Low Temperature Solder Alloys's influence on Solder Joint Reliability

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Summary: The low temperature, lead free assembly processes are a hot topic for the PCB assembly industry ever since the industry moved to lead free materials. As with any assembly process, there have been technical challenges with the low temperature soldering (LTS) process as well, some, like the low melting ternary phase that weakens the joint, have been mitigated by the complete elimination of lead, others like the mechanical performance of the joint, are still of utmost importance today and the continuous materials development, both alloys and chemistries, are aiming to improve on those aspects. The mechanical performance of the joints, for both mixed alloys joints and standalone joints (joints formed with a combination of two or more alloys) are top requirements for the PCB assembly industry, the LTS process being no exception. A particular case, for the LTS assembly process is the mixed alloy joints formed with an LTS alloy and a SAC alloy and this aspect have been a high priority requirement for all the new LTS materials that have been developed lately.

Keywords: Low temperature assembly, reliability, high bismuth alloys, drop shock, thermal cycling, mixed alloy joints

Introduction and Practical

The benefits of using a LTS assembly process have always been placing the LTS materials at the top of the priority list for all material suppliers and the PCB assemblers. The reduction of carbon footprint and the potential dollar savings add to the appeal of the low temperature process [1]. The appeal of the LTS process have been further enhanced most recently by the increase in the multi-step assembly processes, the increase in the use of temperature sensitive components and substrates. Different LTS alloys have been considered for the LTS process and a comprehensive study have been carried out, using the mechanical performance of the alloys as a differentiator, in order to filter down the final candidates to be considered in the next step of evaluation (Tab. 1). The effect of additives has been considered in the second step (Tab. 2) [2]. The mechanical performance of the alloys is significantly improved when off-eutectic mixtures are used. Further improvements are achieved with the help of other elements in small addition to the base alloy.

Tab. 1: Melting temperatures of various LTS alloys

Alloy	Temperature, [ºC]		Liquid Fraction, [%]			
	Solidus	Liquidus	139ºC	140ºC	142ºC	144ºC
Sn-55Bi	138	144	10	39	96	100
Sn-50Bi	138	155	6	26	90	96
Sn-45Bi	138	168	9	50	75	78
Sn-40Bi	138	178	16	66	75	77
Sn-35Bi	138	186	12	61	70	77

Tab. 2: Melting temperature for Sn-Bi alloys with additives

Alloy	Solidus Temperature, [ºC]	Liquidus Temperature, [ºC]
Sn-57.6Bi-0.4Ag	137	142
Sn-58Bi-1Ag	137	142
Sn-38Bi-1Ag	137	176
Sn-58Bi-1Ag-1In	133	137
Sn-58Bi-1Ag-3In	125	133*

An important attribute, for an alloy that is used for PCB assembly, is the behaviour when in powder form. The study is looking at the performance of a Sn-Bi alloy used in a LTS solder paste, for the deposition process and the impact on solder joint formation. In particular the transfer efficiency has been used for characterizing the printing performance (Fig.1) and the voiding (Fig.2), drop shock (Fig.3) and shear force were used for characterizing the joint formed with a Sn-Bi alloy in an LTS assembly process.

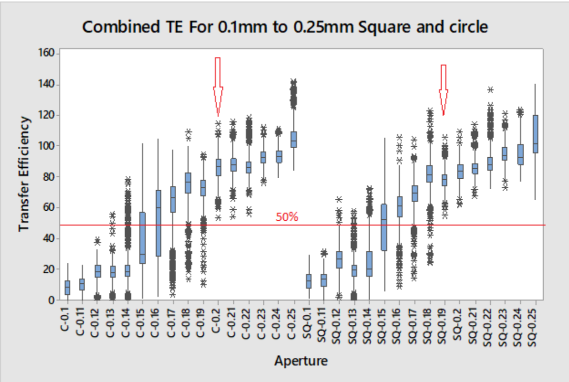

Fig.1 Transfer Efficiency performance for round and square apertures

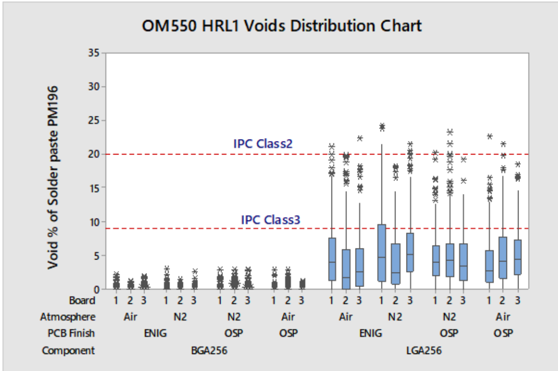

Fig.2 Voiding performance for OM-550 with HRL1 alloy

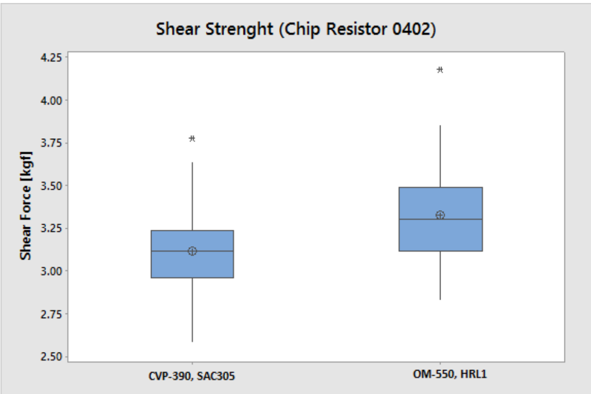

Fig.3 Shear force for 0402 chip resistors assembled with HRL1 and SAC305 alloys

Conclusions

The currently available LTS materials have come a long way, the improvements, versus the initial attempts at the beginning of the transition to Pb free processes, making the LTS alloys a viable option for the lead-free process. Of main importance, considering the mechanical performance of the joint formed, are the off-eutectic mixtures that can get in performance very close with the SAC305 performance. The body of work presented demonstrates the capability of the LTS off-eutectic alloys of high mechanical performance, measured by the means of drop shock and thermal cycling, for both the joints formed with the stand-alone alloy and the mixed joints, when a joint is formed by mixing the LTS alloy with a SAC alloy (used in the BGA spheres).The paste performance, during the battery of tests employed for this experiment, have demonstrated that there are chemistry platforms that are capable to work with LTS alloys, with the right rheology characteristics needed for the deposition processes and the right activation package needed for the reflow process. The LTS process, thanks to the new LTS materials available, makes a compelling proposition for the next generation assemblies, where higher integration, faster computing/processing speeds, lower footprint, lower carbon footprint and lower cost of ownership are targeted.

References

[1] News.lenovo.com. (2017). Lenovo™ Announces Breakthrough, Innovative PC Manufacturing Process | Lenovo Newsroom. [online]

[2] Ribas M, at al., Low Temperature Soldering using Sn-Bi Alloys, Proceedings of SMTA International, September 2017, Rosemont-USA