

AN OVERVIEW OF MANUFACTURING BGA TECHNOLOGY

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Introduction

Ball Grid Array (BGA) technology is one of the leading edge technologies in surface mount manufacturing. The driving force behind the advancement of BGA technology is the lead spacing of standard surface mount devices. As lead pitches drop below 20-mil, manufacturing becomes exponentially more difficult. BGA technology provides the same I/O count in the same body size with a significant increase in pitch. Manufacturing BGAs is comparable to standard surface mount device manufacturing. Standard equipment for paste application, placement, reflow and cleaning will work with first generation BGAs. The paper discusses BGA manufacturing using 20-mil SMT manufacturing as a baseline.

Solder Paste Application

Applying solder paste to a circuit board becomes more difficult with decreasing pitch. Stencils have replaced screens to allow smaller apertures to be printed. Stencil thickness is used to control the volume of solder paste applied to the circuit board. Manufacturers use a step stencil that allows fine pitch parts to be printed using a thinner material than that used to print the rest of the board. Ball grid arrays have changed the paste application process again.

The apertures for BGAs are round, unlike most common surface mount aperture shapes. Although the BGA pitch is larger, the actual area to be printed is smaller. The area ratio, area of aperture walls over the area of the aperture opening, must still be less than 1.5 to allow proper paste release. Table I shows the comparison of BGA to standard SMT device aperture areas and area ratios. The BGA area ratio is much closer to the 1.5 limit than any other SMT device yet BGAs print easier than 20-mil parts. The data shows that round apertures print easier than rectangular apertures.

Paste volume is critical when manufacturing BGAs. Stencil design will be affected based on the size and dimension of the BGA aperture. Many manufacturers use straight 4-mil stencils moving away from step-down stencils used to build fine pitch products. Four-mil stencils will not apply sufficient paste for BGA manufacturing. A reverse step stencil, with the BGA components at 8-mil, is an alternative for applying sufficient amounts of solder paste to BGA components.

Stencil printing BGAs is simpler than printing 20-mil pitch leaded devices. Pitch increases and aperture size decreases have created very few solder paste problems during the application process. Printing 20-mil pitch pads presents several difficulties. First, spacing between pads is about 8-mil, and paste bridging occurs easily. Second, the orientation of the pads makes a difference in the paste application process. Rectangular apertures present different profiles to the squeegee blade. BGA apertures do not have the same print direction problem because they are round. The stencil printing process window is larger for BGAs than for 20-mil pitch pads. Changes in the print speed, pressure, and paste characteristics have less effect when printing BGA apertures.

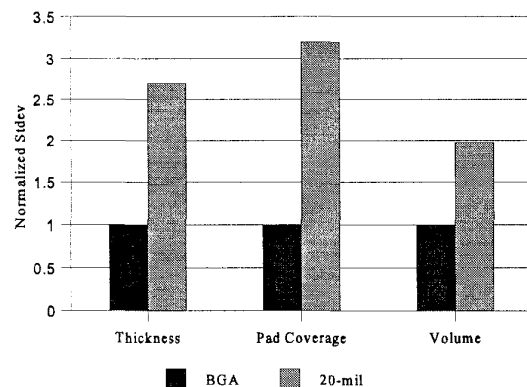


Figure 1. Print Speed Effects

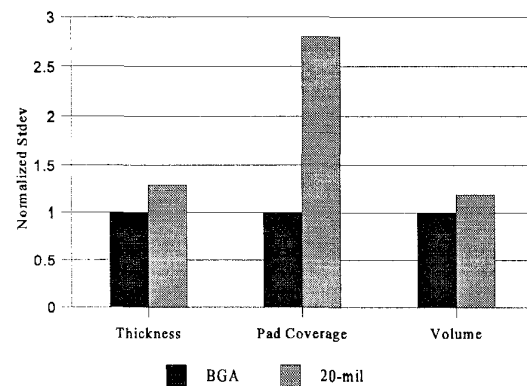


Figure 2. Squeegee Pressure Effects

Table I. Area Ratio Comparison

Pitch	Stencil Thkns	Aperture Area	Wall Area	Area Ratio
50	8	2000	1680	0.84
25	4	1000	736	0.74
20	4	800	720	0.90
BGA	8	491	628	1.28

all measurements are in mils or mils²

Component Placement

BGAs have presented a unique problem to the pick and place process. Equipment manufacturers have added sophisticated vision systems for component alignment. The vision systems can determine defects in the component leads before placement. The vision systems also use local fiducials on the circuit board to ensure proper alignment of the component leads with the pads. Placement systems use these technologies accurately to place fine pitch leaded devices.

BGA leads consist of solder balls on the bottom of the component body which makes standard inspection systems ineffective. BGA components are often placed with mechanical or component body centering due to the lack of vision capable equipment. One problem with mechanical or component body centering is the repeatability of the component. The balls on the bottom of the component are not always in the same position relative to the edges of the component. Using the edge of the component for placement accuracy can offset the component by as much as 8-mil. Figures 3 and 4 show a BGA offset by 15-mils, self centering after reflow. Component self-centering during reflow will most likely correct the problem, but pick and place equipment manufacturers are currently adding vision capability for placing BGAs. Upgraded systems can align the outside rows of balls to the outside rows of the pads, achieving a more accurate part placement.

Reflow

Reflowing SMT product is accomplished by mass reflow equipment with multiple heating zones. Difficulties in reflow often arise from the product design. Location of components on the board will affect the thermal gradients across the board. Placing several larger components together on one section of the board will make proper reflow profiles more difficult to attain. This is true regardless of whether BGAs or fine pitch devices are used. The heat necessary to reflow a circuit board is directly related to component size, board density, and component location on the circuit board.

BGAs offer more thermal mass when compared with 20-mil leaded devices. The reflow challenge is caused by putting solder joints directly under the component body. Because solder joints are directly under the component the BGA must remain above reflow longer to ensure total reflow of solder paste underneath the component. Other reflow profile characteristics are controlled by the solder paste. In addition, when manufacturing BGAs, the suggested paste profile should match the suggested BGA part profile. Incompatibilities between profiles will cause defects and increase the need for final inspection and rework.

The reflow process is the same regardless of the component mounting technology. Component size and composition will affect the reflow process much more than whether the device is leaded or not. The biggest technology driven change in the reflow process has been the necessity for increased control. Reflow oven manufacturers have increased the number of heating zones and improved temperature control circuits to allow the process to handle a large variety of package sizes and material composition on the same assembly.

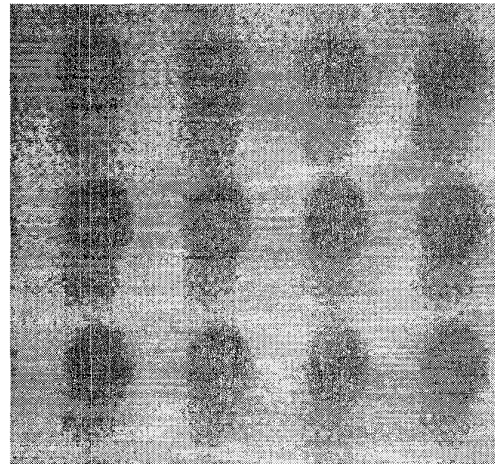


Figure 3. BGA Placed 15-mils off pad

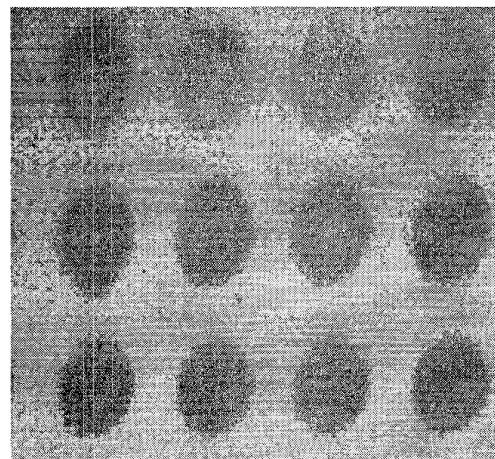


Figure 4. BGA after reflow

Cleaning

Cleaning surface mount assemblies is a major focus of the electronics manufacturing community. Decreased pitch means smaller component standoffs and tighter lead spacing. The smaller the space, the harder it is to clean. Cleaning is only effective when the solution is able to react with residues left on the board after manufacture. Fine pitch surface mount components have hindered the ability of cleaning systems to apply the cleaning solution to all areas of the circuit board. Placing solder joints under the component body has even more potential to hinder the cleaning process.

BGA components, by design, have all soldered connections under the component body. However, component standoff is significantly increased for BGA technology when compared to fine pitch leaded devices. Standoff heights range from 18 to 20-mil for plastic ball grid arrays with eutectic solder balls. Due to the large standoff, cleaning becomes less of a problem.

Initial studies conducted at the EMPF have shown that cleaning under BGAs is not a difficult process¹. Figure 5 shows the cleaning comparison between BGAs and 20-mil leaded devices. The cleaning study was limited to a semi-aqueous cleaning process using RMA type solder paste. The boards were populated with four evenly spaced BGA components. (The simplicity of the board design could account for the lack of cleaning problems.) Future work at the EMPF will include a similar cleaning study on a more representative surface mount board, with a wider variety of components and significantly increased component density.

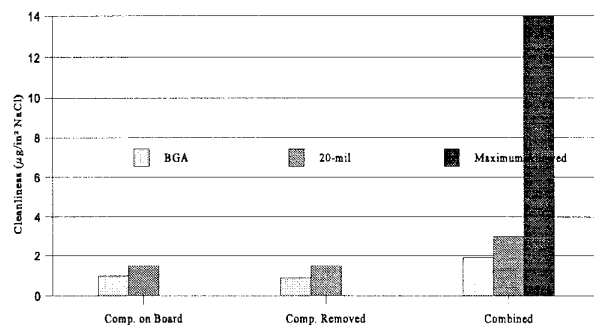


Figure 5. Cleanliness Data

Inspection

Solder joint inspection has been the topic of controversy for many years. Military contractors are required to do 100 percent visual inspection on all electronic products. Visual inspection requires the solder joints to be visible to the naked eye. With the arrival of BGA technology, all solder joints are not visible. The outside row of solder joints can be visually inspected, but the process is difficult and time consuming. If ball grid arrays are to be used in military applications a different method of inspection must be used.

Techniques are available for BGA solder joint inspection, but they are potentially expensive. X-ray laminography is one inspection method for BGA solder joints. Limited research at the EMPF has shown x-ray laminography to be useful for detecting component registration problems (see Figure 3). However, using this technique to determine solder joint quality or esthetics would require extensive research and program development. One practical possibility is to forgo inspection for proven process control.

Rework

Implementing process control will eliminate most, but not all, rework situations. Many rework operations result from factors beyond the control of the manufacturing processes, like design changes or bad components.

Rework has significantly changed with changing surface mount technologies. Components are larger, have more leads, and are generally harder to handle as pitch decreases. One advantage of going to fine pitch leaded devices is the visibility of the solder joints. Solder joint visibility makes the rework process easier to control. The operator can see when the solder reflows keeping rework times to a minimum and reducing product defects. The most difficult fine pitch rework operation is the application of new solder paste.

Mini-stencils have proven to be the most efficient method of reapplying new solder paste in a rework operation. Using a stencil requires very little operator training and effectively controls the volume of solder paste. Other methods are available but are more training intensive and harder to control².

Reworking BGAs is difficult because solder joints are located under the component body. Reflow is "by feel" instead of a visual check, causing the risk of board and component damage to increase. Equipment vendors are currently developing processes and equipment capable of efficiently removing BGAs. Many companies have had success using existing SMT equipment for BGA rework. Using profiles similar to a 68-pin LCC seems to provide good results. Preliminary studies at the EMPF have shown that removal of BGAs with existing technology is feasible.

The major concerns during the rework process are component body temperature, surrounding solder joint temperatures, and component placement. Reworking leaded devices only requires heat to be applied at the solder joints. To reflow all solder joints under the BGA package, the body temperature must be above reflow. Plastic BGAs are sensitive to high temperatures and quick ramp rates. Because the solder joints are underneath the BGAs the time to component removal is longer than with leaded SMT devices. The increased rework time makes surrounding components reach a higher temperature. Heat shields can be used to keep adjacent solder joints from reflowing. Controlling rework process profiles is crucial for successful BGA rework.³

Component placement may be the most difficult rework process. The alignment of the component balls to the pads on the board is very laborious. Using a very small camera angle makes placement possible but is still time consuming. Vision systems are available that will assist with component placement making the process more manageable.

Conclusion

Manufacturing BGA technology is not difficult. Current fine pitch manufacturing equipment can easily handle BGA components. Solder application is easier, but volume is more crucial than with fine pitch devices. Placement of BGAs presents new challenges, but current equipment is capable of handling BGA technology. The reflow process is virtually unchanged. The precautions for developing fine pitch profiles must also be considered for BGAs. Cleaning processes, from preliminary studies, appear to be sufficient. Rework however,

is significantly different. Preliminary studies by the EMPF have shown success when using current techniques and equipment. Equipment manufacturers are making system changes to ease the rework process. Adding BGA technology to existing fine pitch manufacturing floors will require minimal process change. However, process control will be essential if the technology is to be accepted without inspection.

References

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