The Challenge of Lower Temperature Soldering for Large Ball-Grid Array Board-Level Assembly Process

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Outline/Agenda

- Introduction
- Experimental Design
- SAC305/BiSnAg Joints
- SAC305/DFLT & SAC305/DFLT-2 Joints
- Results and Discussion
- Q & A

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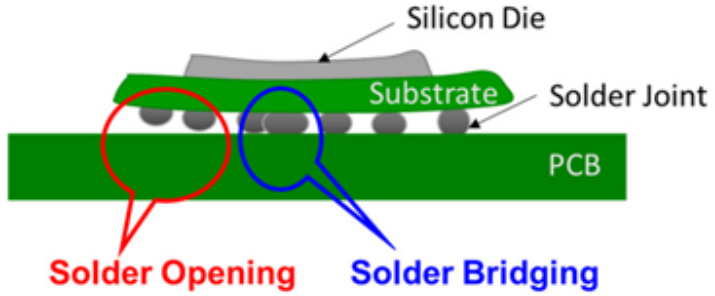
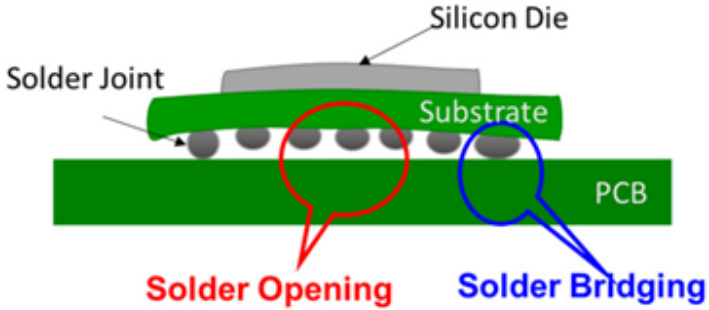
Introduction

- Complicated Dynamic Warpage of Large BGA
- Challenge of Component Design and Board Level Assembly
- LTS were assumed to relieve the impacts from the warpage challenge



I. Concave Warpage of BGA Package



II. Convex Warpage of BGA Package

M.Y. Tsai etc., Thermally-induced Deformation & Warpage of Flip-chip and 2.5D IC Package, Materials, 14(13):3723, 2021

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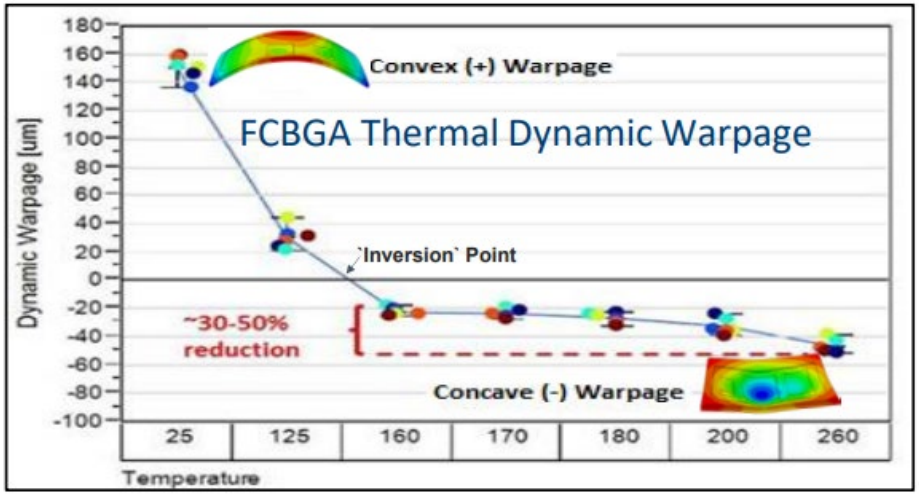
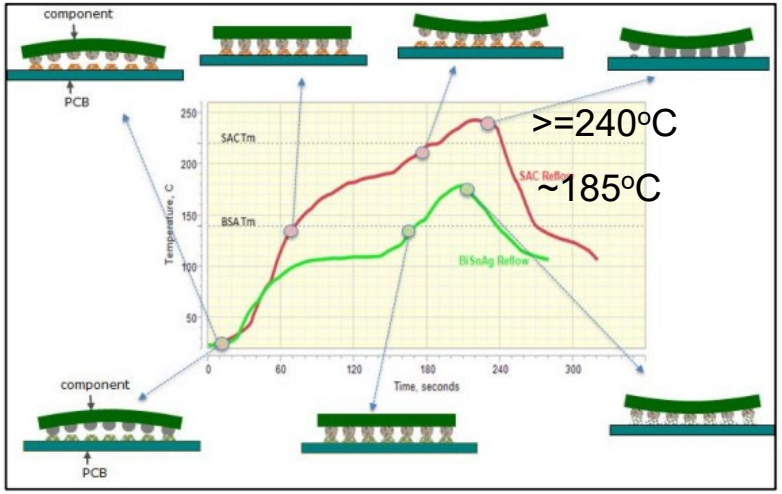
Warpage Mitigation with LTS





SnAgCu Ball of BGA will not melt during reflow

Challenge of **Insufficient Molten Solder vs Warpage**

Challenge of **Joint Solidification vs Warpage**

Challenge of **Hybrid Joint on Reliability**

K.K. Tang, iNEMI Low Temperature Soldering Workshop, Shanghai, 2019

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Purpose of the project

- **Phase 1**

  Processing Feasibility of LTS/MTS for Large BGA assembly

- Phase 2

  TCT Reliability of LTS?MTS for Large BGA assembly

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Experiment I.

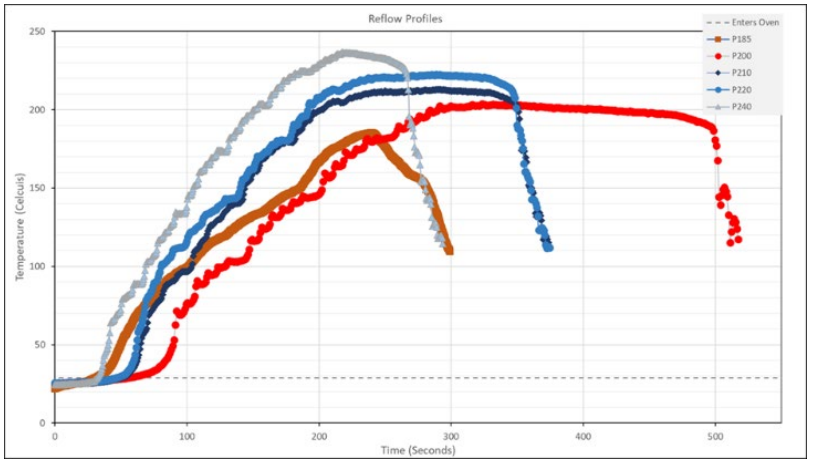
Pastes (LTS & MTS)

	Bi	Sn	In	Ag	Cu
BiSnAg	57	42	-	1	
DFLT	-	84.4	12.5	2.9	0.2
DFLT-2	-	78.8	16.9	3.5	0.7

Melting Temperature
BiSnAg: 138°C
DFLT-2: 180°C to 196°C
DFLT: 189°C to 206°C

Reflow (185 to 240°C Peak Temperature)

Profile #	Peak Temperature (°C)	TAL (s) for BiSnAg	TAL(s) for DFLT	TAL(s) for DFLT-2
P185	185.2	117	-	-
P200	203.8	290	-	200
P210	213.1	-	124	157
P220	222.7	241.8	151	168
P240	236.7	-	65	-



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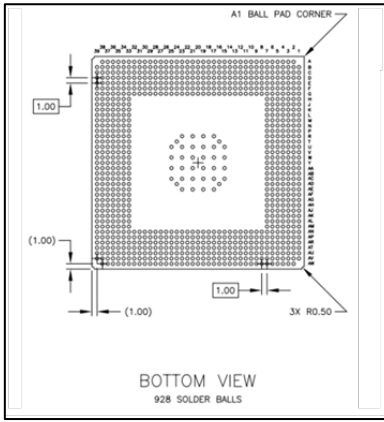
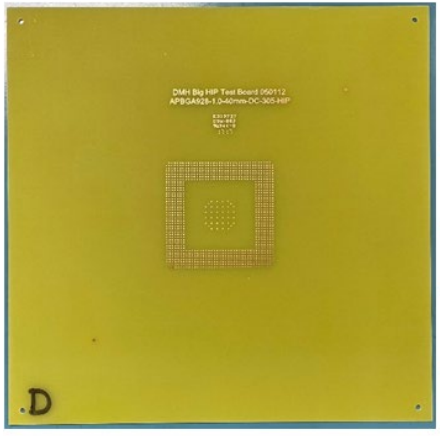
Experiment II.

PBGA 928 BGA



PBGA928	Perimeter Array
Body size (mm)	40x40
Die size (mm)	5x5
Pitch (mm)	1
Solder ball	SAC305
Ball diameter (mm)	0.63

PCB Design



PCB Laminate	FR4
PCB size (mm)	150x150
Tg (°C)	130
Pad finish	Cu-OSP
Pad size (mm)	0.45
Solder Mask	NSMD

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Experiment III.

Stencil Design

Stencil #	Thickness (mm)	Circular Aperture (mm)	Paste-to-ball volume ratio
#1	0.1	0.46	~0.13
#2	0.125	0.58	~0.25
#3	0.175	0.69	~0.5

Inspection

X-ray
Cross-section
Optical Microscopy
SEM

Testing Matrix

	P2B volume ratio	Reflow				
		P185	P200	P210	P220	P240
BiSnAg	0.13	x	x		X	
	0.25	x	x			
	0.5	x	x			
DFLT	0.13		x	x	x	x
	0.25		x	x		
	0.5		x	x		
DFLT-2	0.13		x	x	x	
	0.25		x	x		
	0.5		x	x		

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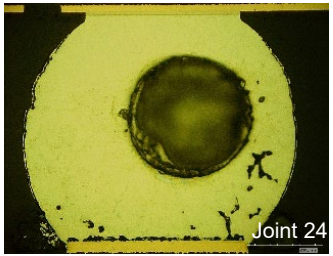
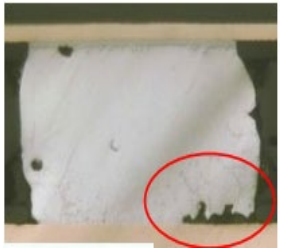
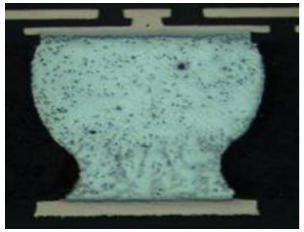
Joint Ranking

Joint Score	Description
1	Open/HIP/NWO/Hot-tearing
2	Necking
3	Oval/Elongated
4	Spherical/Drum

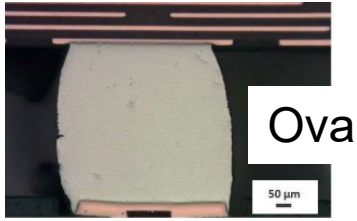




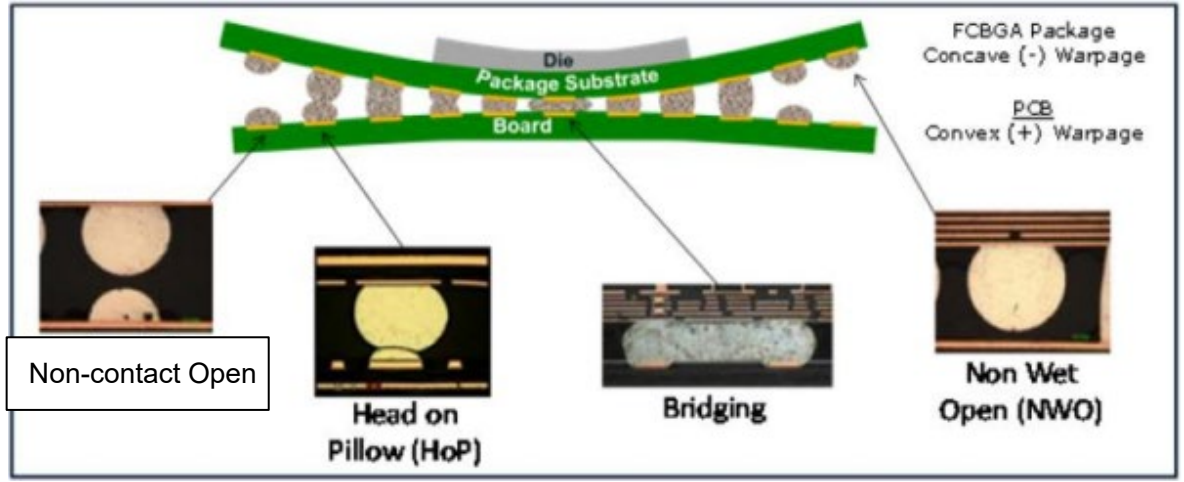
Hot-tearing

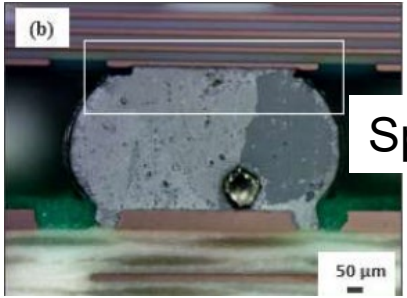


Necking



Oval/Elongated





Spherical/Drum

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SAC305/BIAGSN JOINT

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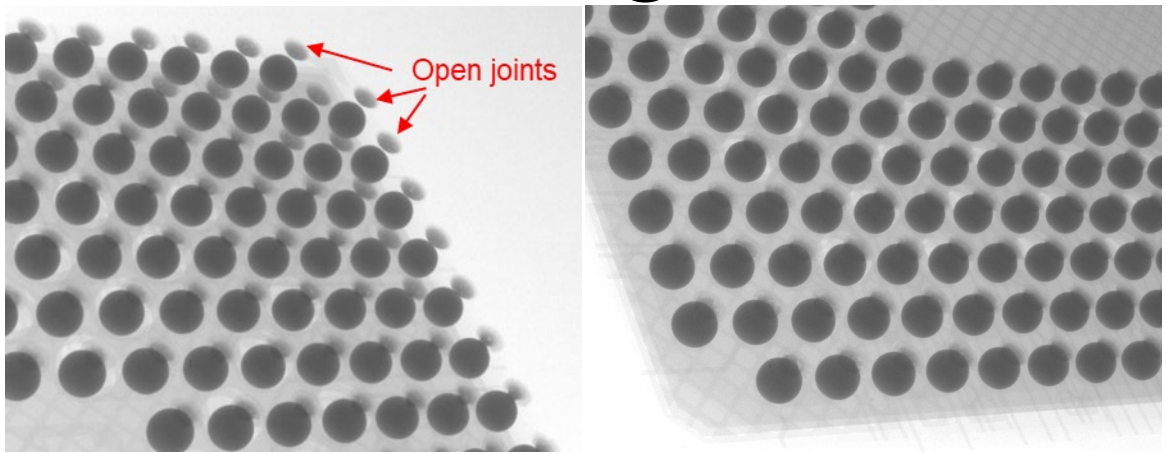
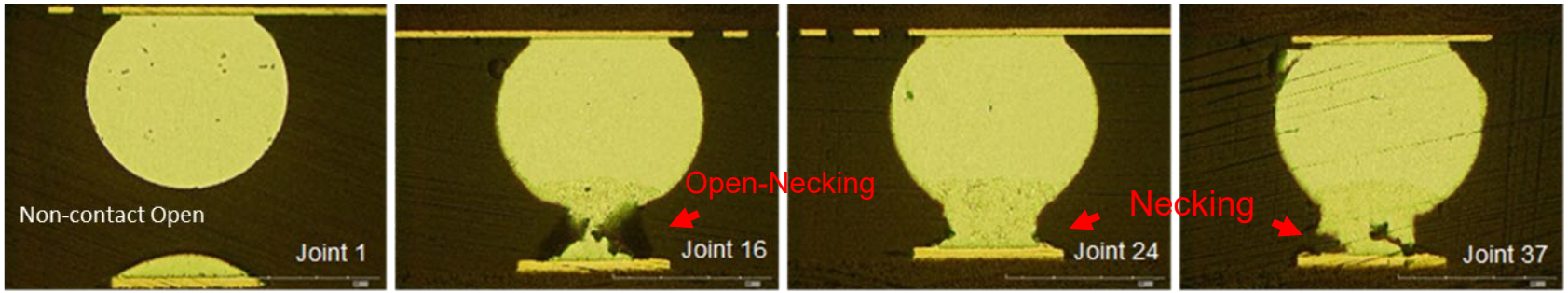
SAC/BiSnAg P185 P2B=0.13



Shortage of LTS paste results in numerous defective joints, including the Non-contact Open & Necking, & Package Tilt etc.

Score: 1



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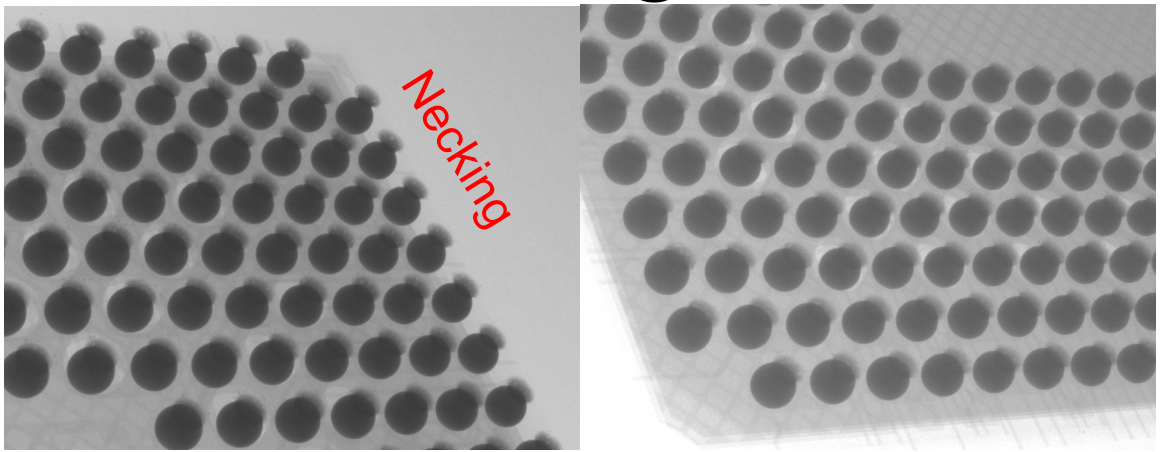
SAC/BiSnAg P185 P2B=0.25



Necking & Interfacial Hot-tearing & Hot-tearing Open & Elongated Joint

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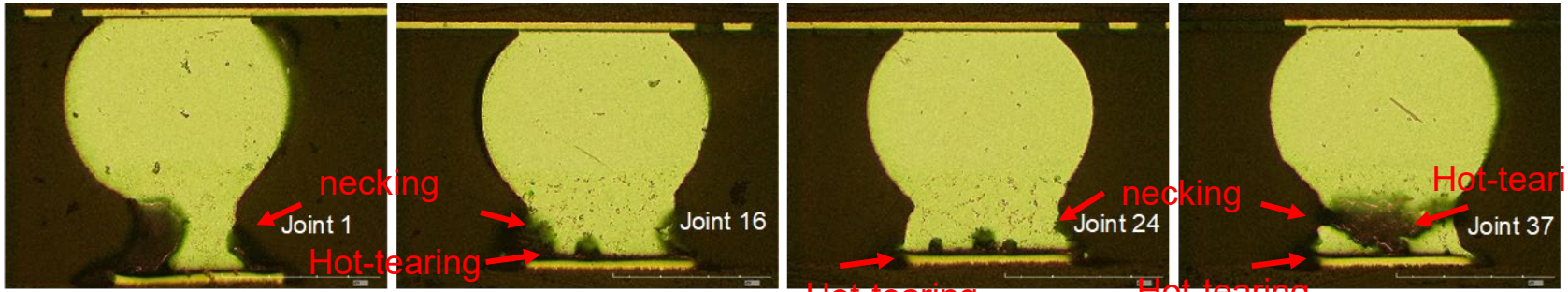

Elongated Joint

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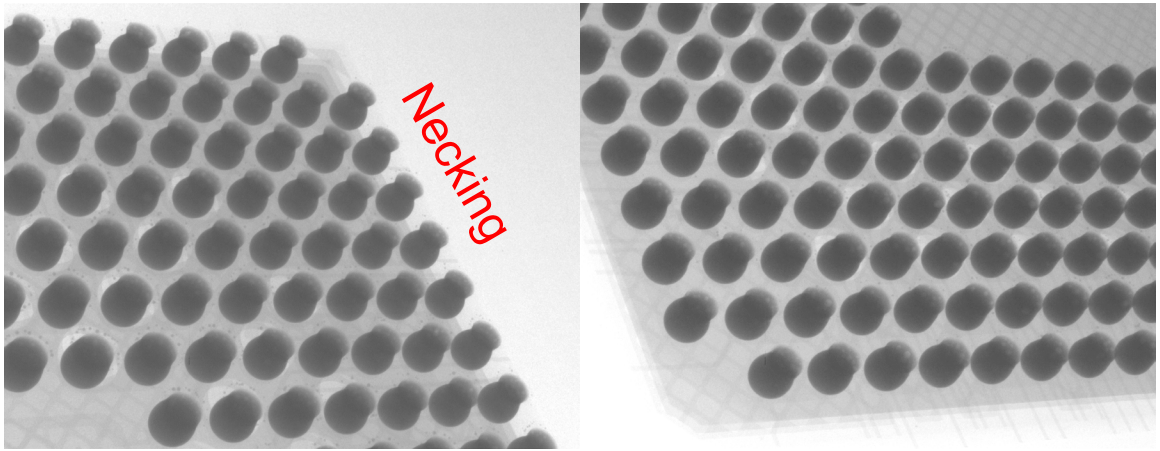
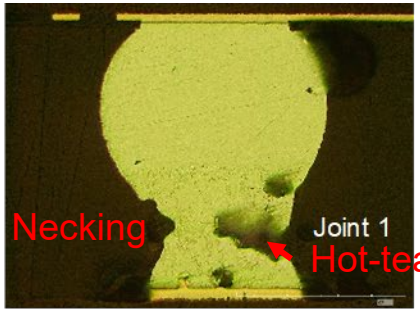
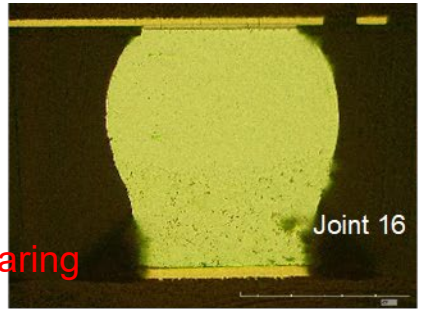
SAC/BiSnAg P185 P2B=0.5

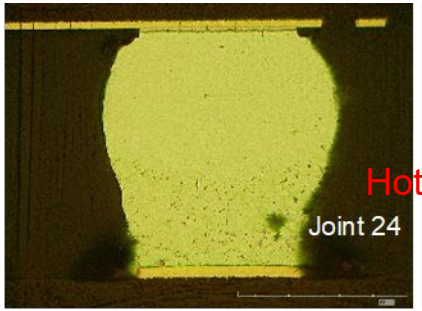


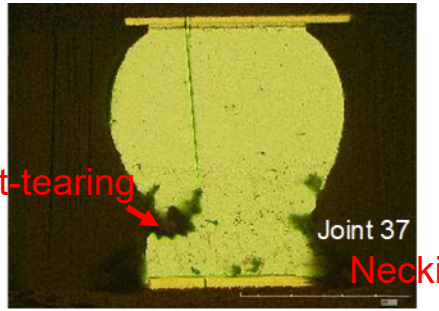
Necking, Hot-tearing and Elongated joint

Score: 1









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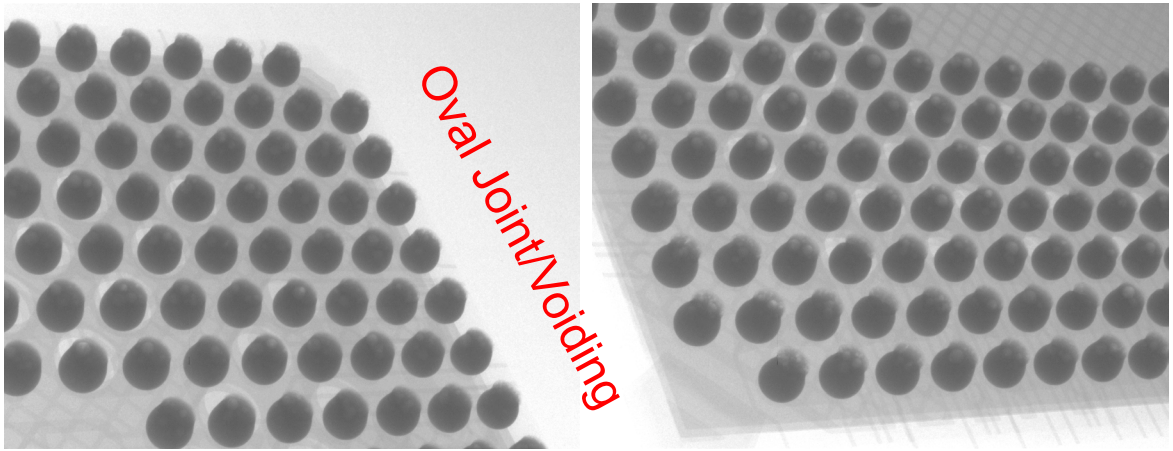
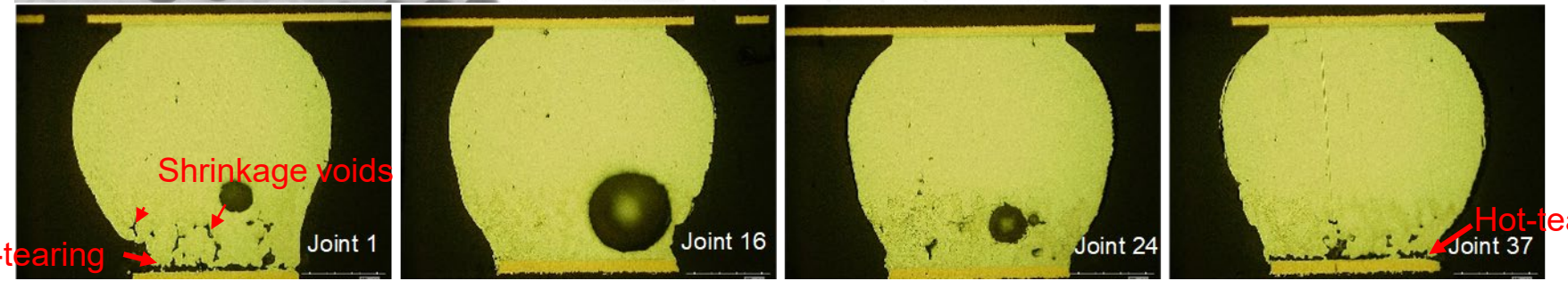
SAC/BiSnAg P200 P2B=0.13



Interfacial hot-tearing &
Shrinkage voids

Score: 1



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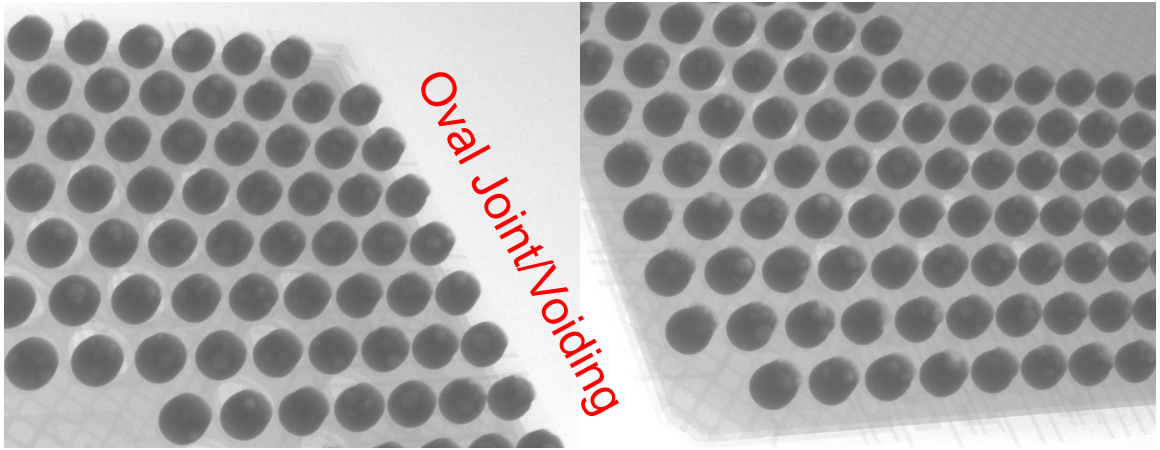
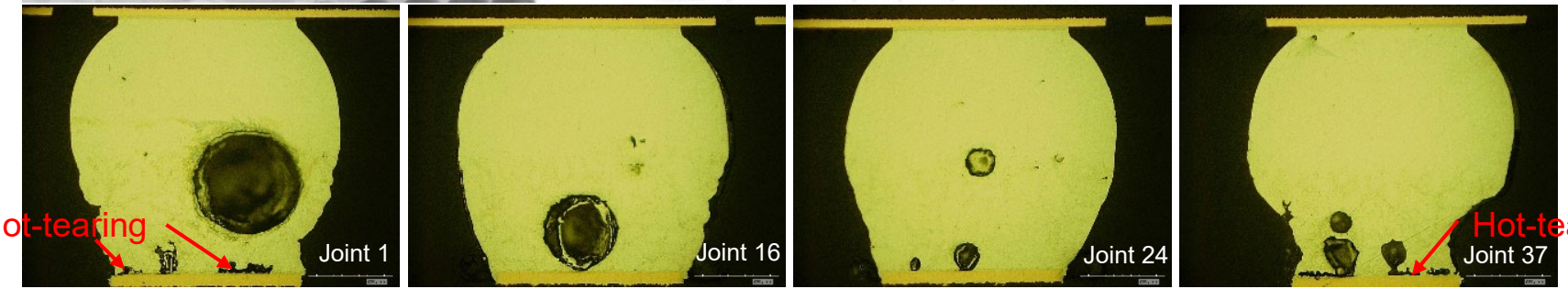


Interfacial hot-tearing &
Shrinkage voids

Score: 1



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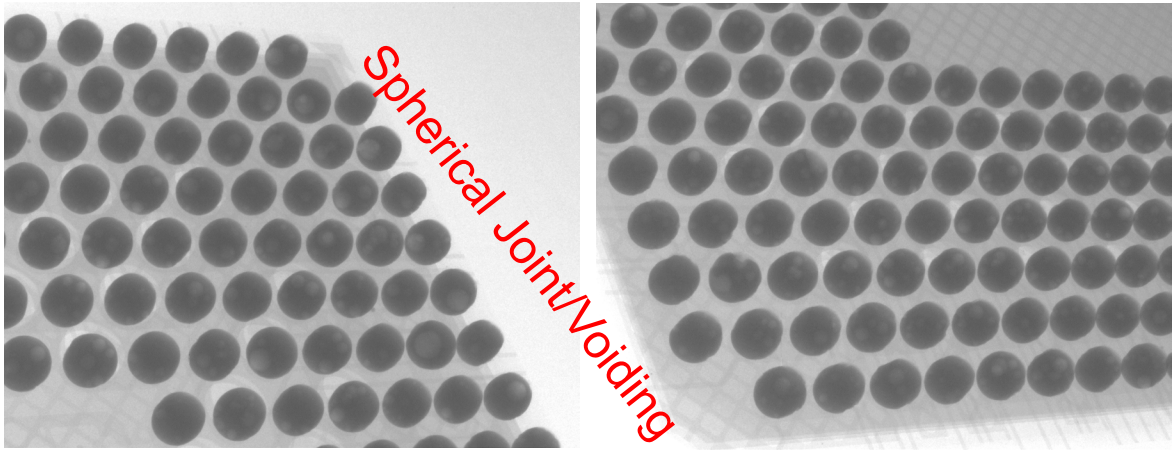
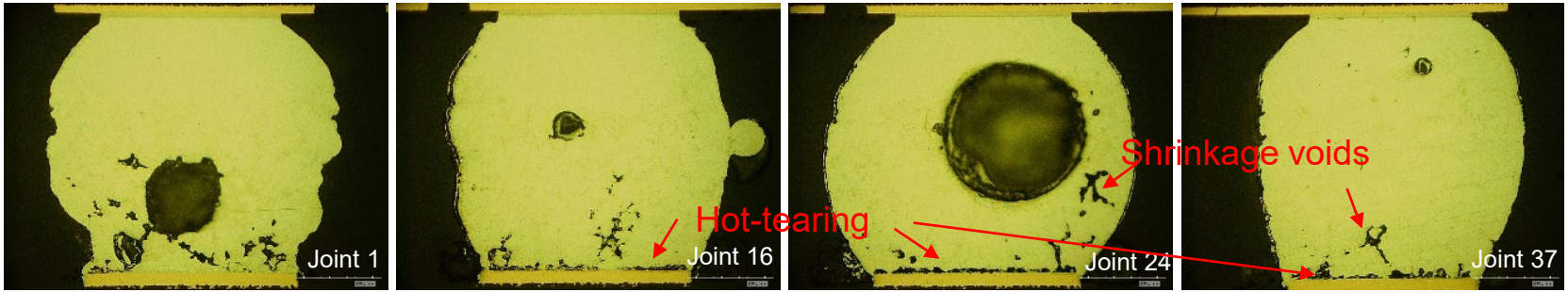


Interfacial hot-tearing &
Shrinkage voids

Score: 1



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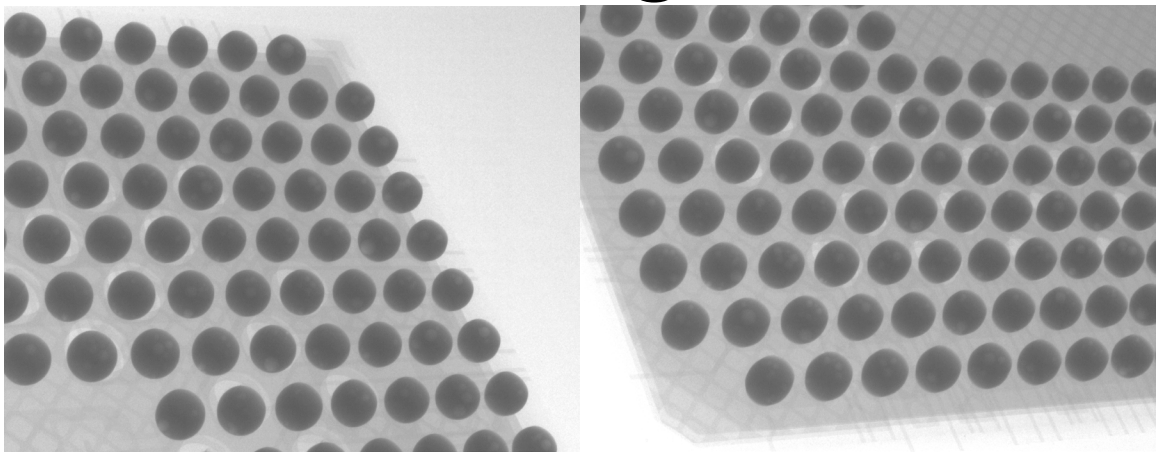
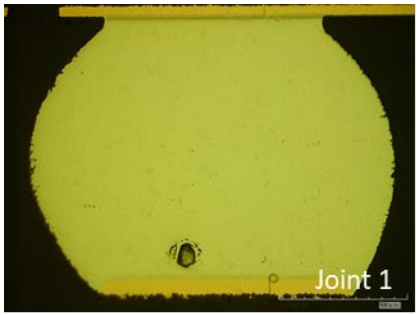
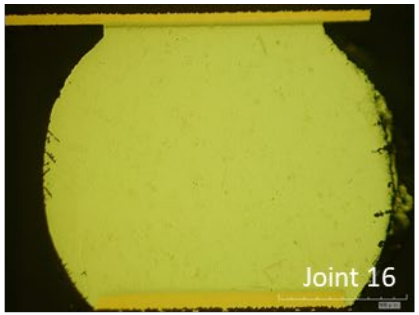
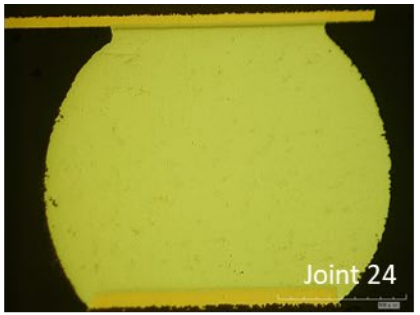


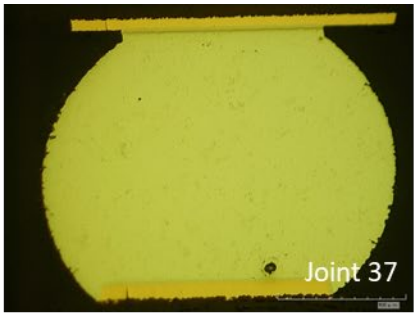
Spherical and healthy joints

Score: 4









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SAC305/DFLT & SAC305/DFLT-2 JOINTS

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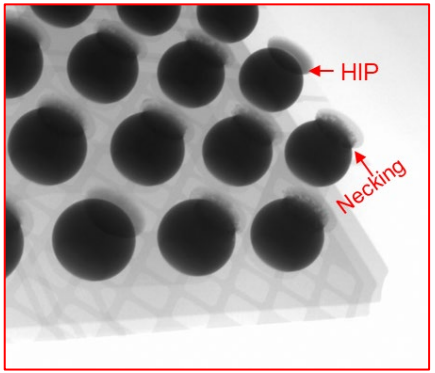
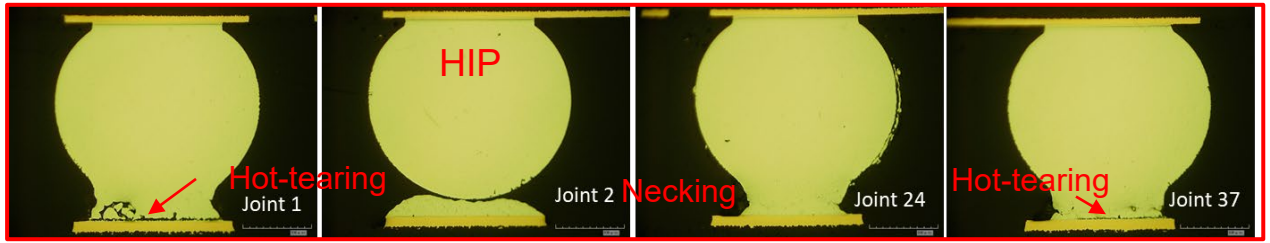
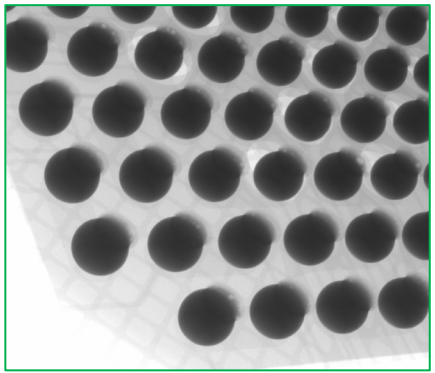
P200 P2B=0.13

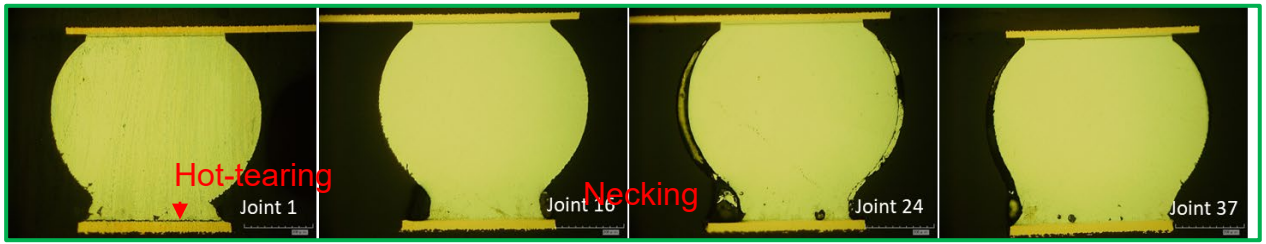




SAC/DFLT

Score: 1





SAC/DFLT-2

Score: 1

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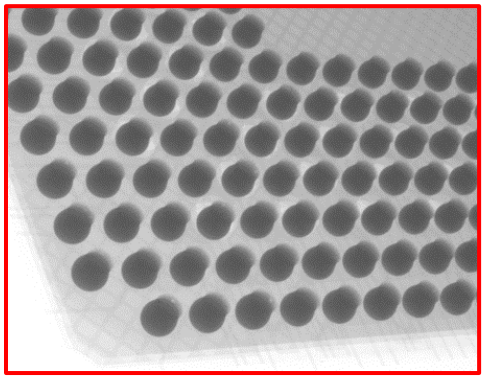
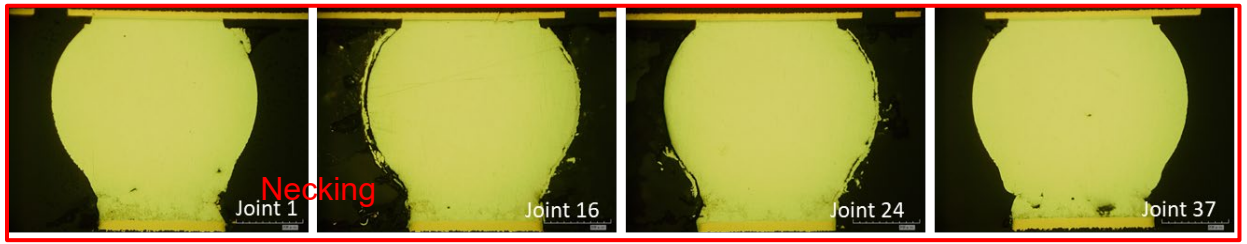
P200 P2B=0.25





SAC/DFLT

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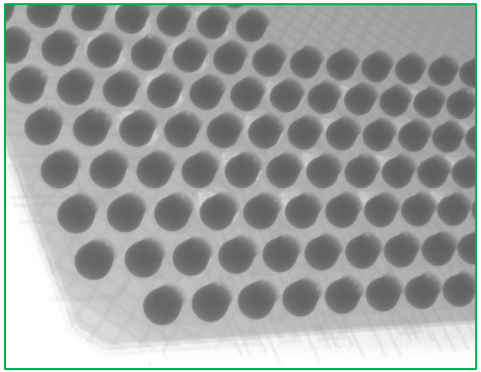

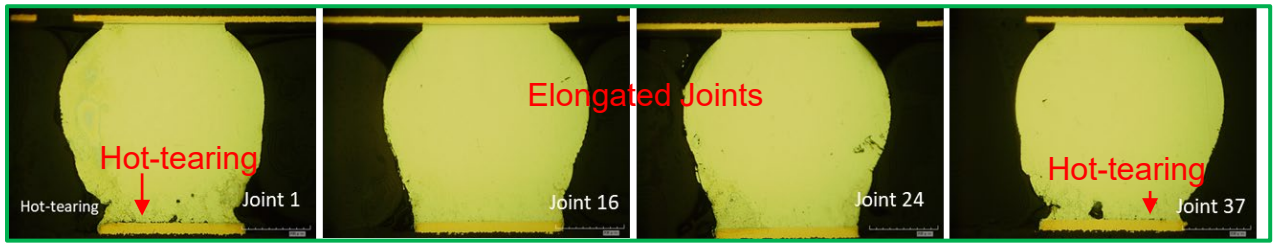

SAC/DFLT-2

Score: 1

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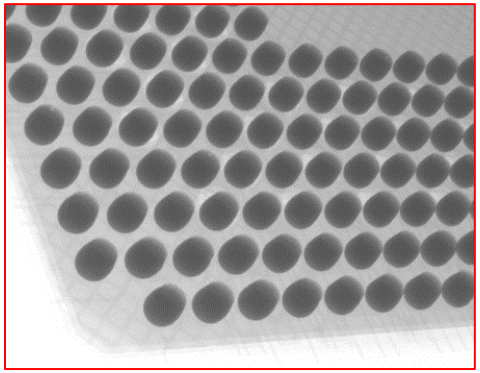
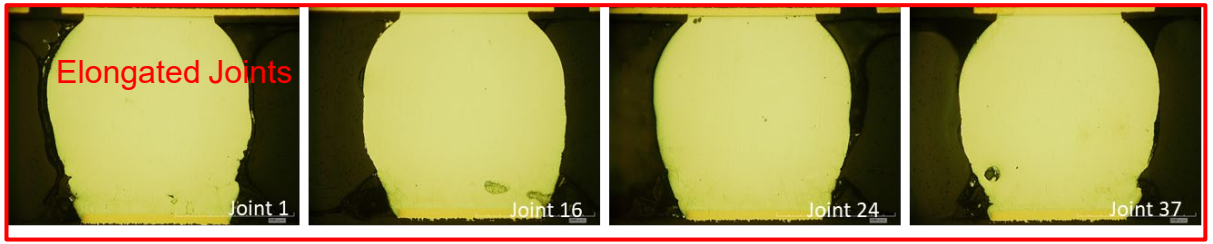
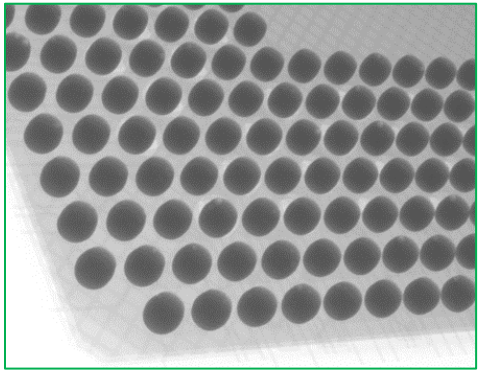
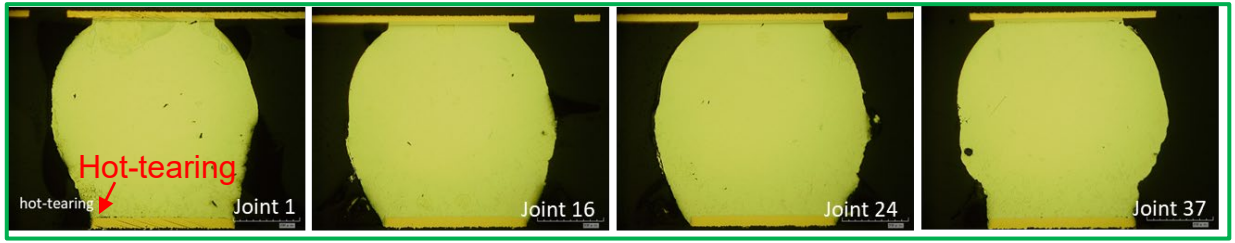




SAC/DFLT

Score: 3





SAC/DFLT-2

Score: 1

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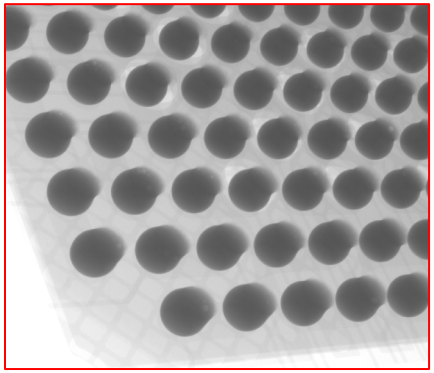
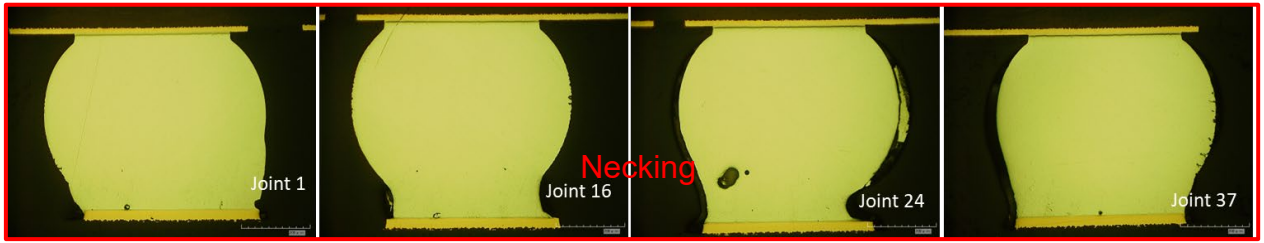
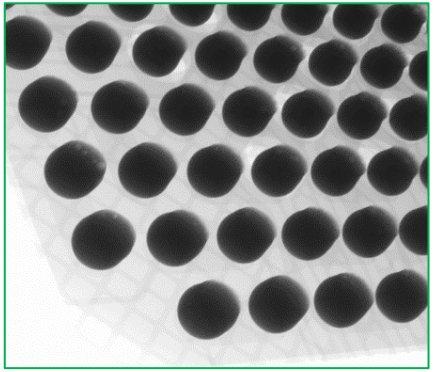
P210 P2B=0.13

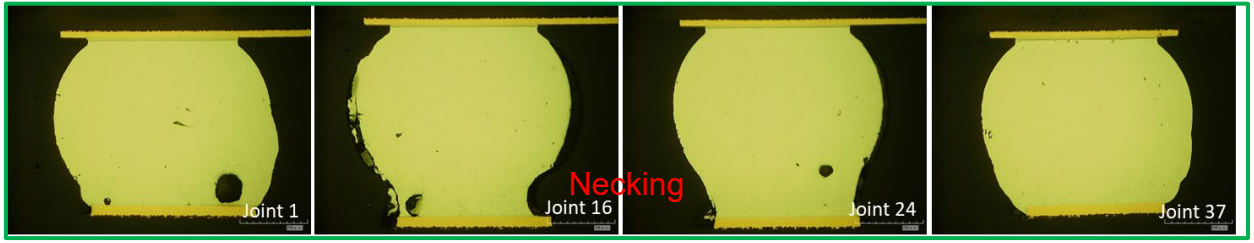




SAC/DFLT

Score: 2





SAC/DFLT-2

Score: 2

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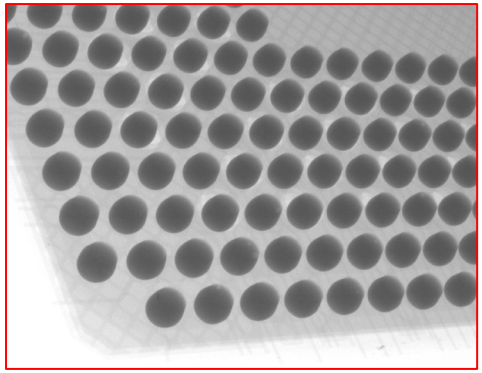
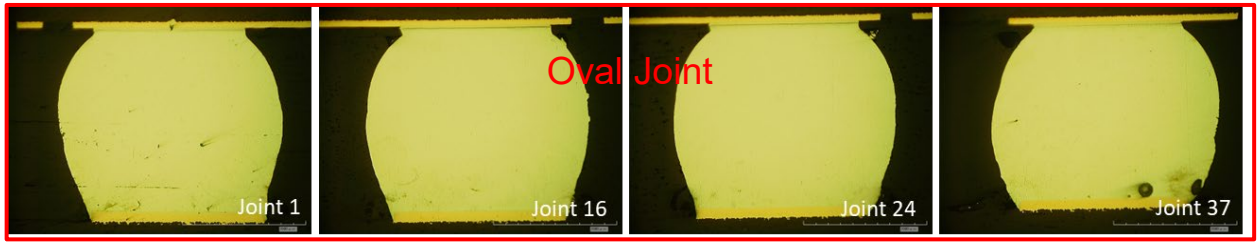
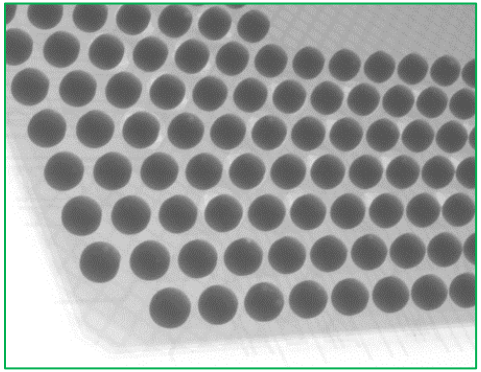
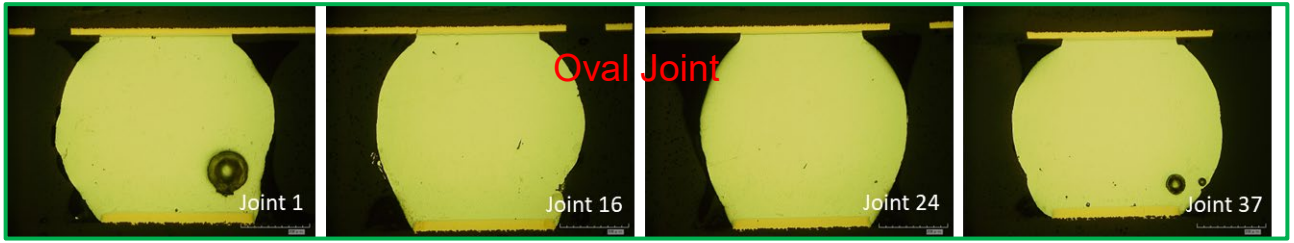
P210 P2B=0.25





SAC/DFLT Score: 3





SAC/DFLT-2 Score: 3

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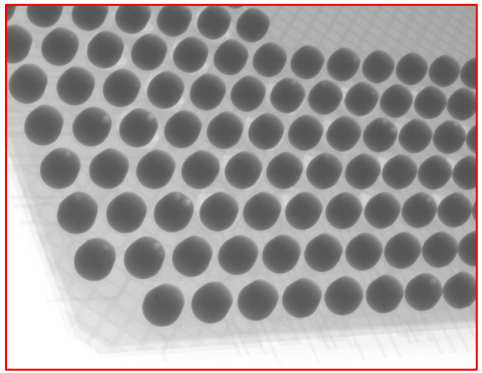
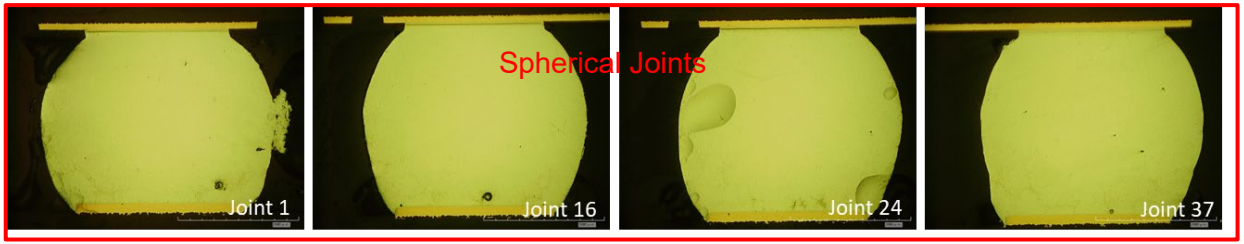
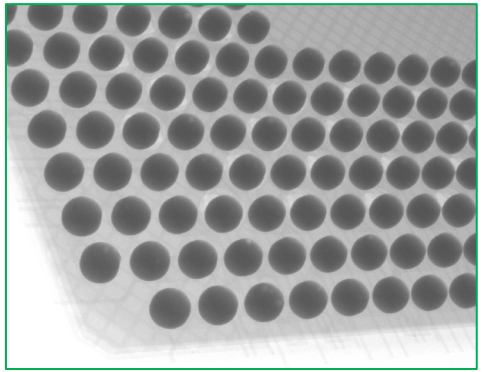
P210 P2B=0.5

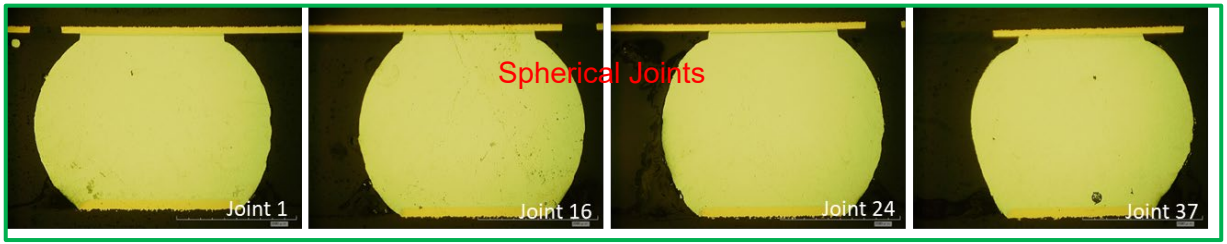




SAC/DFLT

Score: 4





SAC/DFLT-2

Score: 4

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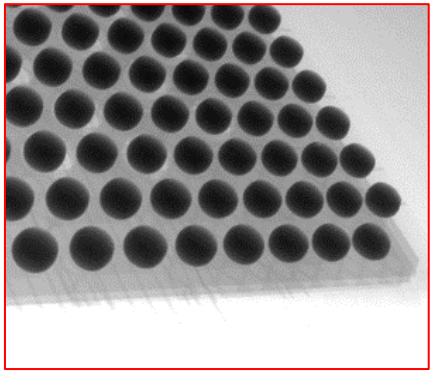
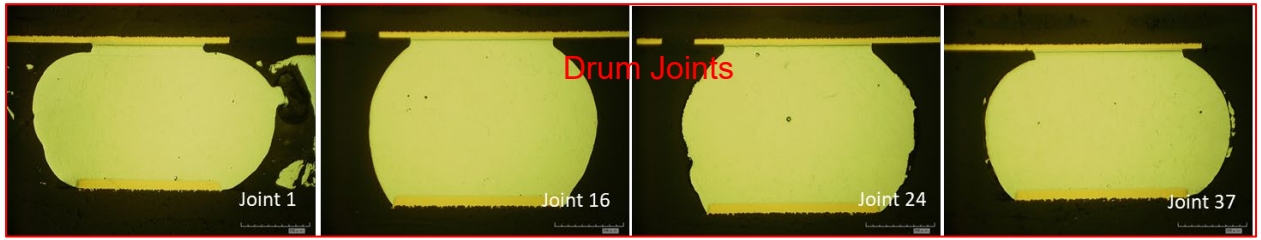
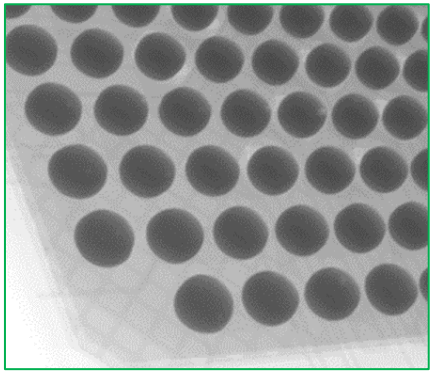
P220 P2B=0.13

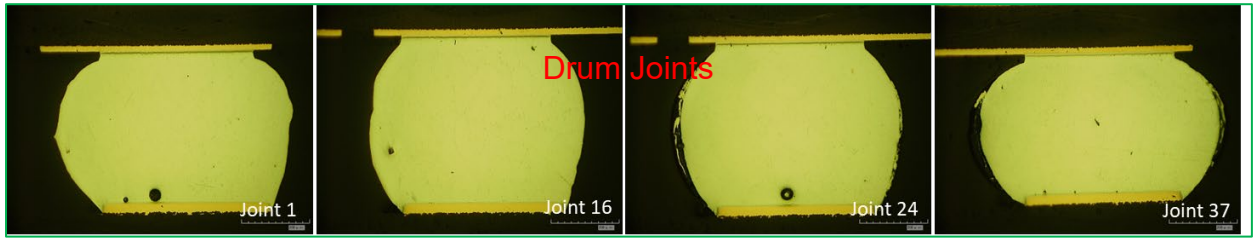




SAC/DFLT

Score: 4





SAC/DFLT-2

Score: 4

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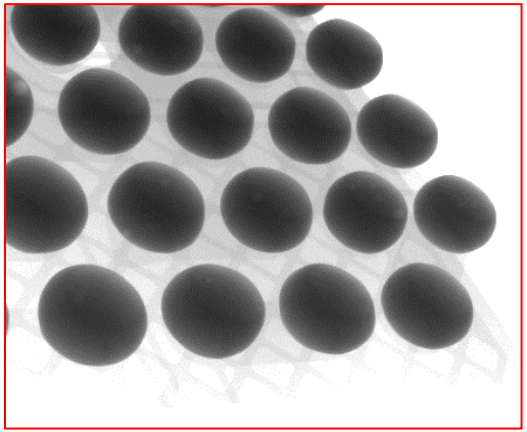
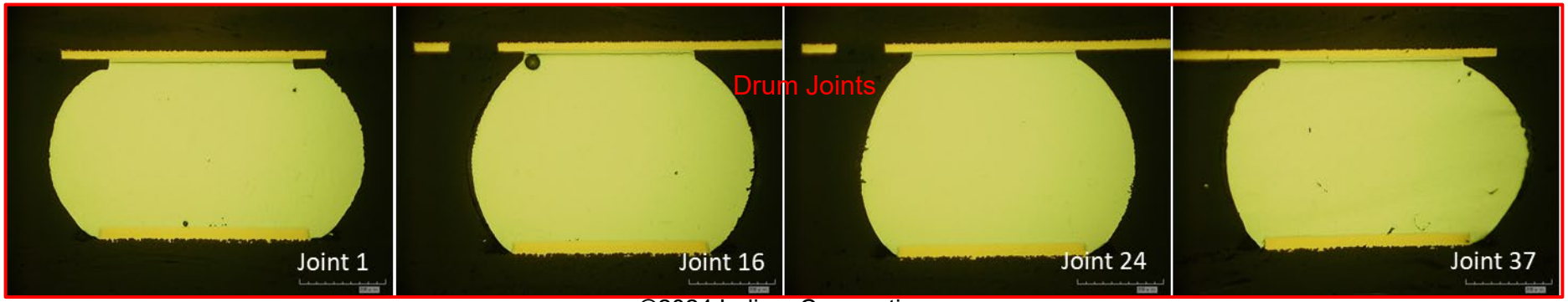
P240 P2B=0.13



SAC/DFLT

Score: 4



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Results of Joint Ranking

Joint Score	P2B volume ratio	Reflow				
		P185	P200	P210	P220	P240
BiSnAg	0.13	1	1		4	
	0.25	1	1			
	0.5	1	1			
DFLT	0.13		1	2	4	4
	0.25		2	3		
	0.5		3	4		
DFLT-2	0.13		1	2	4	
	0.25		1	3		
	0.5		1	4		

Joint Score	Description
1	Open/HIP/NWO/Hot-tearing
2	Necking
3	Oval/Elongated
4	Spherical/Drum

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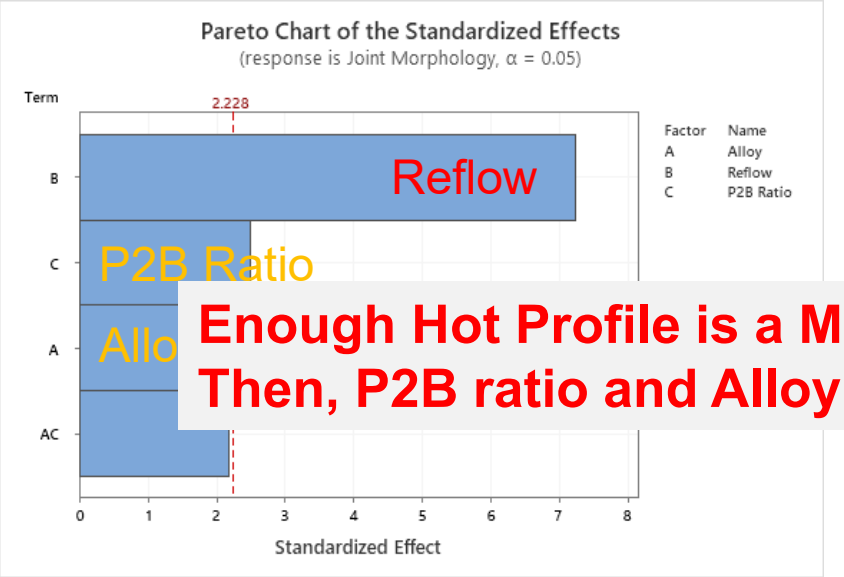
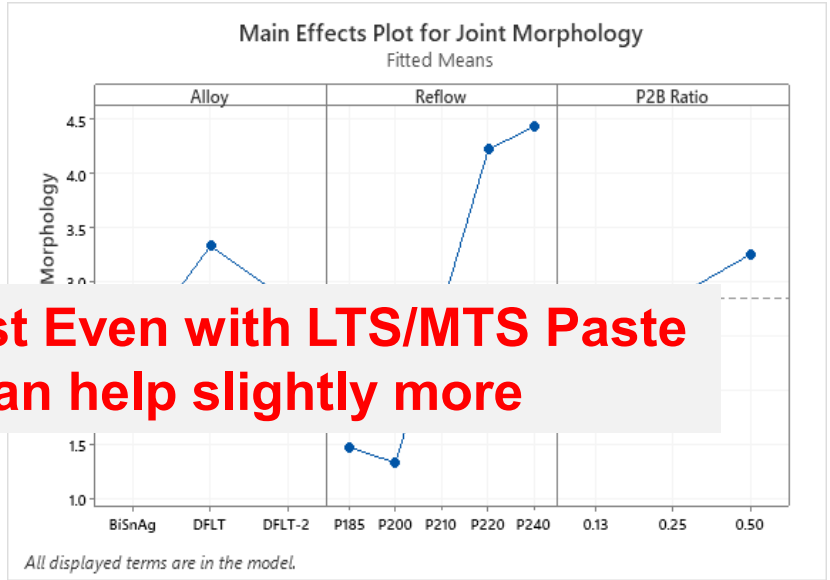
Impact Factors





Enough Hot Profile is a Must Even with LTS/MTS Paste
Then, P2B ratio and Alloy can help slightly more

Reflow have the **Most Important Impact** on Joint Morphology
P2B Ratio and **Alloy** have the similar secondary impact

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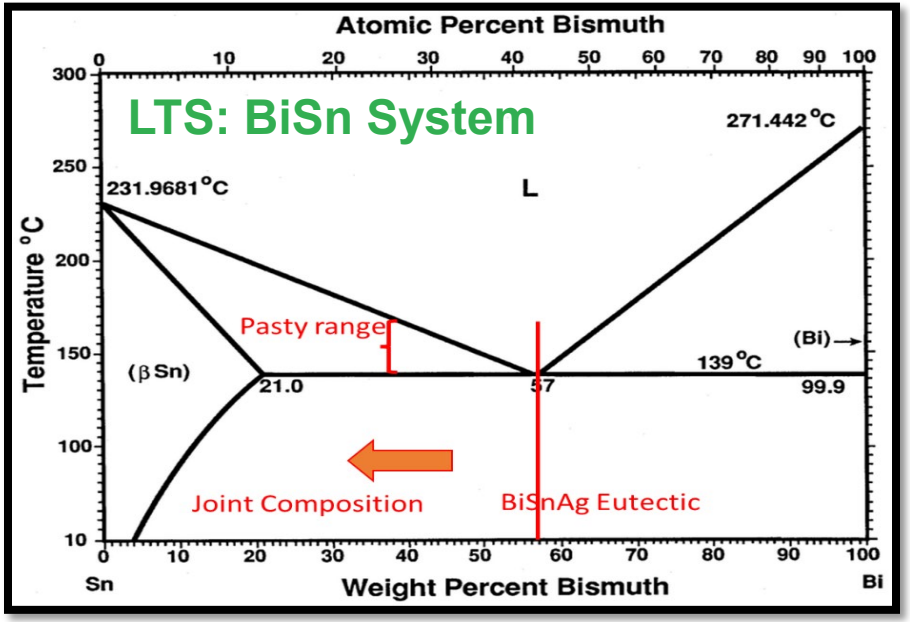
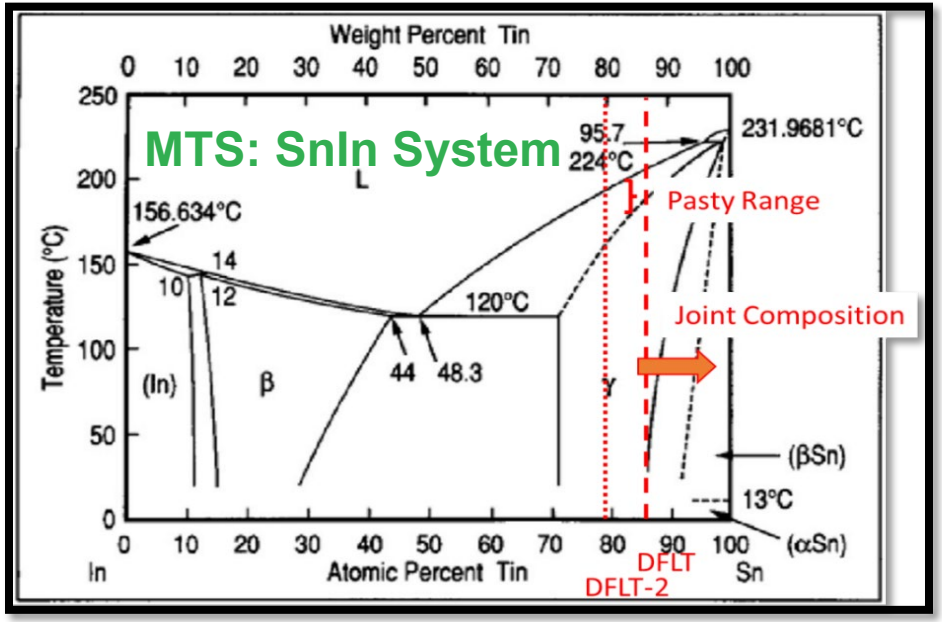
Impact of Alloy Metallurgy





Hot-tearing:

Sufficient molten alloy & Pasty Range & the Coincidence of Pasty Range vs Warpage

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Conclusions

- Reflow Temperature has the most important impact for Large BGA Assembly.
- P2B Ratio and LTS/MTS Alloy can further improve only under the “optimized” profile.
- Combination of Solder Metallurgy Selection and the Warpage of BGA component may be necessary to avoid Hot-tearing

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THANK YOU!

- Questions?

- hzhang@indium.com or askus@indium.com

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