COMPARING THE PERFORMANCE OF ENGINEERED TIN/COPPER ALLOYS IN SELECTIVE SOLDERING

Engineered tin-copper solder is commonly chosen for use in RoHS-compliant selective soldering applications due to the cost advantage compared to silver-bearing alternatives. The added metals alloyed with eutectic tin-copper provide benefits that can differentiate various alloys in the tin-copper family.

An experiment was conducted to compare the soldering performance of two tin-copper alloys in a commercial selective soldering system. The experiment examined the effects of changing preheat temperature, solder contact time, and solder pot temperature on the hole fill performance with each alloy.

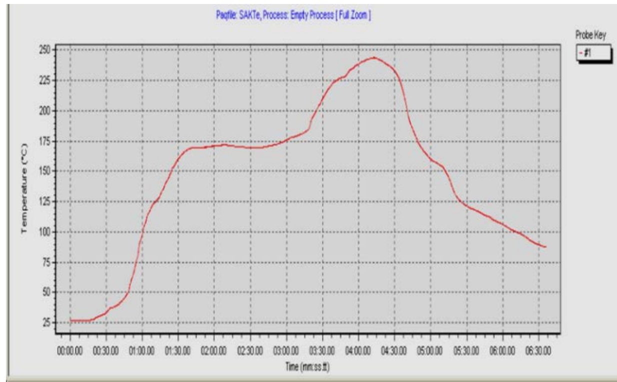
This article is a summary of a paper originally published in the proceedings of SMTA International, Rosemont, IL, September 25 - September 29, 2016.

TEST VEHICLE

The test vehicle is a PCI form factor connector soldered to an FR4 PCB with six 1-oz copper layers – four internal and two surface layers. Low surface energy matte black solder mask is applied and an OSP over bare copper final finish is present on the PCB.

The pins where hole fill was measured in this experiment were directly connected to the internal copper planes, without any thermal relief. This area was studied as it represents the most difficult soldering conditions for flow soldering processes and is a design requirement for certain applications where design for manufacture considerations cannot be accommodated.

The test vehicle was conditioned with two lead-free reflow profiles as shown in **Figure 1**, as most selective soldering occurs after a double-sided reflow SMT assembly process.



Soak 160^{0}C - 60sec, TAL 60sec, Peak 240^{0}C

Figure 1. Lead-free preconditioning reflow profile

SOLDER ALLOYS

Two alloys were compared in this experiment. Each is an engineered variant of the eutectic Sn99.3Cu0.7. Both alloys contain additions of nickel (at <500 ppm) as a copper dissolution reducing agent. Each alloy contains an anti-oxidant agent (at <100 ppm), although the alloys use different materials for this purpose (germanium or phosphorus). Finally, one alloy uses bismuth (at <2000 ppm) as a wetting agent. The two alloys will be referred to as SnCuNi+Ge and SnCuBiNi+P. Each alloy manufacturer reports a melting point of 227^{0}C for their respective alloys.

SELECTIVE SOLDERING PROCESS

The selective soldering system used was a semi-automatic system with manual loading and unloading and automated preheat, flux, and soldering functions. The flux application was performed using a programmed drop-jet flux system. The preheater consisted of an infrared source with a non-contact temperature sensor for closed-loop control of PCB topside surface temperature. The soldering module used a wettable nozzle with a 12 mm outside diameter and surrounded by a local nitrogen blanket. The assembly was held in a fixed position and the solder fountain was programmed to move in three axes.

X-RAY MEASUREMENT SYSTEM

The hole fill was measured using a transmissive X-ray inspection system. The system utilized an image analysis algorithm to measure the percentage of solder fill observed on selected holes. Each measurement location was programmed and fixed for all measurement samples. A sample image taken during this measurement is seen in **Figure 2**.

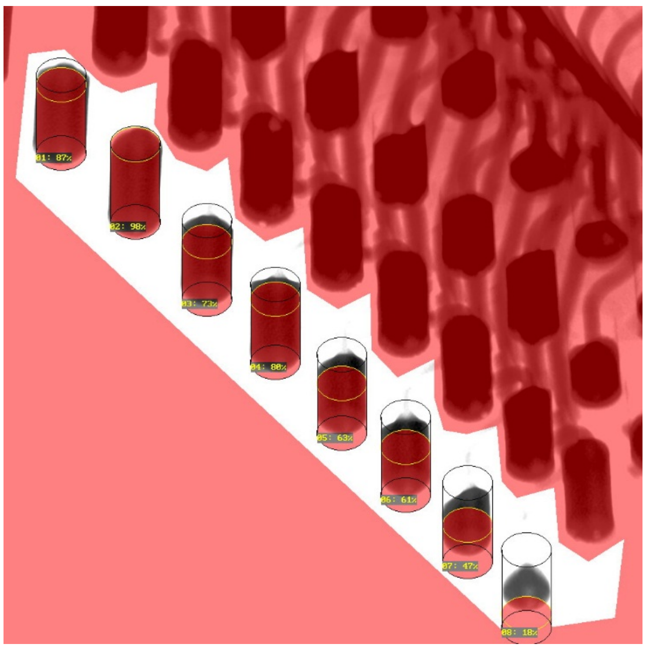


Figure 2. Sample X-ray hole fill measurement

SOLDERING EXPERIMENT DESIGN

This experiment was designed as a full factorial central composite response-surface experiment with three control factors: preheat temperature, solder pot temperature, and contact time.

The design of this type of experiment requires definition of the limits for each factor, and a center point is added as a third level. For preheat temperature, the lower and upper conditions were 70^{0}C and 130^{0}C with a center point of 100^{0}C added. For solder pot temperature, the lower and upper conditions were 280^{0}C and 310^{0}C with a center point of 295^{0}C added. For contact time, the lower and upper conditions were 2 and 5 seconds with a center point of 3.5 seconds added.

In an experiment of this type, with three input factors, a contour plot showing the relationship between predicted response and two factors can be generated when holding one factor at a fixed value.

Figure 3 shows the color key for the contour plots presented. Note that J-STD-001F 6.2.2 provides a minimum requirement of 75% hole fill for Class 3 assemblies. The same 75% minimum hole fill applies to Class 2 assemblies, with an exception for devices with 14 or more leads. That exception allows a minimum acceptable hole fill of 50% for PCBs that are 2.4 mm or less thick.

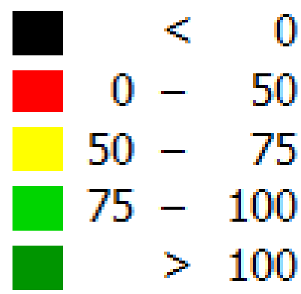


Figure 3. Hole fill percentage color key

HOLE FILL CORRELATION USING THICK BOARDS

The test vehicle in this experiment was 2.4 mm thick, but 1.6 mm thick PCBs are common. The hole fill performance on the thicker board can be used to predict hole fill on thinner boards using the correlation model developed by Ferrer, *et al.*[1] This correlates absolute vertical hole fill distance regardless of the actual PCB thickness. For an example, see **Figure 4**.

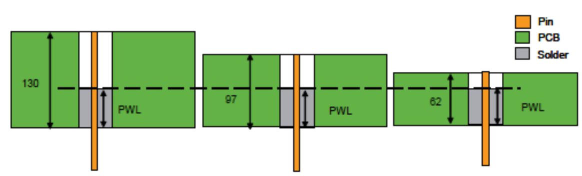


Figure 4. Hole-filling correlation model [1]

HOLE FILL ON 1.6 MM THICK PCBS

Figure 5 shows the predicted hole fill comparison for each alloy at 280^{0}C, 295^{0}C, and 310^{0}C.

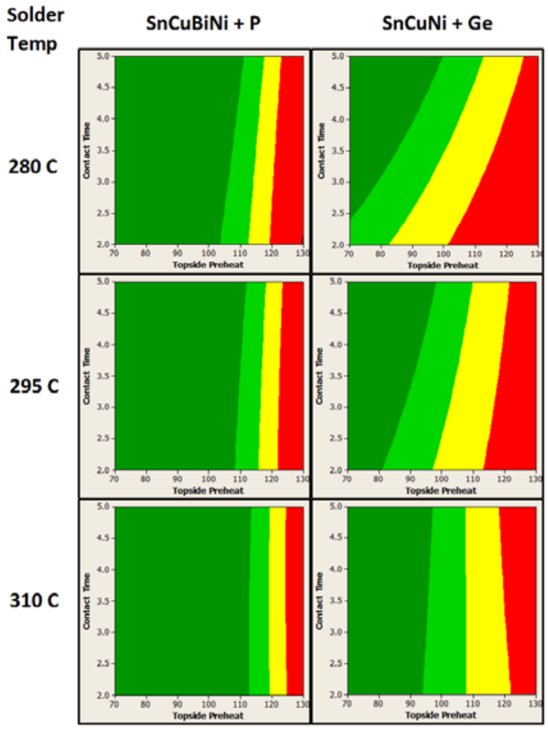


Figure 5. Hole fill prediction for 1.6 mm thick PCBs.

HOLE FILL ON 2.4 MM THICK PCBS

Figure 6 shows the predicted hole fill comparison for each alloy at 280^{0}C, 295^{0}C, and 310^{0}C.

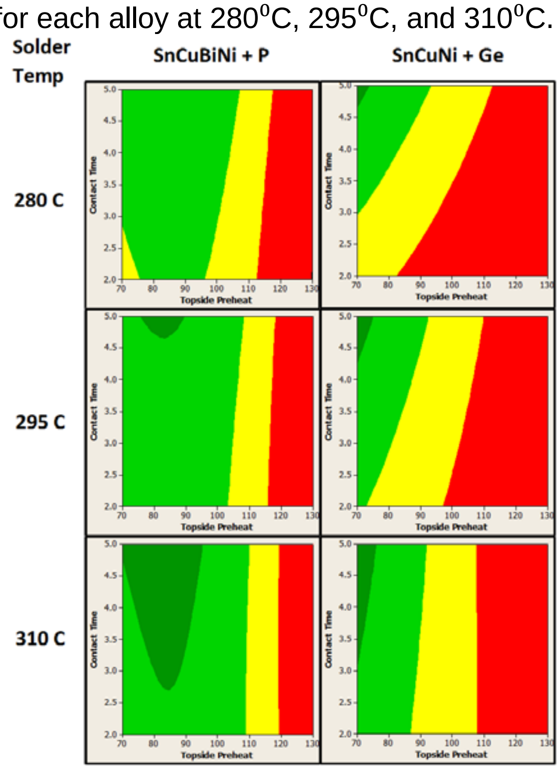


Figure 6. Hole fill predictions for 2.4 mm thick PCBs

CONCLUSIONS

The contour plots comparing the two alloys demonstrate a significant performance advantage when selective soldering with the SnCuBiNi+P alloy over the SnCuNi+Ge alloy under conditions that are thermally challenging.

With 1.6 mm thick boards, the performance of SnCuBiNi+P was consistent across a wide range of solder contact times. For the tested range of 280^{0}C - 310^{0}C solder temperature and 2.0 – 5.0 solder contact seconds, any preheat temperature between 70^{0}C - 100^{0}C is expected to provide complete hole fill. Even the best results for the SnCuNi+Ge alloy, at the highest solder temperature of 310^{0}C, was only expected to provide complete hole fill at preheat temperatures between 70^{0}C - 90^{0}C.

In addition, the SnCuBiNi+P alloy was predicted to provide acceptable hole fill at consistently higher preheat temperatures than the SnCuNi+Ge alloy under similar solder temperature conditions, particularly with low solder contact times.

The 2.4 mm thick board results, as expected, showed a reduced window of conditions that are predicted to provide acceptable hole fill results. With 2.4 mm thick boards, the SnCuBiNi+P alloy had a wider range of conditions that are expected to produce acceptable hole fill results when compared to the SnCuNi+Ge alloy under all solder temperature conditions tested.

For all solder pot temperature conditions tested, the SnCuBiNi+P alloy was predicted to result in acceptable hole fill when solder contact time was between 3.0 - 5.0 seconds and preheat temperature was between 70^{0}C - 100^{0}C. With the SnCuNi+Ge alloy, the only conditions that resulted in acceptable hole fill over all solder temperatures tested are those with preheat temperatures between 70^{0}C - 80^{0}C and solder contact time between 4.0 - 5.0 seconds.

REFERENCES

[1] Ernesto Ferrer, Elizabeth Benedetto, Garry Freedman, Francois Billaut, Helen Holder. 2006. "Reliability of Partially Filled SAC305 Through-Hole Joints." *IPC Printed Circuits Expo® and the Designers Summit.* Anaheim, CA: IPC