TECHNOLOGY TODAY FEATURE

ADVANCEMENTS IN LOW TEMPERATURE SOLDERING

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ALPHA ASSEMBLY SOLUTIONS

Revolutionary new solder alloy enables peak reflow at lower temperatures while improving mechanical reliability and radically reducing warpage.

Low temperature alloys have been under consideration ever since the proposal of change in legislation restricting the use of lead (Pb) in electronics soldering. Despite the limitations previously encountered with Sn-Bi solders in the past, a recent shift in requirements for various market segments within the electronics industry have brought them back to the forefront of soldering technology for their progressive contributions to low temperature soldering.

Usually, bismuth and indium are two obvious choices for lowering melting temperatures of Sn-based solders. Table 1 shows examples of alloys that could be used for soldering and their respective melting temperatures. Among them, the alloys with melting temperatures below the eutectic Sn-Pb have bismuth and/or indium addition. However, due to its lower cost and availability, Sn-In alloys were quickly discarded and the 42Sn-58Bi alloy was initially evaluated as a Pb-free solder candidate. This was also an opportunity to improve upon issues encountered while using Sn-Pb solders, such as poor thermal reliability. Indeed, depending on the experimental conditions, its fatigue life could surpass that of the eutectic Sn-Pb [1-3]. Unfortunately, all the low temperature alloys showed below presented higher degree of brittleness than Sn-Ag-Cu and Sn-Cu systems. Besides its lower melting point limiting its storage and operating temperatures, 42Sn-58Bi's poor ductility surely resulted in lower fatigue life than other Pb-free solders such as SnAg/SnAgCu [2-3]. Such drawbacks have been limiting Sn-Bi solders application as soldering material.

ALLOY	MELTING RANGE, °C
99.3Sn-0.7Cu	227 - 232
99Sn-0.3Ag-0.7Cu	217 - 227
96.5Sn-3Ag-0.5Cu	217 - 221
62Sn-38Pb	183 (E)
42Sn-58Bi	138 (E)
48Sn-52In	118 (E)
67Bi-33In	109 (E)
52In-46Sn-2Zn	108 (E)

Table 1.
Melting range of selected solder alloys.

KEY FACTORS DRIVING THE USE OF LOW TEMPERATURE SOLDERS

A recent surge in the use of temperature sensitive substrates and components has brought Sn-Bi solder back into the spotlight. There is a strong economical motivation for reducing the overall cost of the electronics assembly process, which is also supported by growing technical challenges and environmental concerns. Use of low temperature solders enable significant cost reduction in assembly materials, for example by use of lower cost printed circuit boards, and energy. It also increases long-term reliability by reducing thermal exposure to higher reflow temperatures, and reduces the assembly process cycle time. Besides considerable hard dollar savings from reduced energy cost, reduction in carbon emissions is a welcome outcome for the environment as well [4]. Additionally, use of low temperature soldering facilitates multi-step assembly processes, in which additional components can be assembled using low temperature solder paste on the same printed circuit containing Sn-Ag-Cu solder assembled packages.

THE ROLE SN-BI ALLOYS PLAY IN REDUCING DYNAMIC WARPAGE

Perhaps, the most pressing aspect accelerating the re-introduction of Sn-Bi alloys for soldering is the need for reducing dynamic warpage when assembling the latest generation of ultra-thin microprocessors [5-7]. Just reducing the reflow temperature is not enough in this case, as mechanical shock and thermal cycling reliability are also required. Yet, most of the Sn-Bi solders previously evaluated do not match Sn-Ag-Cu mechanical shock performance [8-10].

The 42Sn-58Bi alloy has a typical lamellar microstructure (Figure 1), in which Bi (lighter colour) precipitates in the Sn-rich phase. Minor alloying additions can be used for modifying its microstructure, especially for attempting to reduce its brittle mechanical behaviour. The addition of

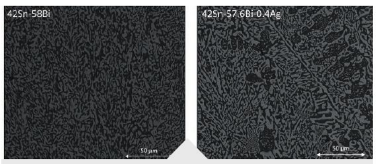

Figure 1.
Microstructure of 42Sn-58Bi and 42Sn-57.6Bi-0.4Ag

Ag has been one of the most common ways to modify 42Sn-58Bi microstructure and mechanical properties [11]. Similar to other soldering materials companies, Alpha Assembly Solutions has also used this technique. However, during extensive research on low temperature solders, Alpha

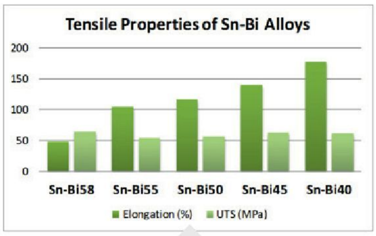

Figure 2.
Tensile properties of Sn-Bi alloys. ©2013 IEEE. Reprinted, with permission, from Ref. [13].

has showed that other micro-alloying additives can significantly improve 42Sn-58Bi and 42Sn-57.6Bi-0.4Ag mechanical shock and thermal cycling properties [12-15]. In agreement with other studies [13,16], Alpha has also showed that non-eutectic alloys with reduced Bi content have improved elongation and negligible changes in the ultimate tensile strength (UTS), as showed in Figure 2. However, in our most recent results we show that, reducing Bi content alone is not sufficient for improving Sn-Bi mechanical reliability in solder joints [17].

In order to benefit from reduced reflow temperatures and resolve dynamic warpage, it is important to limit reflow profiles to below 200oC. Table 2 shows the solidus and liquidus temperature of four Sn-Bi alloys with varying Bi content. Reflow profiles for SMT applications generally have peak temperatures that are 25-30oC above the solder melting point. Thus, a 60Sn-40Bi alloy would require a peak reflow temperature around 200oC, and Sn-Bi alloys with Bi content below 40 wt.% would not be appropriate for such applications. Since there is a pasty range as the temperature increases between the solidus and liquidus, it is also important to keep in mind the liquid fraction of these non-eutectic alloys. Reducing the Bi content from 58 to 55 wt.% moves the liquidus to 144oC, i.e., 100% liquid fraction. At the same temperature, alloys with Bi content below 45 wt.% present less than 78% liquid fraction and are at a certain disadvantage for forming mixed Sn-Bi/Sn-Ag-Cu solder joints.

A BRAND NEW SN-BI ALLOY TO REVOLUTIONIZE LOW TEMPERATURE SOLDERING

The latest, patented Sn-Bi solder alloy from Alpha Assembly Solutions, HRL1, has a liquidus temperature of 151oC, enabling peak reflow temperatures as low as 185oC. One example of such profiles in showed in Figure 3, which provides enough flexibility to account for adjustments in time above liquidus (TAL) based on specific board design, in order to achieve maximum performance. Selected physical properties of the HRL1 solder alloy are presented in Table 3. Compared to 42Sn-58Bi and 42Sn-57.6Bi-0.4Ag, HRL1 solder has lower tensile and yield

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strength, but higher Young's modulus. The latter is particularly important when selecting alloys for improved mechanical shock (i.e., drop shock) resistance. In fact, as showed in the table, 96.5Sn-3Ag-0.5Cu has lower tensile and yield strength, and higher Young's modulus than other Sn-Bi solder alloys.

*Measured by ultrasonic pulse-echo technique. The 42Sn-58Bi alloy drop shock characteristic life is 4.3 times lower than Sn-3Ag-0.5Cu, and by reducing Bi content this difference was reduced to 1.7 times [17]. Figure 4 shows the drop shock performance of HRL1 solder alloy using CTBGA84 components with 96.5Sn-3Ag-0.5Cu solder balls. There is a dramatic increase in the HRL1 drop shock characteristic life (951 drops), which is equal or better than 96.5Sn-3Ag-0.5Cu (875 drops).

TEMPERATURE, °C				LIQUID FRACTION, %		
ALLOY	SOLIDUS	LIQUIDUS	139°C	140°C	142°C	144°C
45Sn-55Bi	138	144	10	39	96	100
HRL1	138	151	80	92	97	99
55Sn-45Bi	138	168	9	50	75	78
60Sn-40Bi	138	178	16	66	75	77

Table 2.
Melting temperatures of various alloys.

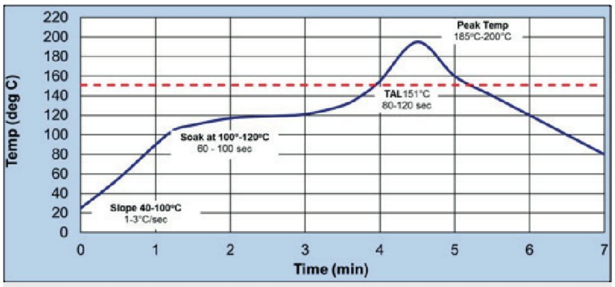

Figure 3.
Example of reflow profile to be used with HRL1 solder alloy.

ALLOY	SOLIDUS TEMP (°C)	LIQUIDUS TEMP (°C)	UTS (MPa)	YS (MPa)	ELONGATION (%)	E* (GPA)
45Sn-55Bi	138	144	10	39	96	100
HRL1	138	151	80	92	97	99
55Sn-45Bi	138	168	9	50	75	78
60Sn-40Bi	138	178	16	66	75	77

Table 3.
Melting temperatures, ultimate tensile strength (UTS), yield strength (YS), elongation and Young's modulus (E).

THE FUTURE OF LOW TEMPERATURE SOLDERING

ALPHA® OM-550 HRL1 Low Temperature Solder Paste will be commercially available this Fall – and will prove to be the most revolutionary advancement in solder paste since the introduction of lead-free. In addition to the data presented here, Alpha has performed a series of experiments that demonstrate its superior performance and reliability. ALPHA® OM-550 cuts the soldering temperature required for SAC alloys by 50°C, while dramatically reducing power consumption and carbon emissions. The result is a highly reliable, cost effective, energy sufficient soldering process with up to 99% less warpage and significantly fewer defects. Additional findings will be published in the future.

Morgana Ribas will be presenting on Low Temperature Soldering Using Sn-Bi Alloys at the 2017 SMTA International Technical Conference in Rosemont, Illinois.

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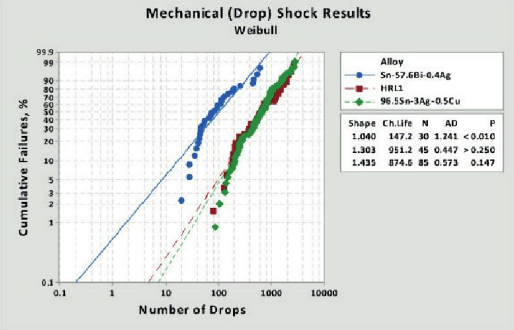

Figure 4.
Mechanical shock performance.

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