Properties of Mixing SAC Solder Alloys with Bismuth-Containing Solder Alloys for a Low Reflow Temperature Process

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ABSTRACT

The subject of extensive research has been the establishing of lower temperature soldering of electronic assemblies that are similar to the once common yet still preferred eutectic Tin-Lead (SnPb) soldering processes that are below 217°C. This research measured and compared the mixing mechanisms of paste and ball dissolution. Mixed soldered assemblies will have different dissolution results that are dependent on the peak reflow temperature. The hypothesis for this experiment was to determine the relationship of various times above the melting point of low temperature solders containing Bismuth. The results measured are from solder joints of both SAC305 and Bismuth containing solders formed at lower process temperatures compared to the standard high temperatures which peak at 230°C-260°C. The Bismuth containing solders evaluated start with the highest to lowest weight percentage of Bismuth, the eutectic 58Bismuth/42Tin (58Bi/42Sn), 57Bi/42Sn/1Ag and a propriety alloy that has a lower Bismuth content along with various micro alloys, defined as 40-58Bi/Sn/X (X representing proprietary micro alloys or doping). The assembly was with an 18mil 96.5Tin/3.0Silver/0.5Copper (SAC305) solder ball mixed with each solder paste. These solder alloys were exposed to three different peak temperatures 180°C, 195°C, 205°C. Another reflow profile attribute of focus was times above 138°C - the melting point of the eutectic Sn58Bi alloy, this term used throughout the study is referred to Time Above Melting (TAM). The ball and paste assembly used the times above melting of 120sec and 240sec to represent process extremes and verify their significance on improving mixing level results. The average mixing % levels were recorded and compared for each solder joint combination to test the theory that the solder paste solidifies during the time above melting (TAM) within the reflow oven. [1] This experiment effectively demonstrates that the reflow profile parameter for time above melting has limited effectiveness in additionally mixing the paste with the BGA solder ball. Optimization of mixing percentages will need to be achieved by optimizing the paste and ball volumes.

Key words: Mixing SAC Solder, Bismuth-Containing Solder Alloys, Low Reflow Temperature, BGA

INTRODUCTION

The subject of extensive research has been implementing Low Temperature soldering of electronic assemblies that are a near drop in alternatives to the eutectic SnPb manufacturing process.

The objective for nearly two decades has been replacing the hazardous SnPb solder alloy with a suitable alternative based off manufacturability, cost, reliability at high temperature and long life. [2] The widely adopted alloy at this point has been 96.5Sn-3.0Ag-0.5Cu (by weight percentage) and is a hypoeutectic alloy from the Sn-Ag-Cu (SAC) ternary system and has a melting point starting at 217°C which is 34°C above the tradition eutectic SnPb temperature of 183°C. [3-4]

The acceptance of SAC305 came after considerable research on the many other Pb-free alloy alternatives including Sn-Bi that better fits as a near drop in alternative alloy to fit the SnPb manufacturing process, though it lacked comparable mechanical properties. [5-8]

SAC alloy adoption in the electronics industry has disrupted manufacturing processes along with component supply chain. The there are many difficulties in managing the higher temperatures of the new manufacturing processes that accommodated the widespread use of Pb-free solders particularly the SAC solder alloys. Considerable effort to address this dilemma has been driven by industry collaborations in consortia organizing massive data analysis projects to contribute more data on mixed solder alloy assemblies that can be formed at lower process temperatures. [9-11] The rationale behind this paper is to provide mixing data for various reflow profiles to assist in developing optimal reflow profiles for industries efforts to implementing low temperature soldering processes.

LITERATURE REVIEW

Prior Low Temperature Solder Studies

During the lead-free transition in 2006, lower process temperatures were enabled by mixing SnPb solder paste with SAC solder alloys, this method was referred to as backwards compatibility. The mixed assembly research consisted of SAC alloyed components like ball grid arrays (BGAs) with SnPb solder paste. The key factors found at that time were establishing acceptable mixing. One paper [13] suggestion greater than 30% mixing was required to mitigate the defect of hot tearing at the PCB land interface yet less than 80% to avoid the defect of brittle rupture at the package land-solder interface. Related mixing research has been tested at temperatures peaking as low as 208□ yielding non-homogenous solder joints exhibiting uneven compositions and microstructures that do outperform traditional leaded assemblies in thermal fatigue testing. [13] The literature also reveals information on partial mixed solder joints that show a measurable degradation in reliability compared to full mixing which enable self-alignment and fully collapsed joints that yield key characteristics of acceptable solder joint geometry and quality. [14] The limitation of the impact of these mixing studies is that they are not applicable to the entire industry only those currently still exempt from RoHS. These leads to the synthesis of another mixed alloy assembly approach revisiting the various of Pb-free solders like 58Bi/42Sn or Sn-Bi compositions that could further reduce the manufacturing process temperatures required for SAC solder alloys. [15-17] Reducing the peak temperatures can lead to even greater improvements in yield. The warpage of a common component was found to be reduced by 30-50% when reflow peak temperatures were in the range of 160˚C -180˚C. [18]

Bismuth is of great interest for a SnBi solder alloy alternative to SnPb in the years surrounding the RoHS directive mainly for its cost, availability and environmental impact. [1,2,4,6,10-14] Promising results of tensile strength and creep resistance of eutectic SnBi which melts at 138°C compared to be better than that of SnPb same properties. [19-23] Still the eutectic SnBi was discredited as a viable solution from poor mechanical shock and fatigue resistance from the very nature of the element Bismuth is known to be more brittle than most. [24-25] These properties of Bi lead to an understanding of poor drop performance compared to Sn-Ag3.0-Cu0.5 that has a drop shock performance 4x of the SnBi alloy. [26] Despite the decline in Sn-Bi the results of many micro alloying studies show the addition of Ag by 0.25wt% to 1.0wt% to SnBi improved the ductility and reduced brittleness an increase in tensile strength and elongation and young's modulus, a good indicator of drop shock performance of a SnBi solder joint. [27-28] A study {27} confirmed these improved mechanical and thermal properties of SnBi with small Ag additions and the preferred alloy being commercialized is Sn42/Bi57.6/Ag0.4.

The struggle still exists of the high temperatures of SAC alloys and alternatives for use in microelectronic interconnections and for package-on-package assemblies continues to be researched to enable lower temperature processes. [29-31] Also the goal remains for Electronic Manufacturing Service (EMS) providers to once again utilize low Tg substrates and other component materials previously reliable for SnPb to further reduce costs. [32]

The large efforts to identify a Low Temperature solder alloy drives the need for understanding the metallurgical condition through reflow and correlate that to reliability. Areas of knowledge gaps regarding mixed alloy assemblies are associated with the challenges in manufacturing processes and reliability. Mixed alloy assembly studies are beginning to rise in numbers attempting to fully characterize the complex microstructure of mixed SnBi with SAC solder alloy and the influence on electrical, mechanical and thermal properties.

As the industry considered backwards compatible mixed SAC/SnPb alloy assembles there are cross references to be made including the complex solidification behavior of mixed alloy assemblies revealing that shrinkage voids in rework or crack propagations can occur through the low melt accumulation region of a mixed SAC Sn-Pb alloy assembly. An indication of a potentially similar challenge for mixed SAC-SnBi alloy assemblies exists in literature. [15, 26, 33]

Research must address manufacturing process influences on mixing with the concern of proper solder joint collapse related to correct volumes of pastes and optimal profiles of various size components or risk further reduction of mechanical properties compared to SAC alloy solder joints. [12, 23, 34] Optimal reflow profiles are a key factor for mixing and solder joint collapse height as a function of peak temperature. [16, 18, 35, 36]

Anselm et al [38]. has presented extensive work of the relationship of mixed SAC/SnBi alloy assemblies including results showing the Bismuth mixing with various peak temperatures and the associated shear strength associated with the microstructures of these mixed solder joints. Gomez et al. [38] recently published work that advanced LTS process development by characterizing the mixing relationship of three SnBiX solders mixed with SAC305 assembled at peak temperatures 175C-215C increment every 5C degrees to begin to build a modeling database for EMS providers. It was found that there existing mixing mechanisms that are more dominant in some solder alloys than others. Mixing mechanisms can vary. Some solder joints demonstrate a dissolution of the center of the SAC solder ball while others dissolve along the outside of the solder joints. The other mechanism showed the wetting of the solder going higher on the outside of the solder joint then compared to the center which remained significantly lower, this was determined to be a function of flux as well as melting temperature.

In 2017, Gomez et. al., and industry partners at Intel determined two mixing mechanisms for mixed solder alloys. [37,39] Mechanism #1, center diffusion is when the SnBi solder paste diffuses into the solder ball via the center of the solder joint shown in Figure 1. Significant factors to increase lattice or grain boundary diffusion of Bi is the Bismuth concentration gradient and the SAC ball alloy composition [37]..

Figure 2 represents mechanism #2 wetting for which a lower temperature solder paste will be able to mix more with a solder ball by wetting around the undiffused high melting solder ball. This wetting/wicking of solder paste over the solder ball limits the ability for the solder ball to get higher center diffusing levels driven by the paste flux covering the ball reducing its energy. [37] The lighter grey area in both figures is off-eutectic and either solidified or in the pasty range of the alloy. These various conditions during reflow will dramatically reduce the dissolution rate of the SAC305 solder ball.

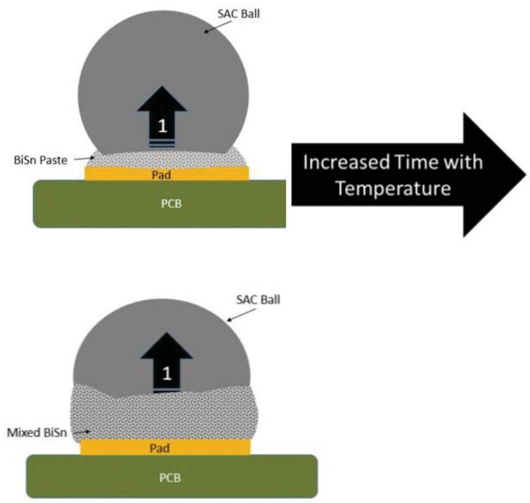


Figure 1: Mixing Mechanism #1

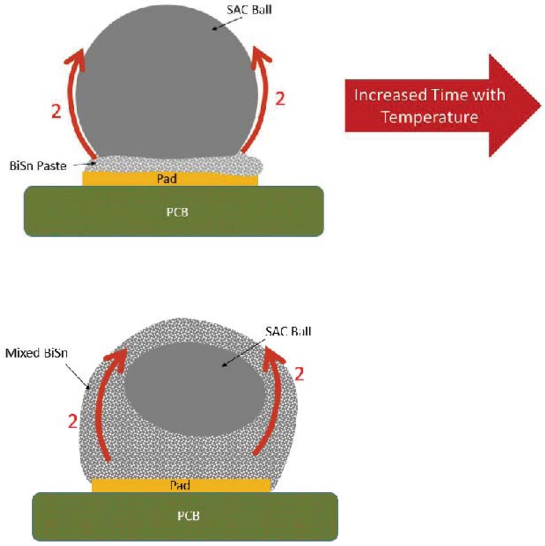


Figure 2: Mixing Mechanism #2

The limitation of the previous three studies merely remain in the assembly method of the mix solder joints being of isolated solder balls manually placed on low temperature solder paste. This practice of ball and paste assembly is efficient for metallurgical comparisons though full system testing of actual components could alter the results significantly.

This study characterizes the mixing relationship of multiple SnBiX solders mixed with SAC alloys specific to component size while also gaining insight on the influence that the time above the melting point of the SnBiX solders will impact mixing.

EXPERIMENT #1 BALL AND PASTE ASSEMBLY

Objective and Motivation

The objective of this study was to observe the mixing of SnBiX-SAC Solder Ball Joints at extended reflow times above melting ≥ 138°C at various peak temperatures.

Table 1: Experiment #1 Test Matrix

DOE Test Matrix	Level-1	Level-2	Level-3
Reflow Profile Max. Temperature, °C	180°C	195°C	205°C
Lead Free Paste	A (58% Bi 42% Sn)	"B" (40%-58% of Bi)	"C" (57%Bi 42%Sn 1% Ag)
Time Above Melting (TAM) ≥ 138°C	120 sec	240 sec	
Solder Ball Details	Sn3.0Ag0.5Cu (SAC305) Diameter = 18 mils		

This study includes the quantitative and yield Bismuth mixing percentages to explore the correlational to time above melting. The significance of the direct correlation between higher peak convection reflow temperatures with longer times above melting and higher mixing percentages of SnBi-SnAgCu Solder Ball Joints analyzed.

The independent variables include; Reflow Profile Maximum Temperature, Low Temperature Solder Pastes, Time Above Melting (TAM). The dependent variables; Mixing Percentage of Solder Pastes and Solder Ball. The control factor in this experiment is the Solder Ball Composition of Sn96.5%Ag3.0Cu0.5%, SAC305.

Materials

Three Tin-Bismuth solder alloy pastes have been selected to validate and further accumulate data similar to another low temperature solder project. [38] These solder pastes mixed with widely accepted default Pb-Free solder alloy SAC305. The alloy names, constituent elements, minimum melting temperatures are shown below.

Table 2: Experiment #1 Material Properties

#	RIT Solder Alloy Name	Known Alloy Constituents and Composition	Melting Temp. (˚C)	Sphere Diam.
1	"A"	58% Bi/Sn42%	138°C	Type 4
2	"B"	Bi% between 40% and 58% plus additional micro-alloy additives	Around ~151°C	Type 4
3	"C"	57%Bi/42%Sn/1%Ag	~ 140°C	Type 4
4	SAC305 Solder Ball	96.5%Sn3%Ag0.5%Cu	~ 217°C	18 mils

"A" is the Eutectic Tin-Bismuth solder alloy and represents the largest percentage of Bismuth for a Pb-Free solder paste alternative. "C" has a slightly lower Bi content and includes Ag while also having an increased melting temperature. The "B" combination is marketed as more a reliable LTS for harsher environments as compared to SAC305.

Test Vehicle

This study utilizes a PCB with the following attributes: 18mil diameter pads that were Non-Solder Masked Defined with an Organic Solderability Preservative (OSP) finish. The assembly location is outlined in red, reflow direction indicated by the arrow, and reflow profiling thermocouple locations marked in yellow.

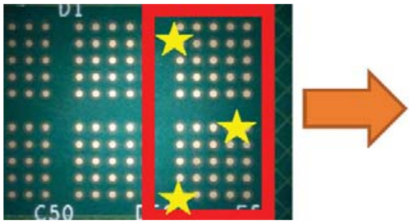


Figure 3: Experiment #1 Test Vehicle

Assembly Details

The assembly technique used is categorized as a Ball and Paste (BP) method, this is describing that a solder ball will be placed on the solder pad locations that have solder paste. The procedure of this assembly technique follows the following modified surface mount assembly steps:

1.) Application of Solder paste by Stencil and Squeegee

2.) Placement of Solder balls by operator using tweezers and microscope

3.) Convection Reflow Oven to melt and join solder

There is risk of errors associated with the manually placement of the solder balls with this assembly method. The cost and academic nature of the expected results justified manually placement despite the risk of misalignment and placement pressure variability. The overall effects on results have been anticipated and have been qualitatively not deemed a significant error on the mixing of the solder ball to solder joint. This is still acknowledged as a deficiency within this method of assembly. This method of assembly is not realistic for production and the results to provide metallurgical evidence of the broad influence of Time Above Melting on practical manufacturing process parameters.

Stencil Printing

In the Printing process of the solder pastes on the board the DEK Horizons 01ix Proactive Stencil Printer was programmed with a speed of 50 mm/s and a pressure of 5.0 kg force. All solder paste printed locations were analyzed with an inline Koh Young Solder Paste inspection machine along with manual visual inspection to determine paste transfer efficiency of each print. Each board was analyzed with a pass/fail criterion that accounted for volume, area, shape and height of each solder paste deposits. The volume of solder

Paste to volume of the solder sphere is a 0.21:1 ratio.

Table 3: Experiment #1 Stencil Printing Details

Stencil Details	
Thickness	5 mils
Aperture	18 mils
Finish	Laser Cut
Size	VG260 (23" Vector Guard)
Stencil Printer Machine Setting	
Speed	50 mm/s
Pressure	5.0 kg
Squeegee	Metal, 60°
Supports	Magnetic

Solder Mixture Composition Calculations

The aperture design of the stencil and the weight percentage of the elements in the solder paste and solder ball enable an approximation for determining the mixed solder joints element composition to compare. Finding the theoretical volume of the paste uses the volume of a cylinder formula V= πr2h. Assuming that the radius of the stencil is 9 mils and that the thickness of the stencil is 5 mils, we can obtain the following:

Vol. paste deposit = π x (0.009 mils)^{2}x 0.005
= 1.2717 x 10-6 inch^3
= 2.084 x 10-5 cm^3 (1 inch^3 = 16.387 cm^3)

Since all the solder pastes that were used are a Type 4 Solder Paste, they are 50% metal content and 50% flux, requiring the necessity to divide the Vol. paste deposit in two which will estimate the volume of the metal of the solder deposited.

Vol. paste deposit = 1.042 x 10-5 cm^3

Taking the volume of the metal content and knowing that the density of 58Bi/Sn42 is 8.56 g/cm^3, we can calculate the Mass of the metal content:

Mass = Density x Volume
= 8.56 g/cm^3 x (1.042 x 10-5 cm^3) = 0.0892 mg
Mass of the metal content for 58Bi/42Sn = 0.0892 mg

Next, we can calculate the metal content of the 96.5Sn/3.0Ag/0.5Cu (SAC305) solder ball, V = 4/3 πr^3. Assuming that the radius of the BGA sphere is 9 mils, we can obtain the following:

Vol. SAC305 = 4/3 x (0.009)^3
= 3.05 x 10 -6 inch^3
= 5.0x10-5 cm^3 (1 inch^3 = 16.387 cm^3)

Taking the volume of the metal content and knowing that the density of SAC305 is 7.40 g/cm^3, we can calculate the Mass of the metal content:

= 7.40 g/cm^3 x 5.0 x 10-5cm^3 =0.00037g
Mass SAC305 = 0.37 mg

The total mass would be Mass 58Bi/Sn42 + Mass SAC305 = 0.4592 mg

Table 4: Experiment # 1 Reflow Profile Parameters

Process Parameter	#1	#2	#3	#4	#5	#6
Peak Reflow Temperature (°C)	180°C	180°C	195°C	195°C	205°C	205°C
Time Above Melting (TAM) ≥ 138°C	120 sec	240 sec	120 sec	240 sec	120 sec	240 sec
Cooling Rate (°C/sec)	1-3 °C/sec					
Initial Ramp Rate (°C/sec)	1-3 °C/sec					
Soak Time (100 – 120 °C) sec	60 – 90 sec					

The composition of the 58Bi/Sn42 Paste is: Bi - 58 wt% /Sn - 42 wt% , and that the composition for SAC305 is: Sn - 96.5 wt% / Ag - 3.0 wt% / Cu - 0.5 wt%. We can then multiply the composition of the 58Bi/Sn42 paste with the mass of the 58Bi/Sn42 paste in order to obtain the mass of each element in the 58Bi/Sn42 paste deposit:

Bi - 0.05174 mg/ Sn - 0. 03746 mg (6)

Repeat for SAC305:

Sn – 0.3571 mg / Ag - 0.0111 mg / Cu - 0.00185 mg

This was done for the 57Bi/Sn42/1Ag in the table below, missing due to proprietary restrictions is the "B".

Table 5: Experiment #1 Mixed Solder Alloy Composition in Wt%

Mixed Solder Alloy	Composition in Wt% of Solder Mixture
58Bi/42Sn + 96.5 Sn/3.0 Ag/0.5 Cu	Sn% – 85.91 wt% Bi% – 11.27 wt% Ag% – 2.42 wt% Cu% - 0.40 wt%
57Bi/42Sn/1Ag + 96.5Sn/3.0Ag/0.5Cu	Sn% – 85.91 wt% Bi% – 11.08 wt% Ag% – 2.61 wt% Cu% - 0.40 wt%

Reflow Oven Profile Details

The convection reflow oven used was the 8-heating zone Heller 1808 MK III and profile developments utilizing the KIC RPI Reflow Software and SPS wireless reflow profiler hardware. This profile development software enabled accurate process parameters to be met according to our research design of peak temperatures and times above melting. K-type thermocouples were epoxied to the locations marked in yellow in Figure 3 to get temperature distribution data across the assembly location. This temperature data also enabled the KIC RPI Reflow Software to utilize its prediction algorithms to enhance profile development. The reflow profile process specifications for this study are shown in the table below and were defined in collaboration with our industry partner. Another reflow profile attribute of focus was times above 138˚C the melting point of the eutectic 58Bi/42Sn alloy, this term used throughout the study is referred to Time Above Melting (TAM).

Measurement Methods

The assembled test boards went through the process of being potted completely in an epoxy resin to enable grinding and polishing of the cross-sectional view of half the mixed alloy solder joint. The diamond particles used polishing of the cross-section will rid the surface of any scratched that might otherwise be hindering our ability to measure the mixing levels of the solder joint.

The method of measuring the mixed SAC305 + SnBi solder joints is determined by the heights of the diffusion of the Bi region into the solder joint on the left, right and center of the solder joint along with the overall height of the solder joint. [39]

Table 6: Experiment #1 Build Matrix

Board #	Reflow Condition	Reflow Condition	Solder Paste
1	180C Peak	120 sec TAM	"A" (58%Bi 42%Sn)
2	195C Peak	120 sec TAM	
3	205C Peak	120 sec TAM	
4	180C Peak	240 sec TAM	
5	195C Peak	240 sec TAM	
6	205C Peak	240 sec TAM	
Board #	Reflow Condition	Reflow Condition	Solder Paste
7	180C Peak	120 sec TAM	"B" Paste (40%- 58% Bi)
8	195C Peak	120 sec TAM	
9	205C Peak	120 sec TAM	
10	180C Peak	240 sec TAM	
11	195C Peak	240 sec TAM	
12	205C Peak	240 sec TAM	
Board #	Reflow Condition	Reflow Condition	Solder Paste
13	180C Peak	120 sec TAM	"C" (57%Bi 42%Sn 1% Ag)
14	195C Peak	120 sec TAM	
15	205C Peak	120 sec TAM	
16	180C Peak	240 sec TAM	
17	195C Peak	240 sec TAM	

The equation below shows a method to use the heights for the average mixing percentage of a solder joint. [37, 38]

$$Average\ Mixing\% = \frac{((HL + HC + HR)}{3 * HSOH} * 100$$

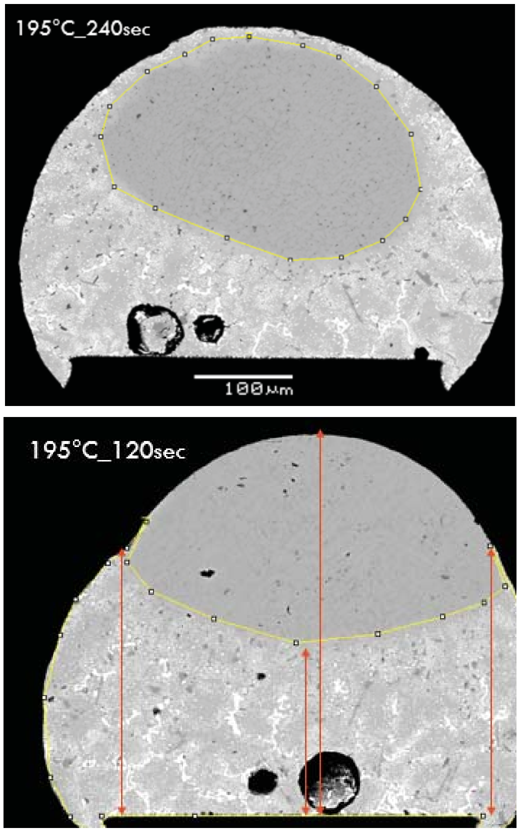
H_L = Height Left H_C = Height Center
H_R = Height Right H_{SOH} = Solder Overall Height

Equation 1: Average Solder Mixing % Calculation

Previous mixed alloys studies have been able to use these linear measurement methods and calculations though this study brought upon a new need for measuring surface area to calculate mixing. Shown in Figure 5 is the method used to measure mixing % with the surface areas of a cross-section. Utilizing a polygon selection tool in the National Institutes of Health (NIH) Image-J software, measurements were possible to calculate mixing percentages of solder joints that had solder paste wet over top of the SAC305 Solder ball without first fully diffusing the two solder alloys in the center.

$$Average\ Mixing\% = \frac{(Solder\ Joint\ Surface\ Area - SAC305\ Surface\ Area)}{Solder\ Joint\ Surface\ Area} * 100$$

Equation 2: Alternate Solder Mixing % Calculation



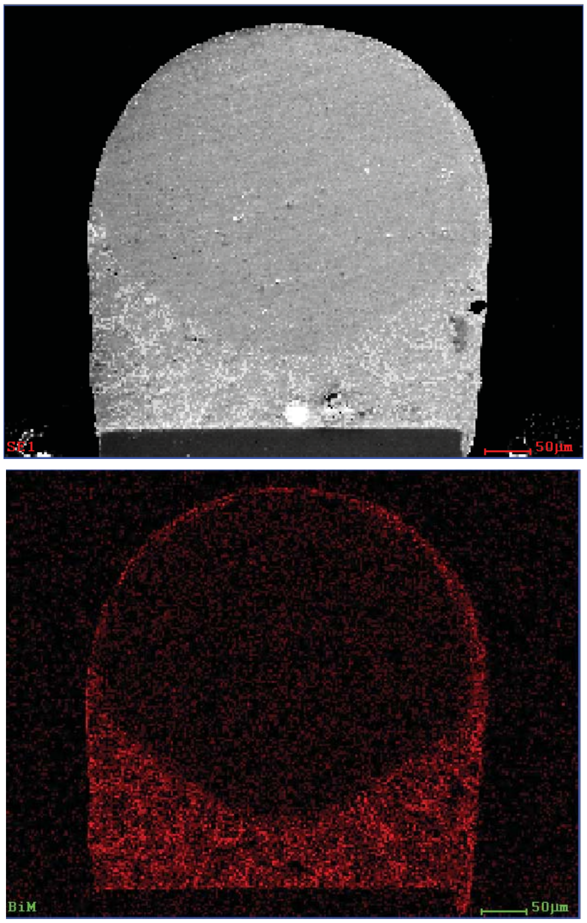
a.)

b.)

Figure 5: Comparison of Solder Mixing % Calculations of a.) Original and b.) Alternative Method

SEM and EDX Analysis

The longer times above melting revealed that at the solder pastes were more susceptible to begin to start wetting up and around the solder ball. The cross-sectional images of the solder joints in Figure 10 are in a greyscale though the bright white areas are the Bismuth rich areas along the unmixed SAC305 regions. The element analysis feature on the SEM identifies elements present on the surface in view and on the next page the EDX capture the presence of Bi, Sn, Ag along separating them by color. The locations of the red area on the Energy Dispersive X-Ray Analysis (EDX) map would overlay on bright regions indicating the presence of Bismuth. In Figure 10 location "c" the SnBi paste has wetted up over the top of the solder ball, a feature that is not desired. Figure 11 below separates the elements of the mixed solder joint and the top left image is the presence of the Bismuth that wetted over top of the solder ball and could pose as a reliability threat if this was an electronics assembly that could now have two brittle interface at the top and bottom of the solder joint.



a.)

b.)

Figure 6: a.) SEM Image b.) EDX Map of the element Bi in a Mixed SnBi-SAC Solder Joint

To confirm the presence of Bismuth the EDX spectrum analysis is seen in Figure 7 and quantifies the Bismuth located at the top center of a solder joint.

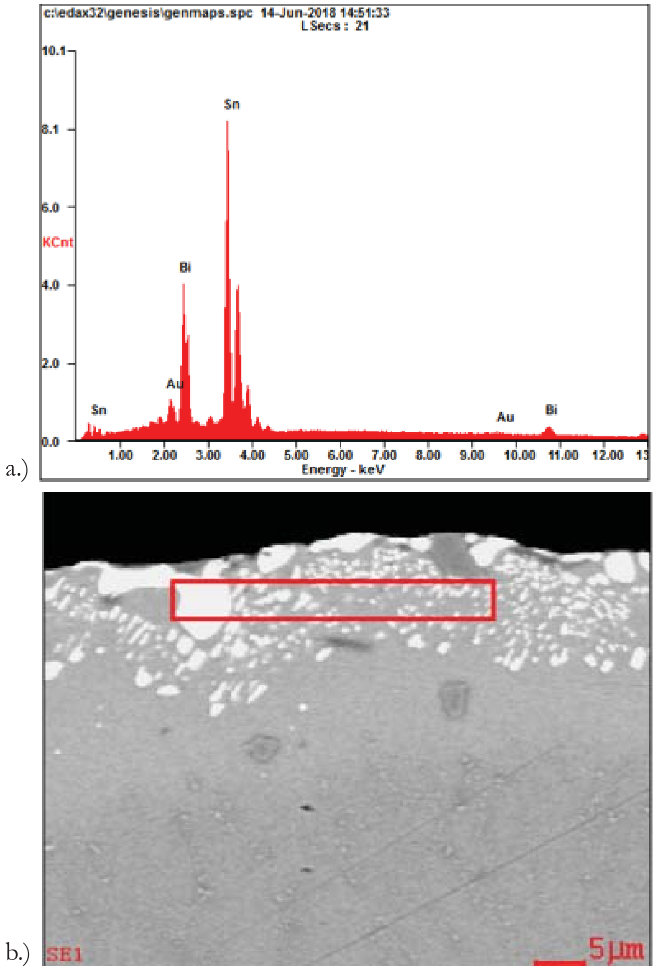


Figure 7: a.) Spectrum Analysis Results b.) SEM Image of top of Mixed SnBi-SAC Solder Joint Area of Interest

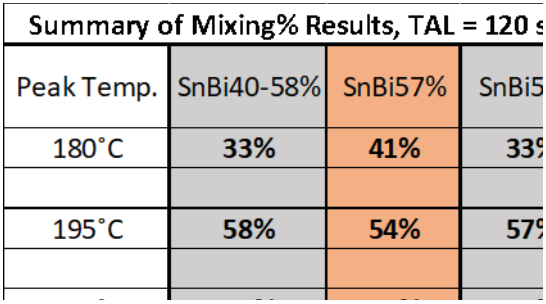
RESULTS

The cross-sectional images of all the solder joints revealed the mixing mechanism and enabled calculations to quantify the different effects of the temperatures and the times above melting for each SnBi-SAC solder joint.

To test significant effects of TAL points and peak temperature a side by side quantitative mixing % calculations were made and the results are shown in the Table 7 a-b and sample image below of one mixed solder joint, eutectic SnBi-SAC305.

Table 7: Summary of Mixing Results, a.) TAL=120 sec b.) TAL=240 sec.

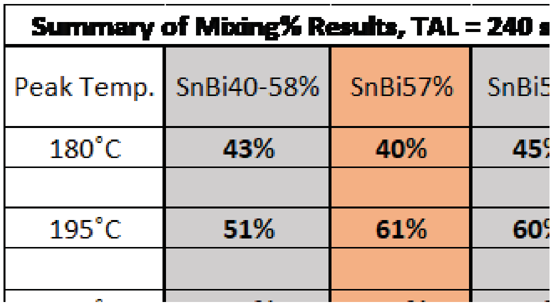
a.)



Summary of Mixing% Results, TAL = 120

Peak Temp.	SnBi40-58%	SnBi57%	SnBi5
180˚C	33%	41%	33
195˚C	58%	54%	57

b.)



Summary of Mixing% Results, TAL = 240

Peak Temp.	SnBi40-58%	SnBi57%	SnBi5
180˚C	43%	40%	45
195˚C	51%	61%	60

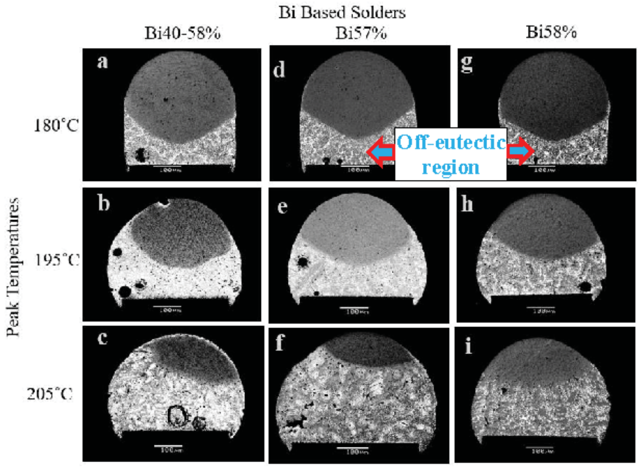


Figure 8: Cross-sectional SEM Images of the Averaged Mixed Solder Joint Combinations at TAL:120sec

The raw data reveals that there are no significantly different mixing levels at 195˚C between all three solder pastes. The solder pastes "B"(40-58%Bi) and "A"(58Bi/42Sn) had no significant differences between them.

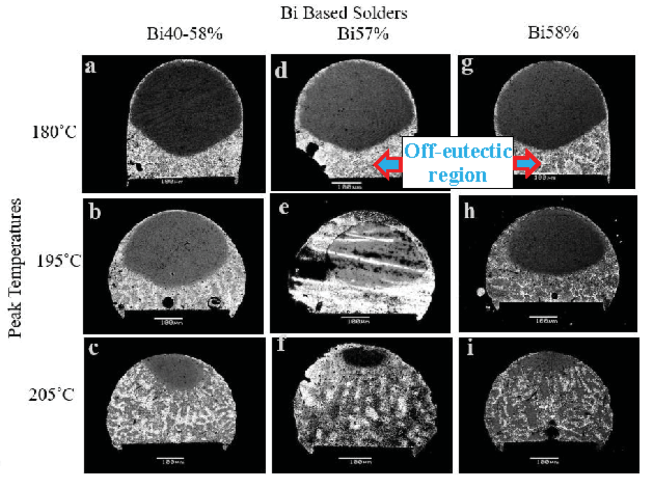


Figure 9: Cross-sectional SEM Images of the Averaged Mixed Solder Joint Combinations at TAL: 240sec.

The mixing results for SnBi40-58 are significantly different at the peak temperature of 195C. Cross-sectional SEM images of all mixed solder joints with a TAL: 240sec expose the explicit mixing mechanism that the solder joints create with an extremely long time above their melting point. At each peak temperature the solder joint has the Bi-based solder paste wet to the top of the solder joint risking the strength of the solder joint.

A summary of the mixing results for the various profiles and TALs are shown in Figure 120 below.

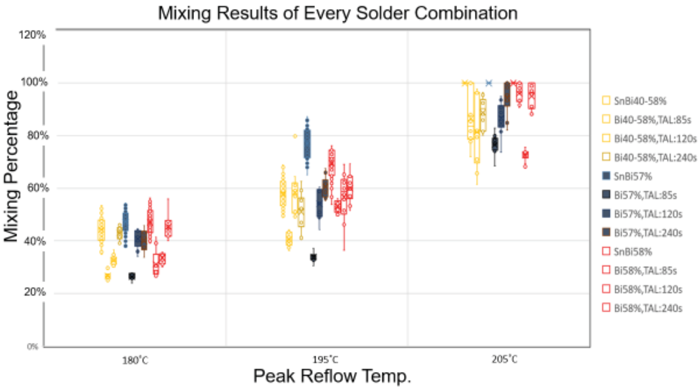


Figure 10: Plot of Bismuth Mixing % of all Solder Joints

SUMMARY

The comparison of all the Bismuth Mixing results at the of the solder pastes verifies that the rational production parameters of a time above melting/liquidus can be 85-90 seconds to achieve statistically similar mixing percentages with Bismuth containing solder pastes and SAC305 solder spheres. This experiment effectively demonstrates that the reflow profile parameter for time above melting has limited effectiveness in additionally mixing the paste with the BGA solder ball. Optimization of mixing percentages will need to be achieved by optimizing the paste and ball volumes. Profile TAM should follow paste manufacturer recommendations to ensure good wetting and reduction of other reflow related defects such as solder balling and voiding.

FUTURE STUDIES

There is more analysis that can be done with these same mixed solders with a ball grid array component to further understand the mixing dissolution properties of these solder joints. A new parameter in future studies should be with the material properties of the solder ball which is SAC405. Following the micro-structural analysis of these BGA assemblies there will be thermal fatigue tests performed. Thermal fatigue tests will yield reliability results in relation to low temperature mixed solder joints as well as which mixing mechanisms lead to greater reliability.

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Tayler Swanson now works as an engineer at Digital Instruments supporting their electronics design and production located in Buffalo, NY.

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