Rework Challenges for Leading Edge Components BGA, QFN and LED in Today's Fast Moving Industry

Paul Wood
OK International / Metcal
Cypress, California

Abstract
The industry continues to face the challenges associated with BGA, QFN/BTC, and LED packages. The demand for more performance by consumers drives change, which results in greater component density. Component density on printed circuit boards continues to decrease with a corresponding increase in component complexity and reduction in pitches. Good examples of these industrial trends are smart phones, tablets and wearables.

In modern production lines, the complexity of these devices drives manufacturers to rely on automated equipment and strict production processes to control variables such as paste deposition volumes, reflow times, and component placement when working with new boards. However, in a rework scenario, controlling all of the variables required to remove and replace one component is challenging. Each of the variables involved with soldering these devices require management on an individual basis. Herein lies the challenge.

Many rework processes are still manual ranging from hot air pencils to automated rework machines. These tools are required to duplicate the production process on an individual level. Solder balls up to one thousand I/O and a pitch of 0.35mm on a BGA are becoming more common than 0.4mm or 0.5mm in a package size of 14mm square. QFNs, traditionally, are difficult to rework due to their excellent thermal characteristics. QFNs with a 0.35mm pitch and double row terminals on the perimeter and various size ground pads in the middle are increasingly common. LED technology has seen a massive growth, with larger packages and higher wattage output in today's leading edge printed circuit boards. Higher wattage output requires the use of metal backplanes to dissipate the heat. Contrast the backplane requirement with a relatively low temperature lens and the challenges become evident. This requires more thermal energy in rework without melting the case of the LED. This is a different situation to when LEDs first became mainstream. This paper will show rework processes for all of these challenging components.

Introduction
The industry continues to face the challenges associated with ball grid arrays (BGA), quad flat no-lead and land grid arrays (QFN/LGA), and light emitting diode (LED) packages. The demand for more performance by consumers drives change, which results in greater component density. Component density on printed circuit boards continues to decrease with a corresponding increase in component complexity and reduction in pitches. Good examples of these industrial trends are smart phones, tablets and wearables.

Successful rework encompasses three key points. Component removal without damage to the printed circuit board or adjacent components, preparing the lands for component replacement and replacement of the component. BGA, QFN/LGA, and LED packages have been in use for years. The challenge in rework is the improvements made to these packages over those years that continues to increase the challenges associate with rework.

Ball Grid Array (BGA) Technology
The demand for more performance or portability drives manufacturers to develop components that meet increasingly complex requirements. The trend in the computer market went from desktop to laptop to portables. The physical size of these devices continues to decrease with a corresponding increase in the performance requirements. The need for fast web access, streaming video and high definition cameras all add to the challenges manufacturers face when presenting a new product to the market.

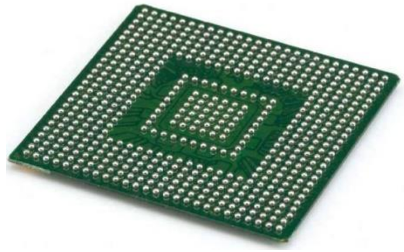

Figure 1 Ball Grid Array

An industry staple for years, the challenges associated with ball grid arrays, Figure 1, continues to increase with advances in technology. This increase in complexity requires a change in approach to the associated rework techniques. The complexities are twofold. The package size continues to shrink while performance demands increase resulting in a more complex array. Four broad categories, high-density arrays, staggered arrays, perimeter arrays with SMT components, and heat-sinked arrays present the greatest challenge for rework. These devices change the thermal requirements necessary to reflow and require a high skill level.

Removing components is the first step of the rework process. The challenge with component removal is the removal process works to undo the design elements employed by the chip designer and board manufacturer to mitigate mechanical and heat failures. Before removal there needs to be an assessment of the component to determine if the PCB manufacturer used underfill epoxy adhesive. Adhesive adds mechanical strength to the part and is common for mobile products or for large components to prevent part migration during reflow. Removal of the bond between the component and substrate is the first step. The most common method and least expensive from an equipment standpoint is removing the edge bond via mechanical means.

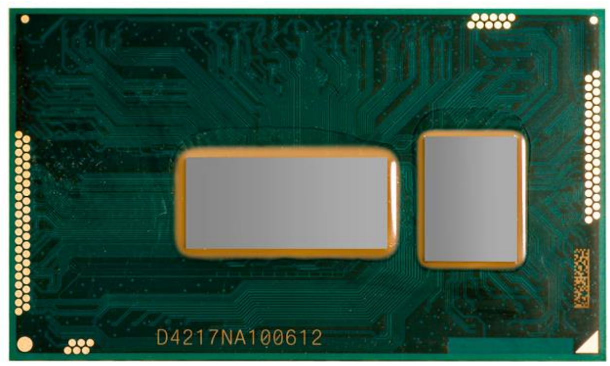

Figure 2 Multiple Die and High Pitch Count

The operator uses a heated tool to score and remove the epoxy. Epoxy removal using this method requires high operator skill to ensure the board remains undamaged during the process. With the epoxy removed, the reflow process begins. The component in Figure 2 is an example of the challenges faced with today’s newer components. The component has a high density of pads on the underside and multiple dies on the top. A component with this complexity often requires an alternative means of removal from the traditional vacuum cup common to most rework systems. Tweezers integrated with the reflow nozzle, multiple vacuum cups or mechanical prying of the part are common methods of removal.

Figure 3 BGA with integral heat sink

Regardless of method, care is necessary to ensure there is no damage to the component, substrate or adjacent components. Heating challenges abound depending on the complexity of the part. Parts with a high density of pads, staggered arrays or multiple pad sizes require the profile to accommodate the thermal transfer of energy to the pads central to the part or to pads of different mass due to differing pad sizes. BGAs with an integral heat sink, as shown in Figure 3, require additional thermal energy, as compared to a similar part without a heat sink, in order to achieve reflow of the solder balls. If possible, the recommendation is to drill and mount a thermocouple to the center and in a corner of the part on the underside of the component to measure the temperature in each location and to monitor the ΔT or temperature difference across the component to ensure full reflow of the solder balls. BGAs with an integral heat sink may require additional ramp-soak processes in the thermal profile to ensure reflow and minimize thermal shock to the substrate. Removal of the BGA without damage to the component or substrate is the first of many challenges.

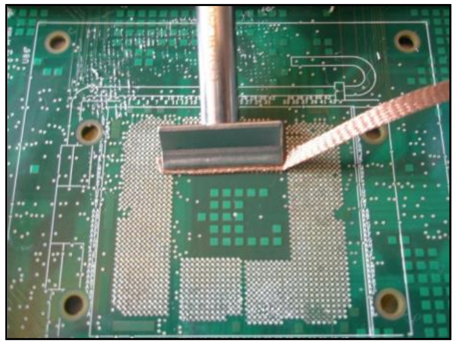

Figure 4 Manual Site Cleaning

Site preparation is the next stage of the rework process. There are two methods to remove residual solder from the pads before component replacement. The most common method of site cleaning is manual, Figure 4, utilizing a soldering iron, wicking braid and flux to melt the residual solder and collect it within the weave of the wicking braid. The risks associated with this method are pad damage, solder resist removal, and printed circuit board delamination. An alternative method of solder removal is the use of a contactless site cleaning system. The contactless site cleaning, more commonly known as a scavenger, applies thermal energy and applies a vacuum to the pad area to collect the solder without coming into contact with the substrate.

With the pads prepped, the component is ready for replacement. The BGAs require the addition of flux or solder paste to aid in reflowing the solder balls during the reflow process. There are two common methods of applying flux and one for solder paste. The first is brushing flux on either the pad or the component prior to placement. The brush method does not apply the flux equally to the solder balls or pads and can result in cold or dry solder joints. The second method is flux dipping in terms of dipping the component to half the ball height in "tacky flux" and proceeding with board placement.

The challenge with the first two methods is new components constructed in a way to make the procedures ineffective. Some multiple pitch components exhibit a convex shape along one axis by design. During reflow, these parts lose the convex shape and become flat. Adding additional ramp and soak times to the thermal profile allows the part to relax during reflow.

These type of components are sensitive to warpage creating bridges or shorts during the reflow process if the temperatures are not controlled. Achieving tight tolerances during trials usually requires sacrificing a PCB as a gold standard using matched 40 gauge thermocouples and kept for future reference. Without matched resistance thermocouples, a 5°C difference in measurement is possible.

Figure 5 Different colors depict different solder volumes on the same package

These parts require solder paste applied to the substrate using a stencil to manage the solder volume. Stencil patterns for one package requires multiple volumes as shown in Figure 5. Substrate printing is more complex due to the adjacent components. Keeping stencils flat becomes operator skill dependent. Staggered pitch components offer a similar challenge in that the pads are closely spaced which increases the likelihood of solder bridges or shorts when the thermal profile is insufficient to reflow the solder balls adequately. Additionally, the standoff height is as low as 8-12 mills over a large surface area, so control of the flatness during the reflow process is critical. The recommendation is to use fixtures and equal temperature across the component part. Additional dwell in temperature zones allowing the temperatures to equalize before liqudus are important considerations.

Another new design is the perimeter BGA with decoupling capacitors and resistors within the inner perimeter of solder balls as shown in Figure 6. Using the flux dip process with this BGA will collapse the solder balls and permit the component to rest on the chips. For rework, duplication of the production process is key. Screen-printing the pads with solder paste replicates the production process. Solder paste is used in the assembly process with the metal content calculated during the design phase. The calculation of solder paste increases the standoff height to prevent the part from resting on the components. Finally, BGAs with integral heat sinks offer a challenge similar to the perimeter BGA with components within the array.

The weight of the component requires controlled placement and solder volumes to ensure the solder balls do not squash during placement or reflow. BGA rework of the newer components require current processes to be adapted to meet the new requirements. Each step is critical to achieve repeatability and functionality of the component after rework.

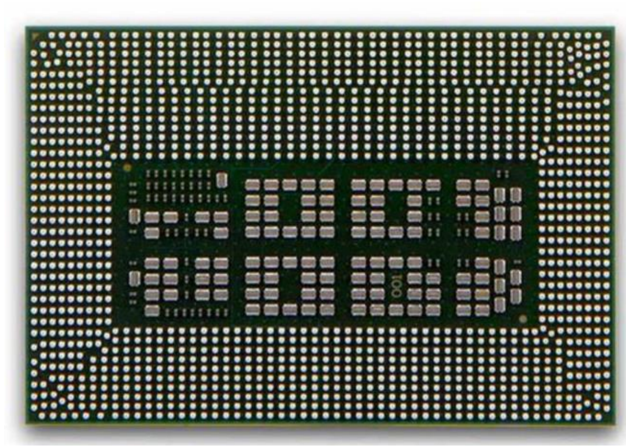

Figure 6 Perimeter BGA with decoupling capacitors and resistors

QFN/LGA/BTC Technology

QFN/LGA (Quad Flat No-leads or land grid array), Figure 7, are common surface-mount technology designed to connect integrated circuits directly to the substrate. A QFN/LGA with perimeter pads of 0.5mm pitch is common. Leading edge designs incorporate pitch sizes as small as 0.35mm. Double row terminals on the perimeter and ground pads of various sizes in the middle are increasingly common. With multiple sized ground and power pads on the bottom, equal heat dissipation across the package surface needs precise control to ensure simultaneous reflow. The ground pad creates challenges during the removal process as the size of the part in relation to the size of the ground pad creates significant surface tension and removal with a vacuum cup difficult. Alternative means as suggested previously for BGA components are a possibility.

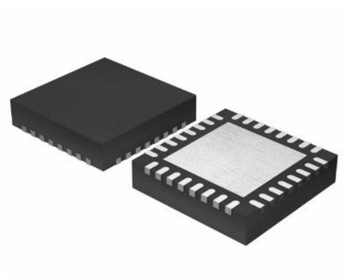

Figure 7 Quad Flat No-lead package

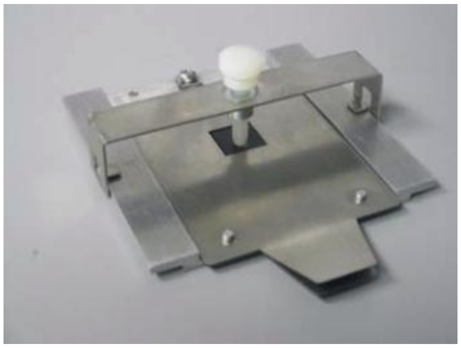

Figure 8 QFN Fixture

Site preparation, as mentioned for BGA components, is the next part of the process. The same risks apply with regard to manual versus contactless cleaning. When manually cleaning, the ground pad tendency is to demand the majority of the thermal energy making the cleaning of the pads more difficult and more prone to the soldering tip adhering to the substrate. Proper cleaning is important as any residual solder on the ground or power pad may cause the part to slide off or tilt during reflow.

Equal heat dissipation across the package surface needs precise control to ensure simultaneous reflow ensuring good solder quality and less solder voids. For rework, the package requires the use of a fixture, as shown in Figure 8, during the solder printing process as precise application of solder paste by hand is impossible. QFN/LGA are more susceptible to voids as the joint reduces to 2 mil of solder from 4 mils of solder paste, and so outgassing of volatiles is less than a comparable BGA where a gap exists between the part and substrate.

Various inner solid pad designs exist from the component manufacturers.
Figure 9 illustrates examples of solder paste patterns. Ground pads are usually broken up to stop rotation due to surface tension and should cover 60-80% of the pad when soldered for good heat dissipation from component into the PCB ground pad.

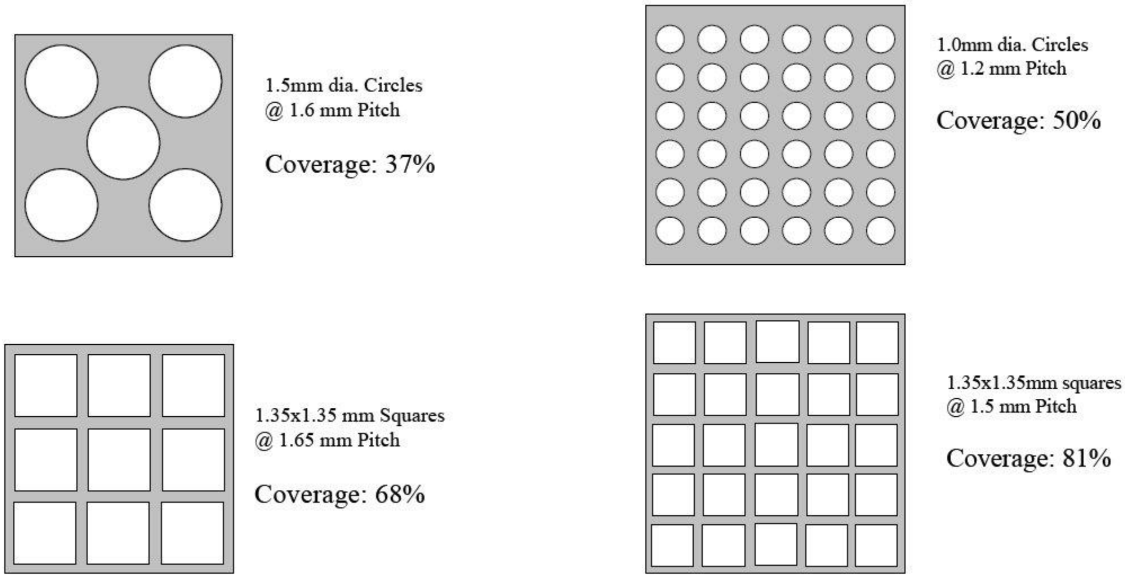

Figure 9 Ground pad solder paste patterns

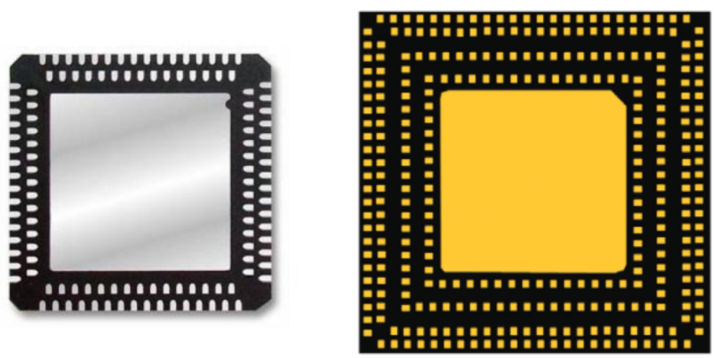

Figure 10 Dual row and multi-row QFN [4]

Some new QFN components are two row, four row or staggered pitches, which makes printing and placement pressures more important, so as not to squash the solder paste on placement. Figure 10 illustrates newer packages that feature the new pad layouts. While small, these surface mount components present some of the largest challenges to the industry in terms of rework.

Light Emitting Diode Technology
Developed in the 1960s, light-emitting diodes (LEDs) have seen massive growth, with larger packages and brightness increases in today’s leading edge applications such as mobile electronics, displays and lighting. These products use small packages, close together, as shown in Figure 11. Some LEDs are high power products that produce a large output of light with a corresponding amount of heat generated. As a result, heavy metal ground backplanes use a heatsink to dissipate the heat generated. This is a different situation to when LEDs first became mainstream. LEDs constructed with a heatsink integral to the design require more heat in rework with the added challenge of not melting the plastic dome on the top of the LED, as shown in Figure 12. As an example, automotive electronics are low cost products with high volume and are

expensive to repair. Repairing one LED on the assembly line requires the same advanced techniques as a display that utilizes 1000s of LEDs.

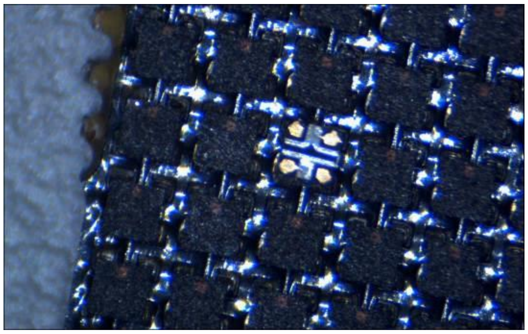

Figure 11 1mm LEDs in a display

Figure 13 Plastic LED on heatsink

The profiles for the LED are faster than for BGAs and with the added complication of minimizing the heat seen on the dome. This requirement means most of the thermal energy for the reflow profile originates from below by targeting spots underneath the LED minimizing the thermal energy from the tip heater.

Failure to follow the recommendation results in heating the entire panel to a high temperature, increasing the risk of damaging adjacent LEDs. To solve the heating issue, the use of inner and outer preheating focusses the thermal energy to the LED under rework and a lower temperature amount of thermal energy to the surrounding area that minimizes the risk of thermal shock and reflowing LEDs not under rework.

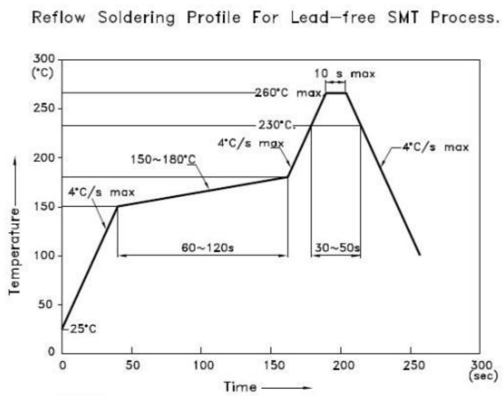

Figure 12 Sample LED thermal profile

Suppliers provide sample thermal profile recommendations for the component as shown in Figure 13. Maximum component surface temperature is 245-260ºC. If the component is on a heatsink, it drives most of the thermal energy from the bottom to reduce the risk of damage to the dome of LED, as shown in Figure 14, or it exceeds component specifications. If the component is not on a metal backed material, then more zones can be added to the top heater but the overall source temperature can be lowered. Adding zones means less thermal shock to the component providing better overall thermal management. The construction of modern LEDs encompasses the same concerns regarding rework as BGAs and QFN/LGAs with the added complication of board density and strict thermal management requirements.

Figure 14 LED dome

Conclusions

Successful rework encompasses three key points. Component removal without damage to the printed circuit board or adjacent components, preparing the lands for component replacement and replacement of the component. BGA, QFN/LGA, and LED packages have been in use for years. The challenge in rework is the improvements made to these packages over those years that continues to increase the challenges associate with rework. Process control via documentation, process, and control and the correct tools and fixtures are critical to success. The need for operator training is equally important as the complexity of parts continues to increase and utilization in the industry is broad. Successful rework is possible with an understanding of all the rework challenges.

General References

1. National Semiconductor (Texas Instruments) LLP/QFN ground pad solder volume designs. National Semiconductor Application Note 1187, October 2002.
2. Luxeon Application note for LED profiles and photos application brief (Application Brief AB32).
3. James Wade, Intel, Solder volumes on 4th generation chips.
4. STS STATS ChipPAC Application note.