Eliminating Mid-Chip Solder Balls:
A Practical Guide to Understanding and Doing Away with this Common Defect

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A well-known and often-seen defect, mid-chip solder balling has been plaguing electronics manufacturers for decades. Though some would argue that mid-chip solder balls can, in some cases, be more a defect of aesthetics rather than reliability, their elimination is nevertheless desirable. The mid-chip solder ball occurs when solder is squeezed under the component and away from the pad and is unable to coalesce back during reflow, remaining hidden under the component or appearing out to the side of the device. Several causes for mid-chip solder balling have been suggested and include excess solder paste on the pad, poor hot slump and insufficient wetting. The mid-chip solder ball phenomenon tends to occur more frequently with chip resistors due to the fact that they have tinning on three sides and a reduced solderable surface as compared to capacitors, though capacitors may also be subject to this defect. The reported occurrences of mid-chip solder balls have changed as the industry has moved toward more miniaturized components and lead-free solder paste materials.

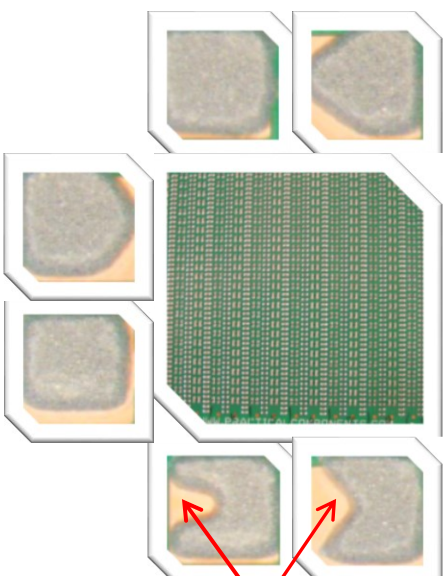
When the industry first transitioned from SnPb to Pb-free solder materials, the change in alloy prompted a different approach to mid-chip solder ball correction. Historically, aperture reduction to control paste deposition volumes was the mechanism manufacturers used when employing SnPb materials because the lower surface tension caused the material to spread more. But, as Pb-free materials have higher surface tensions than SnPb solders, the first Pb-free formulations tended to spread less, which encouraged assemblers to move away from aperture reduction so as not to leave any exposed copper. As Pb-free took hold, early iterations of materials were improved with superior flux technology which promoted surface oxide cleaning at higher temperatures, reducing the surface tension of the solder alloys and encouraging better wetting. At the same time Pb-free materials were being improved, chip resistors and capacitors were getting smaller and this convergence saw older-generation Pb-free materials with a greater occurrence of mid-chip solder balls. In all likelihood, this was because manufacturers failed to change their design rules – i.e. to eliminate over printing as was the case with early Pb-free solder materials. The newer, more capable Pb-free formulations had much better wetting and pad coverage, but with a lack of adaptation in aperture design rules, too much material was deposited, resulting in mid-chip solder balls.

In order to better understand the relationship between component size and type, stencil design rules and solder paste characteristics to the occurrence of mid-chip solder balls, Henkel conducted an evaluation of these factors to determine the best approach for the elimination of this defect. The study was carried out in two phases; the first studied material slump and aperture reduction and the second analyzed the solder paste characteristics of hot slump, cold slump, wetting-solder-balling and transfer efficiency.

During phase one, four different solder pastes were used (see chart below).

	Description	Slump Rating
A	Standard fast print paste	4
AM	Standard paste with extra solder powder added 89% v standard 88.5%	3
AG	Standard paste with increased gelling agent 50% more gel	2
B	Ultralow slump paste Different chemistry	1

The results of this part of the study revealed that reducing slump either by adding a gelling agent or increasing the metal content in the solder paste did lower the occurrence of mid-chip solder balling, but it was not the only factor; reduction of the stencil's inner aperture wall also played an important – if not more significant -- role. What phase one also uncovered was that the frequency of mid-chip solder balling is greater with chip resistors as compared to capacitors. This is most likely due to the solderable surface of capacitors versus resistors: capacitors are tinned on five surfaces, whereas resistors are tinned on three, so the larger wettable surface area of the capacitors helps draw solder away from under the component during reflow. (see below) The architecture of aperture reduction is also important and this study indicates that a "crown" or "u" shape design is most effective for limiting mid-chip solder balling defects.



Crown and U shaped apertures have the greatest impact on mid-chip solder balling reduction.

Phase two of the research evaluated four solder pastes that were different from the pastes in phase one. The intent was to understand the various performance characteristics of each paste and the relative impact on mid-chip solder balling. Slump (hot and cold), material wetting, solder balling (coalescence propensity) and transfer efficiency were analyzed. For both 0402 and 1206 components, it was confirmed that there is a strong correlation to the solder paste characteristics of hot slump, paste volume and solder balling/coalescence activity. During this analysis, it was revealed that Henkel's LOCTITE GC 10 solder paste, which has excellent transfer efficiency, improved coalescence and minimal hot slump, can be effective in the reduction of mid-chip solder ball defects on highly miniaturized devices. While paste characteristics are important, reducing aperture area through the use of "u" or "crown" shaped designs has the greatest effect on mid-chip solder balling reduction. (See images left and below.) In fact, when using the crown design with LOCTITE GC 10, 100% of all mid-chip solder balling occurrences were eliminated and they were significantly reduced among competitive pastes.

To learn more about these evaluations into the causes and solutions to mid-chip solder ball defect, send an e-mail to doug.dixon@henkel.com.