

BGA Repair: A Better Understanding can Reduce Fears, Guarantee Process Control and Save Money

by Mark Cannon

Current international studies reinforce the global trend to area array packages. BGA, CSP and Flip Chip technology not only offer significantly more I/Os (input/output) per mm² of PCB real estate; they also have distinct electrical, mechanical, and unit cost advantages. Increased density, reduced feature size and packaging all add up to shorter distances for signals to travel, hence increasing speed and performance. See Figure 1. Consequently, there is no mystery in the dramatic increase in numbers of Flip Chip and advanced packages expected for 2002, arriving at nearly 2 billion in the year 2003. See Figure 2. Advances in production equipment have allowed for an acceptable ppm failure rate during the production process. For many, however, the concept of quality repair remains an expensive nightmare. A more thorough understanding of the area array package and the production parameters can reduce fears of BGA repair, guarantee process control, and greatly save in rework costs.

Based on the historical experiences of most operators, three repair concerns remain paramount:

1. Removing the component off the board without causing damage to the substrate, the lands, and adjacent components during the process,
2. Re-soldering the components in a process controlled manner and
3. Inspecting the quality of the procedure.

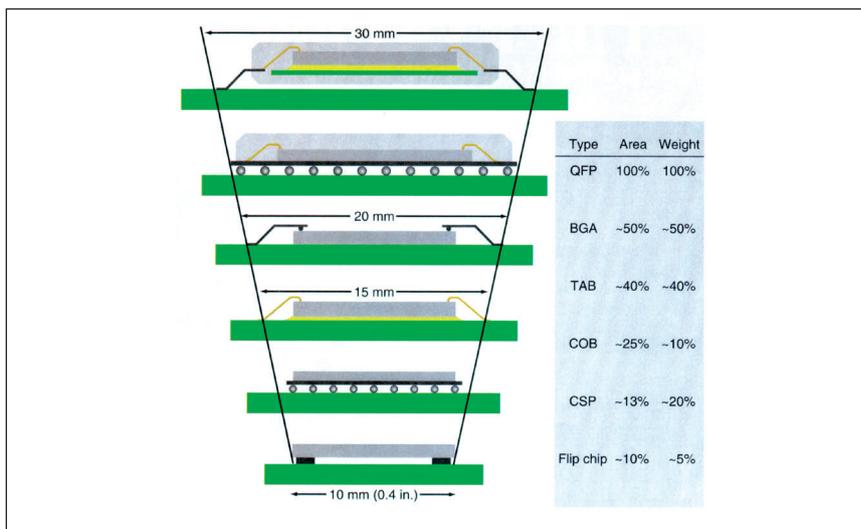


Figure 1: Density and performance requirements driving IC packing toward the size of the bare die

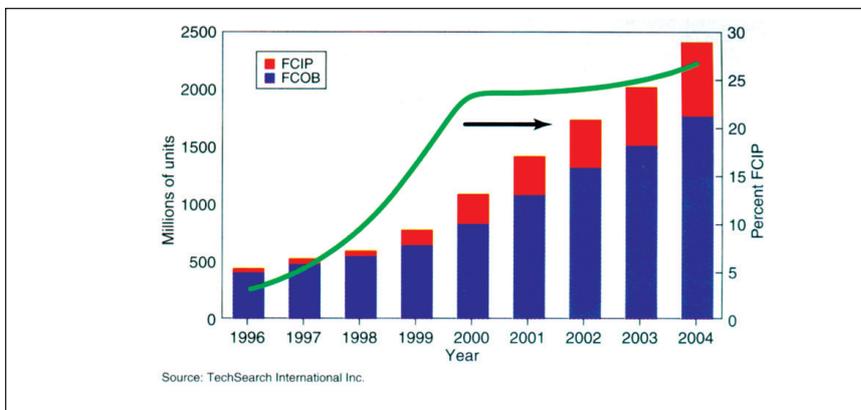


Figure 2: Trends in Flip Chip use

The density and performance requirements that drove the development of fine pitch, externally leaded devices (e.g. QFP, TAB, TCP components) cause enough of a repair headache from a handling, hand soldering and inspection standpoint. While the area array package does not present the same handling problems, the soldering pro-

cess cannot be achieved with typical repair tools, and inspection was, at one time, quite difficult. If the estimates are correct regarding the expected use of such components, something must happen to make area array package repair a viable, user-friendly and cost effective option for millions of repair operators worldwide.

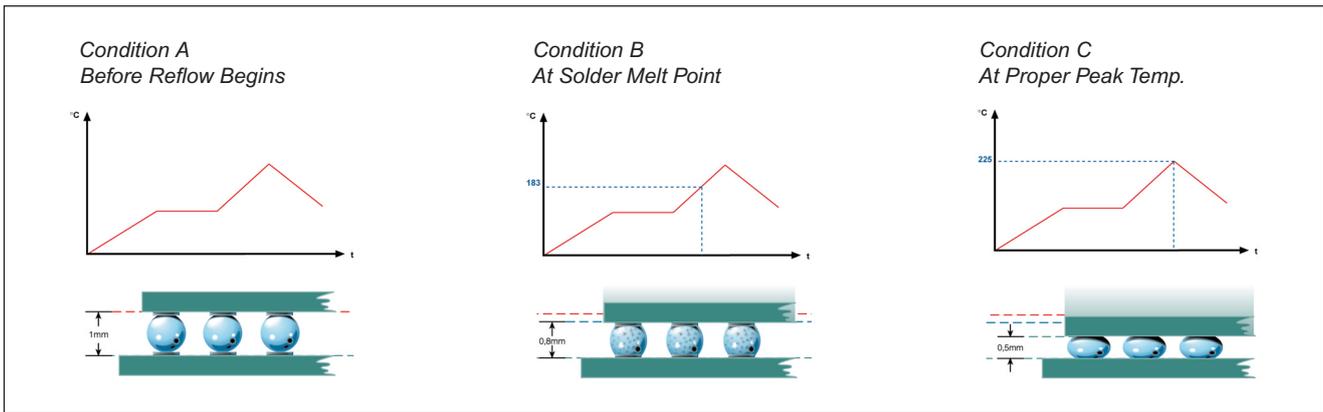


Figure 3: BGA Reflow Process

Let us examine the key considerations during the reflow process. See fig. 3.

Uniform heat distribution and transfer across the entire surface of the area array package and its land pattern on the PCB is critical. The heating process and thermal profile must attempt to cause the package to reach reflow and uniformly „drop“ or lower itself to the lands as the balls melt and form an intermetallic with the pads. See Figure 4 showing an optical picture using the patented ERSAScope, X-ray image and a cross-section of a professionally installed PBGA. Note how the component has dropped, is parallel to the PCB, and how all balls are uniform in shape and are completely „wetted“ or soldered to the land.

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Non-uniform heating, on the other hand, would cause the package to unevenly drop or tilt towards the side or corner

that has prematurely reached reflow. If the process is stopped at this point, the component will not lower itself uniformly, is not coplanar and therefore is insufficiently soldered. In addition, a critical consideration for the extremely small and lightweight CSP/Flip Chip components (see Figure 7) is the airflow rate in the convection reflow ovens. While a minimum air flow rate is required to transfer the heat to the component and PCB, this rate must not allow these light components to be either blown away or to move during the reflow process. When the extremely small eutectic balls are in a liquid state, any movement can cause the surface tension and „support“ function of the balls to be disrupted resulting in the CSP dropping completely onto the board during reflow.

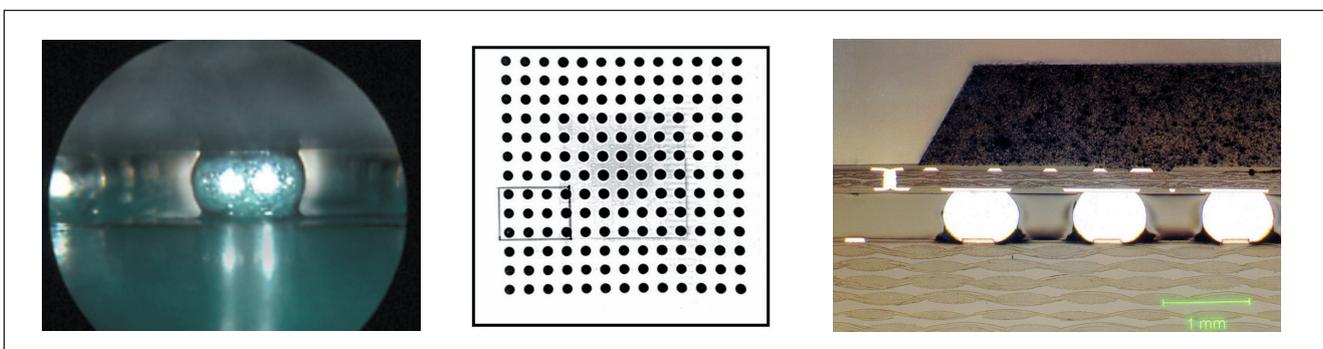


Figure 4: An ERSAScope Image, X-ray image and cross-section of a professionally installed PBGA.

With this in mind, let us address the repair requirements of an area array package and the current shortcomings regarding reflow. While the desoldering process can be handled with the majority of hot air equipment available, it is the re-soldering process that is most difficult to control. In rework, as in production, quality is the ultimate goal. Quality BGA reflow can be achieved for production in the enclosed environment of a reflow oven. Rework, however, cannot be done in a completely enclosed environment since the heating conditions required for BGA reflow are difficult to achieve when blowing hot air through a nozzle. Success here depends on uniform heat distribution across the package and PCB land pattern without blowing or moving the component during reflow. A convective heat transfer in a repair situation involves blowing heated air through a nozzle that has the shape of the component. Air flow dynamics, encompassing the effects of laminar flow, high and low pressure zones and circulation rate, is a complicated science in and of itself. When combining these physical effects with those of heat absorption and distribution, it is clear that the construction of a hot air nozzle for localized area heating and, therefore, proper BGA repair is a difficult task at best. Any pressure fluctuations or problems with the compressed air source or pump required by hot air systems would radically decrease the performance of the machine.

Some hot air nozzles that are designed to contact the PCB in order to provide a more even circulation and heat distribution can experience co-planarity problems and spatial problems if adjacent components are too near, thereby not allowing the nozzle to contact the board. This would disrupt the desired air circulation pattern in the nozzle that would lead to an uneven heating of the BGA. Additionally, the heated air that must exit the nozzle often heats adjacent chips, blowing them away, or burns adjacent plastic components.

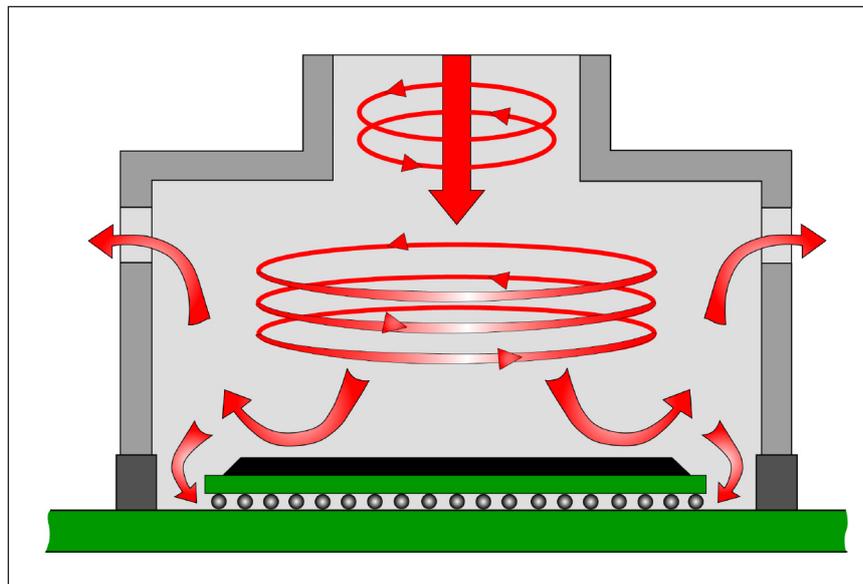


Figure 5: Hot Air Nozzle

Many semi-automatic convective repair systems often offer the feature of storing various numbers of „thermal profiles“. Let us not be misled by this perceived benefit by clearly understanding the purpose of thermal profiling. In a production machine, an accurate thermal profile is the key to process control by assuring that all joints heat uniformly and receive a sufficient peak temperature. The starting point for setting the production parameters is the actual board temperature. By analyzing the actual material temperatures, the process engineer can adjust the machine heating zone parameters in order to achieve the desired thermal profile of the board.

A convective repair machine that can store various profiles of the heating element and/or air flow temperature, can only be an approximate indicator as

to the thermal situation on the board. A more accurate procedure is to monitor and document the actual board or component thermal profile by attaching a K-type thermal couple to the PCB during the reflow process. In addition, actual inspection of the solder joint during the process, i.e. seeing the point of reflow, is the ultimate form of process control. See Figure 6.

A viable repair alternative to the numerous convective heat transfer problems listed above is the use of medium wavelength infrared. The clear advantage for process controlled BGA installations can be seen in the following comparative test results. A thermal image test for uniform heat distribution across a surface reveals a comparison of 3 different hot air nozzles to the alternative of medium wavelength infrared. The nozzles of three different hot air

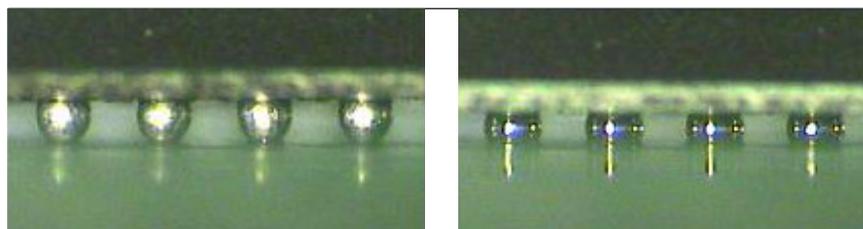


Figure 6: Optical Real Time Capture of Unreflowed and Reflowed BGA During Rework

rework systems ranging from \$25K-75K were lowered to a specially treated FR4 substrate and the machine performed its loaded profile. Although the profile might lead one to believe that the entire area is heated uniformly and reaching a hot enough temperature, this heat distribution test clearly shows hot and cold zones. See Figure 7. The superiority of infrared vs. hot air is a physical effect that can not be denied.

Infrared is not new to the reflow oven and repair equipment arena. It has, however, lost some of its popularity based upon the limiting physical effects of previously used short wavelength IR. The thermal radiation, while uniformly distributed, is unevenly absorbed and reflected by objects lighter or darker in color. Although such a heat source is perfectly acceptable for PCB preheating, the use of short wavelength IR for reflow, often results in overheating of the dark component body and FR4 substrate material before the reflecting leads reach proper reflow temperatures. Medium wavelength or „dark“ IR radiators (2-8 μ on the electromagnetic wavelength spectrum) not only transfer heat perfectly uniform across a surface, but they also reveal an even absorption/reflection ratio between dark and light materials. Figure 8 supports the theory with actual thermal profile test results by an independent scientific research institute. With an optimal design of a medium wavelength IR BGA repair system, K-type thermocouples can be easily placed on the board in order to monitor and document precise thermal profiles during the actual reflow process. Dark IR as a heating source alternative is an ideal solution, both in theory and in practice, for micro BGA, CSP, and Flip Chip repair applications. As there is no required air flow which could blow away or vibrate the component during reflow, the IR can be uniformly focused, directed, and transferred to an exact component size and location on the PCB. Adjacent component heating can be reduced or completely cut out by covering components

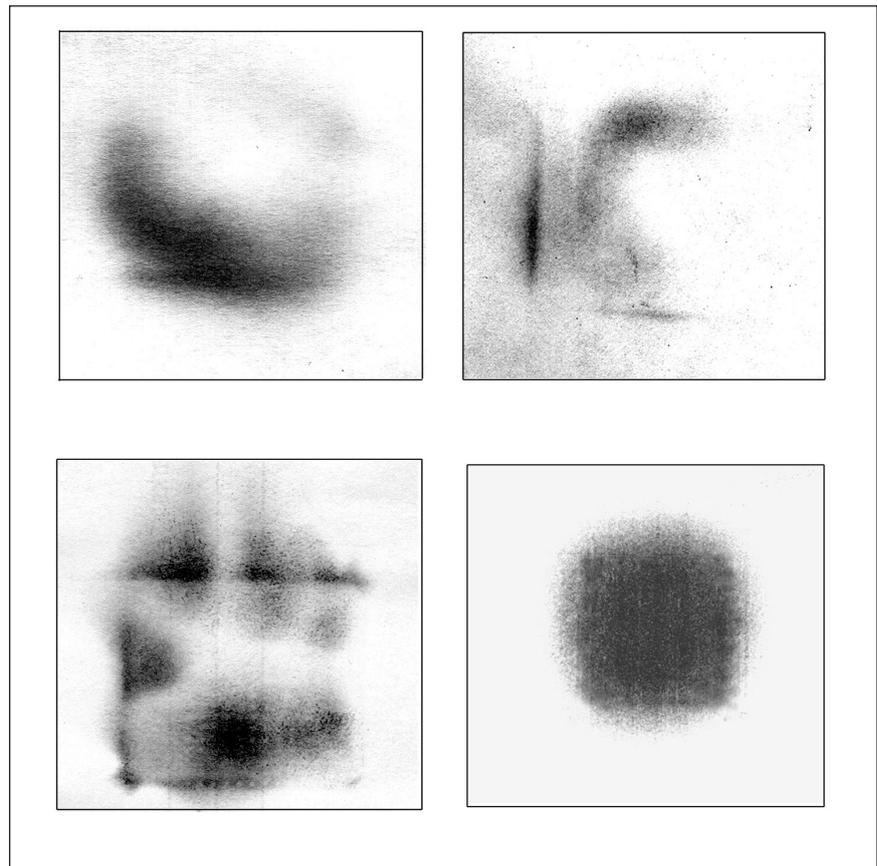


Figure 7: Heat distribution across surface of BGA - convection and dark IR

with reflective foil. Even components situated as close as 0.5 mm from the component to be repaired, can be safely blocked from the heating source. Due to the escaping air and/or required nozzle thickness, this is impossible with a hot air system. Additionally, a top and bottom medium wave IR repair system can also act as an ideal „mini-reflow oven“ for process controlled re-balling of all types of area array packages.

A purchase decision for an area array package repair station must begin with a sound base of the technological requirements, as process control is paramount. The equipment must be able to assure quality always by every operator while increasing ease of use. Its flexibility, in order to supply a high return on its purchase, should have the ability to perform SMD, TH, plastic connectors, etc.

without the need for additional nozzles. This will provide maximum use for minimal cost. By using an open system utilizing IR as opposed to an enclosed environment inherent in hot air systems, you effectively eliminate your current blindness in the rework process. Seeing is believing: by optically capturing reflow in real time during rework you can guarantee even collapse and implement the ultimate form of process control-vision.

Process controlled repair of the area array package is one of the hottest subjects in the industry today. The expected trends in use of this advanced packaging technology, however, need no longer to be the fear of the repair operator, from an ease of use standpoint, the quality control inspector, from a process control standpoint, and the purchasing agent, from a capital investment and

operational cost standpoint. By providing a more detailed understanding of the design of the various area array packages, the production reflow requirements, and the repair technology available, it should be clear that by going back to the basics, everyone wins. Medium wavelength IR, as a perfect heat source alternative, not only provides the most ideal heat transfer and distribution, it also reveals itself as being the most flexible, the most user-friendly, and the most cost-effective. Having an ideal repair solution, don't be afraid of the BGA – let them come in the trillions!

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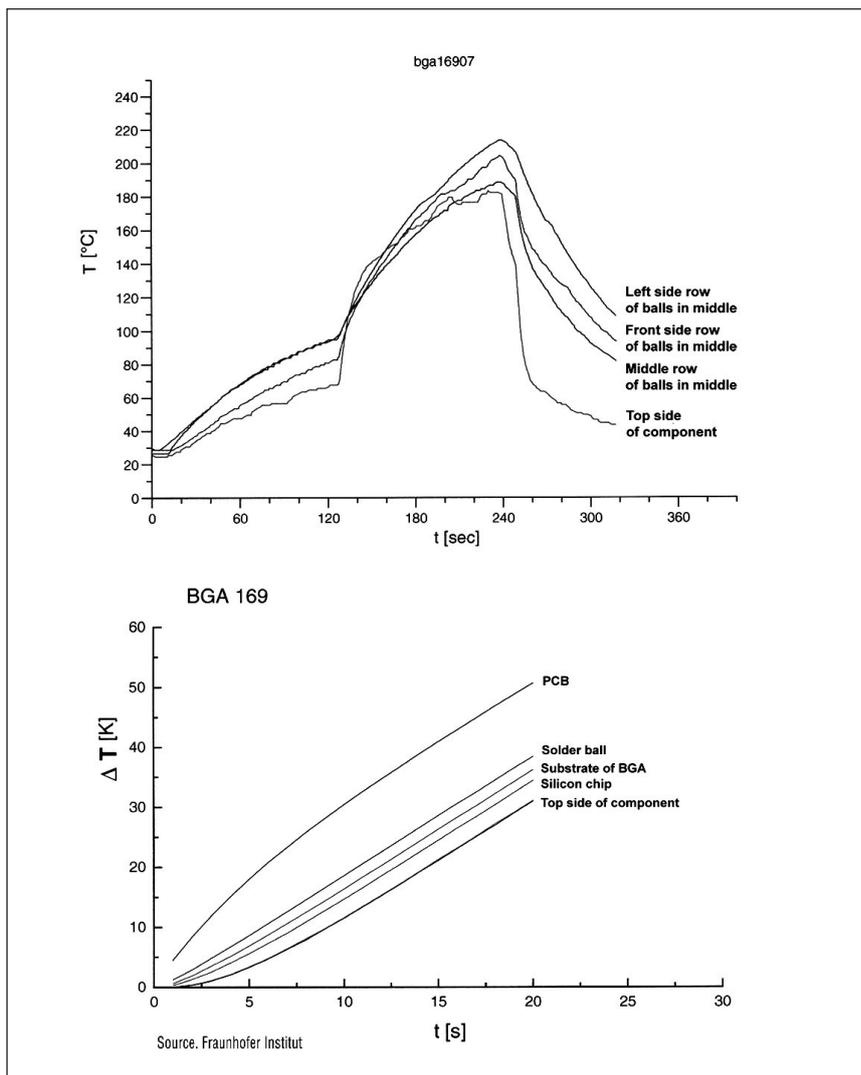


Figure 8: Thermal profiles of BGA 169 installation with IR