Single Ball Reballing and Repair of BGA Components

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Abstract
The trend of increasing complication in the rework arena continues. Sources of today's rework challenges include the development of smaller and smaller components and the continued difficulty of reworking BGAs (with defective, deformed, or missing balls). Add to that, the necessity for contract manufacturers to have a reliable solution to reduce waste continues.

The need exists to blend "typical" rework (SMD components, lead-free solder and 0201) with more complex rework, such as single ball reballing. Or, simply put, to reuse BGA components that have failed capillarity tests or have arrived from the manufacturer as defective parts.

Single Ball Reballing and Repair of BGA Components
"Typical" assembly houses are challenged with manufacturing PCBs that have very little real estate between components. This dilemma has become more and more complicated due to a new extraordinary technology: stacked die within one package, which can be explained in two ways:

1. Stacked die consists of vertically stacking two or more die and connecting them electrically via wire-bond or flip chip technology, thereby reducing the overall package size significantly. Figure 1, showing stacked die within one BGA package, states the overall reduction of PCB real estate has been reduced by 77%. If the size of the PCB is 4 x 2" (which is common for today's cell phones), that would open approximately 9% of the space for other components. This is a significant improvement that would allow for features such as video, radio, MP3 players, and any other new technology on the horizon.

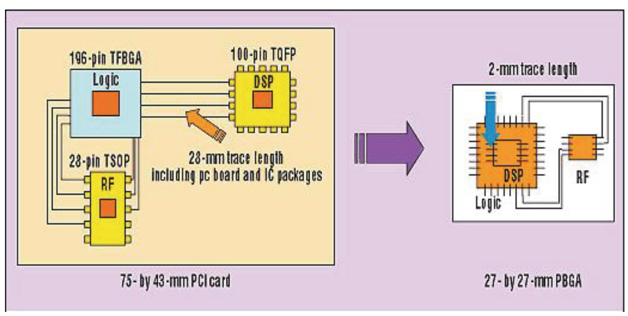

Figure 1 - Mini PCI Card with Three Stacked Die

2. Attaching two interposers via soldering interconnects allows designers to vertically stack packages. In addition to reduced real estate, the performance of the package increases. The time for signals from one component to the next could significantly improve. This is a proven technology used by design engineers for various applications. Whether it is automotive, telecom, or computers, this technology is here to stay. As it matures, the technology will become more efficient and less expensive. The idea of "stacked interposers" in modern assembly designs will also enter the "mainstream" of PCB assembly.

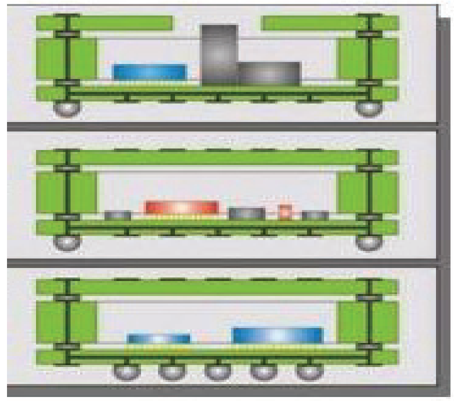

Figure 2 - 3D Stacked Interposer

Why are "stacked die" and "stacked interposers" important relative to single ball reballing and BGA reballing? Components are becoming more and more expensive. Additionally, to reduce the amount of inventory needed to build product, manufacturing engineers are looking for new ways to increase production with little to no cost. Process engineers like having a real solution to reuse expensive components, specifically BGAs, because it provides them with a choice on how to reduce costs. They could order new components and wait for them to be delivered, which sometimes takes weeks, or repair components that have failed for whatever reason. Sometimes, the components arrive from the component manufacturer as defective. It is much easier to repair a single ball (whether it is missing or deformed) than to wait for additional inventory.

Depending on the cost of the component (sometimes less expensive in higher volumes, but more expensive with small or prototype volumes), determining how expensive it is to repair a defective BGA compared to purchasing a new component is quite easy. For example, one BGA component costs $10, which is modest compared to the average of the amount of BGAs within one PCB. Suppose the number of I/Os is 256 (an average number according to Winslow Automation, a company that provides unique solutions to rework BGA components). The cost for a jar of solder balls can run from $100 to $200, depending on the size of the balls and the type of alloy used. The critical factor is the quantity of balls that come in one jar, which range from 250,000 to 1,000,000. To keep it simple, the median number would be 375,000 balls per jar. This is equivalent to 1,465 BGAs that could be reworked, or $0.07 per BGA. This is quite attainable from a manufacturing point of view. If only one or two balls on a defective BGA need to be reworked, the cost is less than $0.01. This makes rework even more worthwhile to consider.

Whatever the reason needed to repair BGAs (either one ball or the entire package), most manufacturers should have a rework tool that is suited for this type of repair. It is critical to have appropriate optics/resolution to view small and large components, as well as excellent thermal management to repair mainstream components (ranging from 0201s to large area BGAs). Since many models of rework equipment are designed for large PCBs, they include poorer optics that result in minimal placement accuracy (15 µm at best). This type of equipment is also designed to produce a significant amount of air, which results in having a minimal amount of thermal management control.

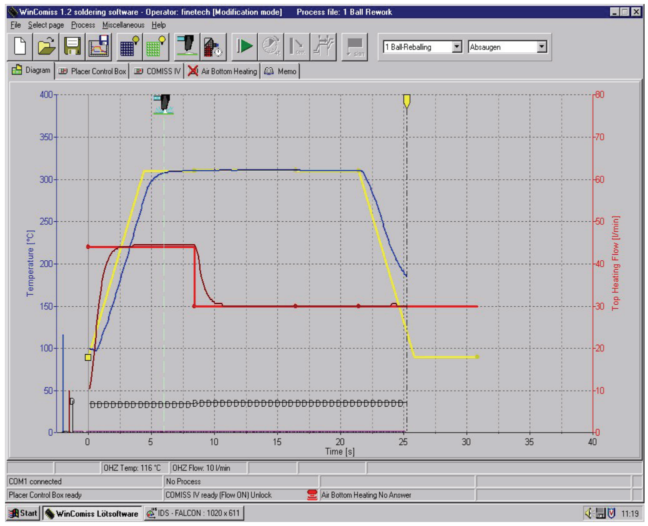

Figure 3 - Flow Rate Indicated with RED Line

The process to develop a successful profile to solder a singe ball is quite simple with a good thermal management system (Figure 3). The temperature of the solder is no different than any other component (low thermal mass like an 0201 device). The use of a tacky flux (Figure 4) to hold the ball in place during the reflow is very similar to the mainstream components. In addition to having a flux dipping station, a soldering nozzle must be developed to not only produce enough vacuum to hold the small ball, but also to precisely channel air/nitrogen to the site that is being repaired without damaging or disturbing the neighboring attached balls.

The defective ball should be identified by an automated optical inspection (AOI) machine or a manual process that might include operator viewing components that are rejected by vision alignment systems on today's chip shooters. The defective components might also be identified by a co-planarity test that shows the difference in overall ball height. The following steps identify the defective component.

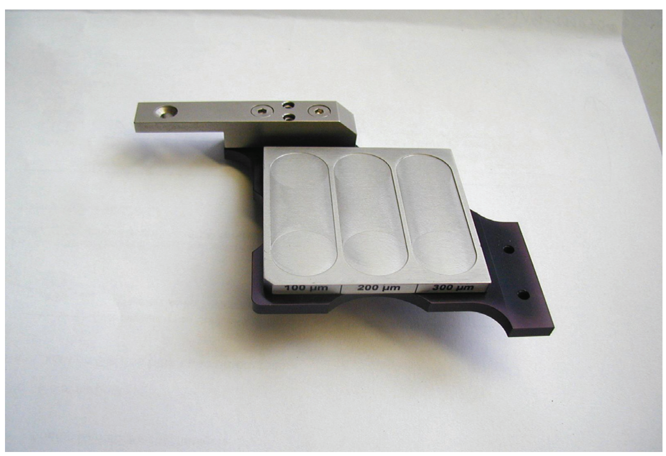

Figure 4 - Lux Dipping Station with Multiple Depths (using tacky flux)

Once the defective ball(s) has been identified, the first repair step is to load the device into a fixture that will support the substrate (ball side up). It is advantageous to design a fixture that can be used for multiple substrates, independent of the interposer size. With today's rework equipment, the use of a solder removal process typically is used. If the ball(s) that is being reworked is located in the center of the BGA package, it becomes difficult for an operator to use the older, standard approach of solder wick and a soldering iron to remove the deformed ball. As with the soldering profile, the solder removal process must also be established so as not to disturb the neighboring solder balls that already pass testing. Figure 5 shows the alignment of the deformed solder ball to the solder removal nozzle — the process to replace the deformed ball is identical with respect to the alignment. Only the profile might be different to include nitrogen to the site because it will provide a "clean" environment to solder the new ball. A clean environment increases the chance of having sufficient shear strength and solder joint reliability.

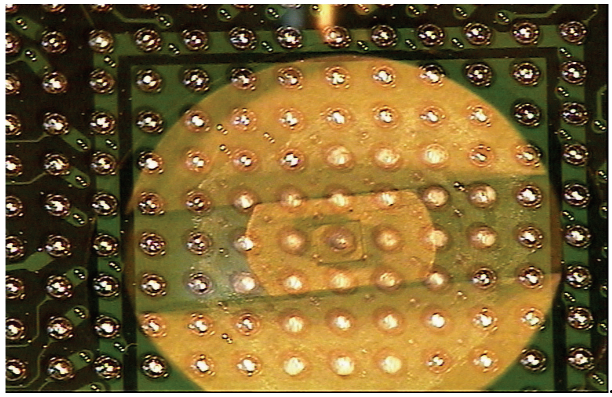

Figure 5 - Alignment of Removal Nozzle to Defective Ball

The next step in repairing the ball involves two parts:
Picking up the new ball, which again uses and tests the resolution of the optics of the rework machine. There are elaborate ways of presenting the new ball, but the most common way is to have an area where balls can simply be placed into a holding cell. The ease of the split optics system provides a sufficient way to identify a known bad ball for repair.

Dipping the ball into a tacky flux bath. The flux does two things:
Flux provides a good surface tension between the interposer and the ball, which helps keep the ball aligned to the pad that it will be soldered to.

It provides a good thermal transfer mechanism between the solder on the board and that which makes up the ball. Compare the flux to the grease used to fry an egg. Using a thermal transfer material always makes the job much easier.

Use of a typical rework machine should somehow indicate that the split optics is reliable. During the reflow of the new ball in a typical tin/lead (63/37%) composition; there are “self alignment” properties that are quite forgiving. According to IPC Spec, landing on 75% of the pad is acceptable for BGA rework. Those properties no longer exist in the lead-free arena.

With the adoption of lead-free alloys, the need for rework systems with precise thermal management and high placement accuracy becomes even greater. Higher reflow temperatures create a narrow process window with risk of component and board damage if not properly managed. Lead-free alloys do not produce the same “self-aligning” characteristics generally seen with tin/lead soldering. They also do not wet the same as a typical leaded solder. When working with leaded solder balls, placing 75% of the ball on the pad is sufficient to allow the ball to “self align” during the soldering step. With lead-free balls, however, if 75% of the ball is placed on the pad, only that same 75% will be attached after the soldering step is complete. This may cause a component placement machine to reject the repaired component, resulting in lost time. The problem is easily avoidable, as long as the repair equipment is extremely accurate when placing the new ball. Even a skilled operator can have trouble placing a single ball or a 0201 component accurately.

Providing a clean environment with nitrogen also adds to the mix of successful rework. As shown in Figure 6, the appearance of the solder post-reflow indicates a well-formed ball, compared to that reflowed in air.

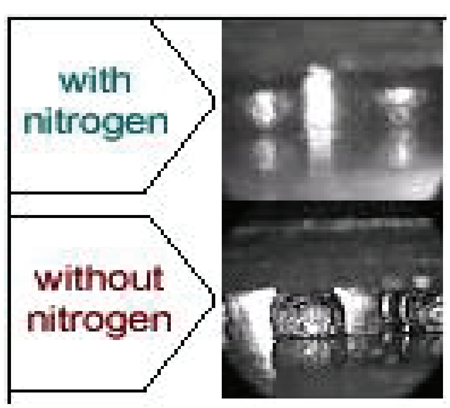

Figure 6 - Solder Ball Comparison Using Nitrogen Versus Air

As the solder becomes molten, a timed vacuum is generated to ensure that the solder is removed from the interposer and collected safely into a container that can be disposed of properly. Figure 7a-d show an in-situ camera removing the solder of the defective ball. The camera shows the ball reflow and shows the surrounding area is left undisturbed.

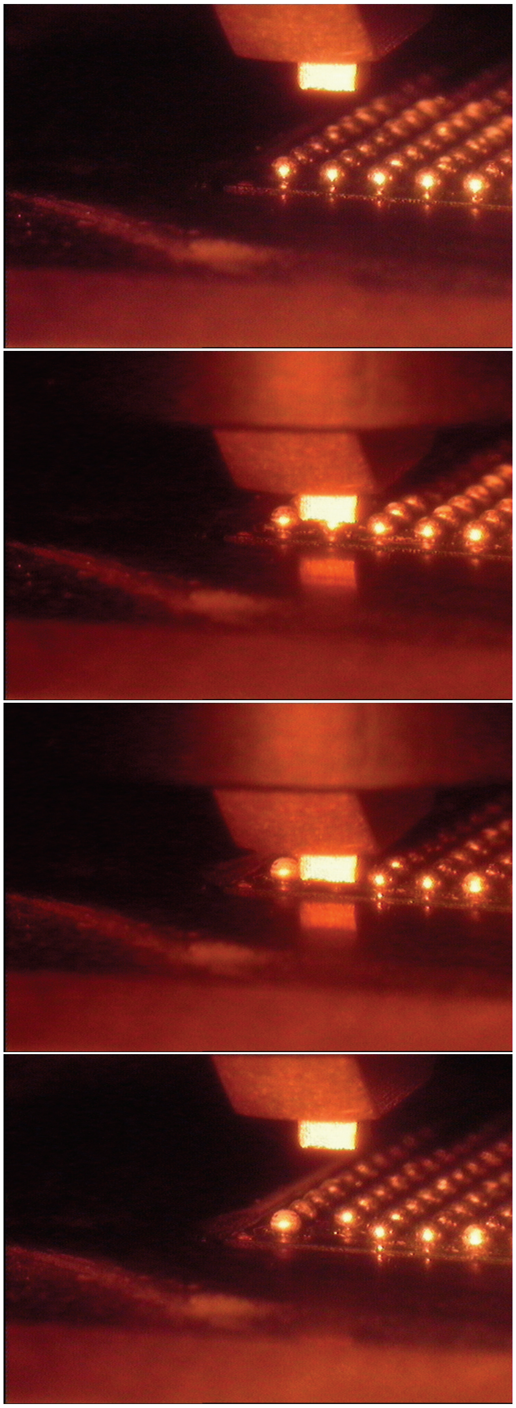

Figure 7a-d - Solder Removal Process Steps

The key to a successful solder removal process is to leave the surrounding area undisturbed.

Two nozzles are needed to repair the component. The first, a solder removal nozzle (Figure 8), uses hot air to liquefy the solder. There is also a vacuum port designed to draw the solder into a container for proper disposal.

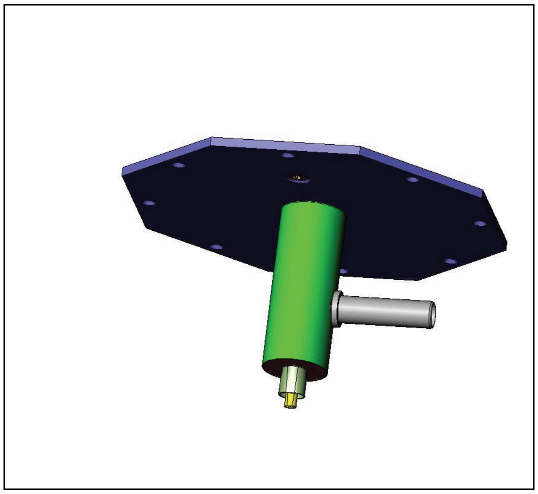

Figure 8 - Solder Removal Nozzle

The second nozzle, which is used to place the ball, is similar to a solder removal nozzle but without the vacuum port used to collect the molten solder. Figure 9 shows the nozzle placing the new ball in the area needing repair. As for the thermal process, it should resemble a typical profile related to the alloy composition. The ramp rate and pre-heat are still important parameters in need of control. When properly controlled, the reliability of the solder joint will remain intact. As stated previously, in addition to excellent thermal management, inducing nitrogen into the area will result in a shiny ball, making the component look as though it was never repaired.

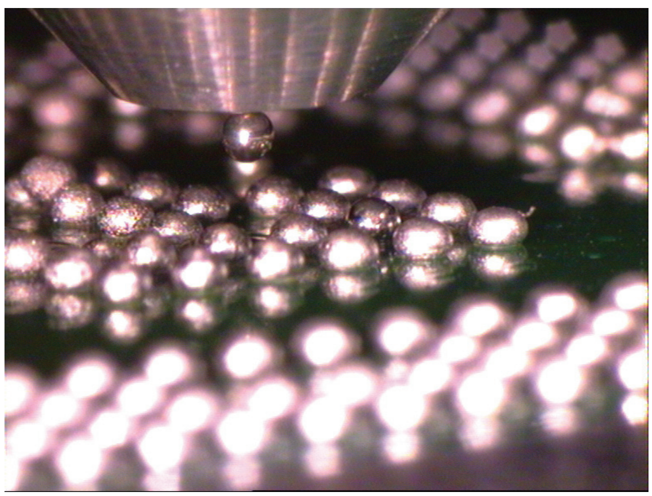

Figure 9 - Placing New Ball to Interposer

Tooling requirements for both solder removal and ball attach should include a "stand off" at the face of the tool to ensure the remaining balls are not touched, as the hot air will make the temperature of the nozzle hot enough to cause damage. This is consistent with standard tools that do not touch neighboring components in mainstream rework.

Conclusion

The concept of reworking product is typically a last resort solution. With that being said, rework is often an unavoidable aspect of the manufacturing process. The ability to rework μBGA components provides a manufacturer with the ability to reuse expensive components. With the increased cost of components and long delivery times involved in ordering replacement components, having a rework solution is well worth the effort. Components are not going to increase in size and the demand to update and improve rework processes already exists. The key is to understand that rework can become a "value added" step in the manufacturing environment and can save both time and money.