voiding extent
  - Solid top < liquid top
  - Overheating less (LT) < overheating more (HT)
  - Pasty range - depends



Paste More Voiding Than Flux

- BGA assembly with solder paste caused much higher voiding than with flux.
- Solder powder wet to the pad concurrently, exclusion of flux from interior becomes fairly troublesome.
- With flux only, the molten ball starts wetting to the pad at the center, followed by progressively pushing the flux outward with advancement of molten solder front.



Conclusion

- Mixed systems less voiding at LT then HT.
- Mixed systems had higher voiding than lead-free systems when reflowed at HT.
- SnPb systems had wider voiding span compared with mixed systems when reflowed at LT under N2.
- Voiding was found to decrease with
  - increasing alloy surface tension (under N2),
  - earlier melt of bottom solder paste,
  - top ball remain solid during reflow,
  - reduced joint overheating,
  - replacing solder paste with flux alone, and
  - narrower pasty range