

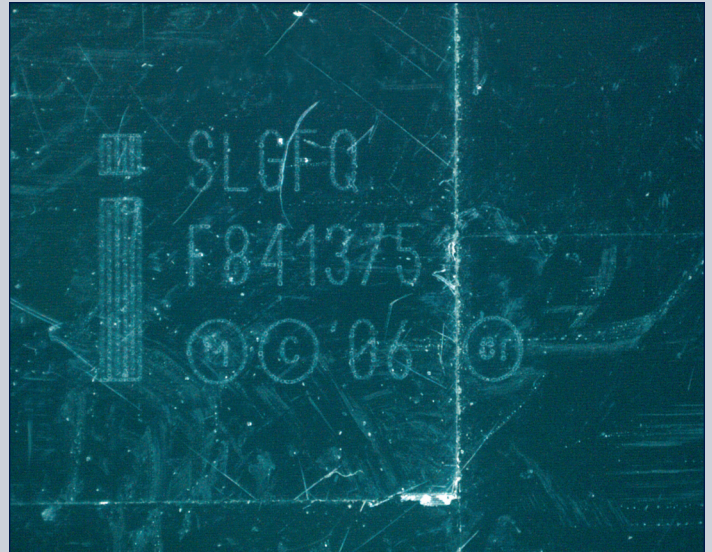
## Lead-Free Risk Mitigation — A Case Study

A company approached ACI Technologies (ACI) for assistance with a new product that was about to undergo its initial proof-of-concept prototype build. This product was an item that was being furnished to the Department of Defense for a program designed to increase the technical capabilities of computer equipment issued to the war fighter. The requirements for this item specified the use of tin-lead solder during assembly of production units. One of the main responsibilities for ACI during this project was to assist the client in mitigating the risk introduced using commercial off-the-shelf materials that may be lead-free.

ACI's first task in this process was to identify the components (from the client's Bill of Material) that were unavailable in a tin-lead finish. The item was a modified version of a familiar commercial PC architecture and as such was designed around a standard CPU platform from a large worldwide component manufacturer. This platform was comprised of several ball grid array (BGA) processors that were widely available lead-free but unavailable in tin-lead. Unlike a leadframe component, where the lead would only be present as a layer of plating on a tin-lead part, a BGA uses a small ball of solder to form the interconnection between the component and the printed circuit board (PCB).

These differences lead to a serious dilemma for the team. Two standard concerns when mixing tin-lead and lead-free solders and components are the effect on long-term reliability of the solder joints and the potential impact of tin whiskers. The initial build was not expected to undergo any form of accelerated life reliability testing, so those two concerns were not significant at that time. However, a new concern arose regarding the compatibility of the lead-free BGAs when used with tin-lead solders. The issue was that a tin-lead reflow profile would not properly reflow the lead-free solder on a BGA.

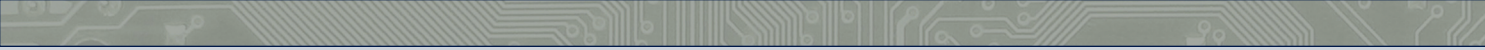
The initial strategy was to have the lead-free balls removed from the BGA and replaced with tin-lead balls. (Techniques to perform this task are described in detail in the BGA Reballing article located here.) This is the best method of mitigating this risk



*Figure 1: A fracture in the exposed die surface.*

factor, as a properly reballled BGA using tin-lead balls will be perfectly compatible with the use of tin-lead soldering processes. The client contracted with another company to reball the BGAs in question and that company was to supply the parts directly to ACI for assembly. Upon receipt, ACI staff identified damage that occurred during the reballing process. This damage (as shown in Figure 1) was a fracture in the exposed die surface of several the components provided to ACI. This damage was a result of improper handling of the parts regarding exposure to moisture and is known as a "popcorn" defect. Popcorning occurs when moisture within the device is rapidly heated during rework processes causing the absorbed moisture to expand causing die fractures. The IPC/JEDEC J-STD-033B provides the requirements that must be followed in order to prevent this type of damage.

The timing of the discovery of the defects when the parts arrived at ACI meant that there was not sufficient time to perform that exercise again and maintain the original project schedule. As the assembly's main requirement was functionality for proof-of-



concept, the decision was made to assemble the board using lead-free solder at ACI. At the same time, the client's factory organization worked to acquire properly reballed BGAs with tin-lead for future builds.

The change to the use of lead-free solders required some changes to the manufacturing process. The most significant change was the elevated melting point and its effect on the reflow process. An additional concern was the capability of the components to withstand the elevated temperature. The original plan involved the use of tin-lead solder so little information was readily available regarding the maximum ratings for some of the parts. However, many of the parts and all the high value parts were dual-rated for both tin-lead and lead-free temperatures. During assembly of the lead-free version of the item two components were discovered to have been damaged by the elevated temperatures in the lead-free process. The first damaged part discovered was a relay. It was deformed and apparent that the plastic used for the housing had begun to melt. The second damaged part was a wire wound inductor where the core had deformed and melted, damaging the windings and changing the value of the inductor.

ACI did not have extra parts on hand to replace the damaged parts and the assemblies were sent to the client for replacement at their engineering offices. However, upon arrival it was determined that the soldering irons on hand at that location were not capable of reaching the elevated temperatures required for lead-free solders. The parts were returned to ACI with replacement components in order to take advantage of the equipment and technicians familiar with lead-free rework available at the ACI's facility.

A valid concern was raised regarding the risk of unobserved damage on other components on the lead-free assemblies. A decision was made to perform another build at ACI using tin-lead processes as a control in order to determine if any potential

failures of the lead-free boards were related to the lead-free assembly process. At that point there was still no availability of many of the BGAs in tin-lead and a mixed process had to be performed. The reflow oven was set to run at the high end of the tin-lead process window in order to maximize the opportunity for the tin-lead solder to join to the lead-free balls. The process was set to ensure that no components exceeded the upper rating for tin-lead components, which is 220°C for most components. The lead-free solder balls on the lead-free BGAs were not expected to significantly melt during this process and the tin-lead solder was expected to wet to the unmelted balls as it would on a plated lead or termination. This lack of proper melt results in a non-standard solder joint geometry that, although perfectly functional, is not expected to have the same level of mechanical reliability as a properly processed BGA solder joint. In this project the long-term reliability of the resulting solder joints was not a concern but in other situations this issue can be a reason to avoid mixing solder types on BGA solder joints.

This project exemplified some of the risks of mixing tin-lead and lead-free components and solders. Conversion of BGAs from a lead-free type to a tin-lead type has associated risk of damage but if performed properly will result in the optimal configuration (tin-lead solder joining a tin-lead BGA to the board). Processing parts that have not been specifically qualified for use with lead-free processes can lead to unexpected component damage. Installing a lead-free BGA with a tin-lead solder results in a non-standard solder joint geometry with unknown reliability but can be sufficient if the only objective is to assemble a board that functions.

ACI can assist you with difficulties encountered in an increasingly lead-free electronics world. Contact the Helpline via email to [helpline@aciusa.org](mailto:helpline@aciusa.org) or by calling 610.362.1320.

ACI Technologies, Inc.



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