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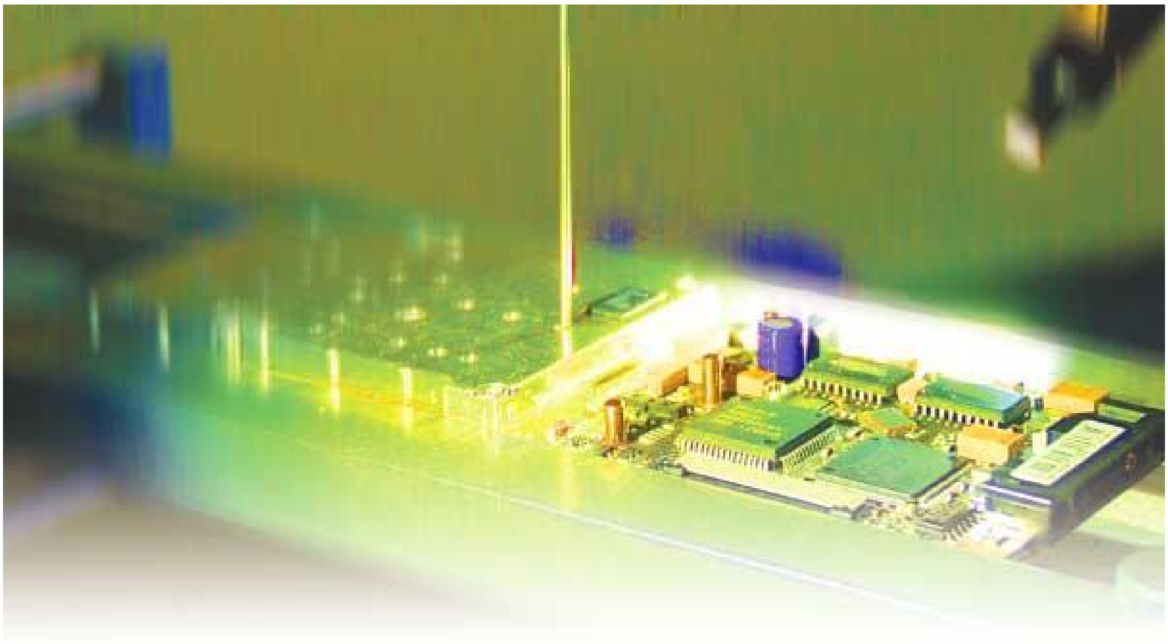
Endoscopic Inspection of Area Array Packages



Meeting Miniaturization Requirements For Defect Detection

BY MARCO KAEMPFERT

Area array packages such as the family of ball grid array (BGA) components — plastic ball grid arrays (PBGAs), column ball grid arrays (CBGAs) and tape ball grid arrays (TBGAs) — are finding ever-increasing use in mass production of electronic assemblies. The leading role is played by the BGA components rather than ceramic column grid array (CCGA) components, because they are less expensive to produce using a base material for contacting — PGBAs. The most striking feature of CCGAs, on the other hand, is their number of I/O contacts (up to 2,577 I/O).

One advantage of all these components is their tendency to tolerate placing errors during production, and high integration through the use of the component underside for contact purposes. There are also disadvantages, such as the use of the underside impairs easy optical solder joint inspection. The high number of solder joints only allows a random quality inspection, since it would be too time-consuming to inspect every solder joint. In some cases, because of the small pitch size, the solder joints are covered by neighboring soldering groups.

BGA Defects

Endoscopic optical inspection systems are suited for finding possible defects at area arrays that occur during production or rework, or in the field caused by environmental and operational influences. In most cases, the type and position of the defects (local areas under the components) depend on production engineering quality and the stresses to which the unit's area array on contact base is chronologically subjected. The chronological course from production of the assembly to failure in the field influences the occurrence of soldering and joining defects (Table 1).

Production	Repair before/after field failure	Field failure
Solder bridges Opens Craters/blowholes Inhomogeneous structure (surface) Microballs Flux residues Too much/too little solder Popcorning (middle area) Solder drains in via	Solder bridges Opens Craters/blowholes Inhomogeneous structure (surface) Microballs Flux residues Too much/too little solder Popcorning Solder drains in via shape of solder joints (inhomogeneous) Unfavourable form of structure solder temperature stress inhomogeneous solder fillets	Cracks in the solder joints (outer areas) Complete separation of balls (outer areas) Separation of balls due to alloy properties (board finish) Contamination between balls (leakage paths) Mechanical influences (assembling)
t=0	t>0, t>x	t=x

Table 1. The chronological course from production to failure in the field influences the occurrence of soldering and joining defects.

While some types of defects (relative to the stress) resemble each other, the mechanisms leading to these defects often vary considerably. If production quality is adequate, defects resulting from production and repair are not to be expected. The production process must be controlled by evaluating production quality. Depending on the objectives or quality and reliability requirements of individual manufacturers, this is achieved through planned random sampling. Controlling the solder joints and the general condition under the components is nearly always essential after repair, because solder, placing and temperature parameters, as well as flux contamination under the components, cannot be compared to those of serial production.

Field failures frequently occur in the outer corner areas of BGAs. This is a result of the varying expansion between the BGAs and the base material that the solder joints have to make up for. Depending on the operational and environmental conditions, as well as the temperature changes that the assembly is exposed to, solder joint fatigue fractures can occur. Mechanical influences such as distortion, which can accompany temperature changes or are caused by design deficiencies, also lead to such defects. In many cases, bad adhesion of BGAs after reflow soldering processes is observed for solder pads with electroless tin. This is caused by structural changes in the intermetallic phase between solder pads and balls.

Locating Soldering Defects

Defects occur not only relative to various stress levels, but also in different locations. This makes optical inspection difficult because many of the systems currently available can only inspect outer areas thoroughly. This type of optical inspection reveals possible solder bridges and contamination between the balls. The surface of the solder balls can be evaluated to select a temperature and transport profile. This usually is achieved with rigid endoscopes, such as those used in medicine, which offer the advantage of delivering quality pictures and have the capability of focusing the image in an adequate range to inspect the second and third rows of an area array. The disadvantage, however, is that any solder joint close to the interior is partially hidden by the solder joint in the row in front of it, and only its contour is visible for inspection. This partial vision is insufficient to thoroughly evaluate a solder joint.

In this context, the geometry of the rigid endoscope is of special importance. With today's closely packed assemblies, there are often other components next to the BGAs or CCGAs that impair area array inspection. Therefore, the diameter of the rigid endoscope must be as small as possible to avoid touching neighboring components. It is not enough to give a value for the "keep out area" (contact surface) required. The rigid endoscope must have this small diameter for at least 35 mm from the tip to prevent from colliding with neighboring components.

During the production process, special importance must be attached to the central area of PBGA components. The property of these components to absorb humidity (hydroscopic properties of the plastic material of the package) caused by unsuitable storage and unfavorable production processes often lead to the "popcorning" effect that can destroy the BGA and also lead to many soldering defects in the central area under the BGA. This effect, which can only be diagnosed after production or repair work, is no longer detectable with the rigid endoscopes that are relatively far away. To carry out inspection "in-situ" in the central area under the BGA, special solutions are required.

One solution is the optical inspection of this central area using a flexible endoscope with an extremely small diameter that records the images in-situ. It can have a diameter of only 300 µm, in which 1,600 imaging fibers and necessary lighting are integrated. This system relies less on the image resolution; it instead uses the varying appearances of reflection directly at the solder joint to draw conclusions on its quality. This type of system enables direct optical inspection at the solder joint without having to convert the recorded information through difficult physical formulas (as in the case of X-ray inspection). Depending on the type of BGA or CCGA, components with a pitch as small as 0.8 mm can be inspected. The quality of the recorded visual information does not correspond to that of rigid endoscopes, but the flexible endoscopes expand the possibilities of optical inspection.

The most important criteria in evaluating a solder joint directly under a BGA/CCGA can be met without difficulty, because opens, solder bridges, flux contamination and deviations in the solder joint geometry are fully detected. The relatively low number of imaging fibers, and the resulting restricted imaging quality for the ultra-thin flexible endoscopes, also reduce the extent of training required for the user.

On the basis of the three-level reflection of direct light on the solder ball under the component, a good evaluation of the intact solder joint is possible (the endoscope illuminates the solder joint and records the reflected image) — first level: reflection of upper solder joint; second level: solder ball; third level: reflection of lower solder joint.

If these reflections are missing, it can be assumed that there is an open. Bridges, on the other hand, produce a total surface reflection without the three discernible reflection points described above and can be detected with ease. Flux residues cause the inspection light to show a turbid (goldish) reflection. Geometrical changes of the solder joints, such as solder draining in the vias (through the dogbones), also change the reflection by the solder joints. The missing solder volume weakens the solder joint, which then can withstand less mechanical stress — reducing the overall reliability of the solder joint.

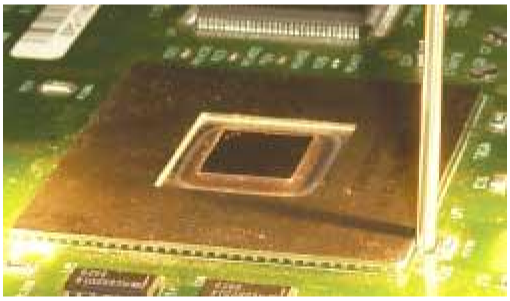


Figure 1. Rigid endoscope shown adjacent to a tape ball grid array.

The reflection of the light from the flexible endoscope allows an evaluation of the solder joint surface. Crater and blowholes, uneven parts on the surface, create deviations in the images. In general, endoscopic inspection necessitates the use of both rigid and flexible endoscopes for fast execution and easy handling.

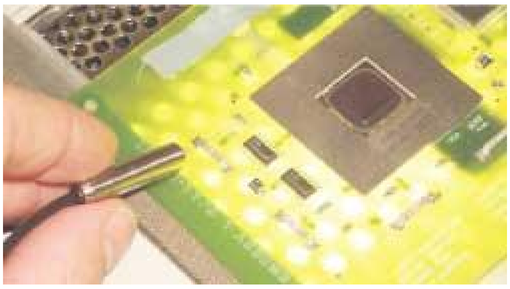


Figure 2. Flexible endoscope under a tape ball grid array.

Endoscope selection depends on the inspection task. Therefore, rigid and flexible endoscopes of different designs and geometries, as well as custom-made endoscopes, are available (Figures 1 and 2).*

BGA vs. CCGA Inspection

Both types of area array components, BGA and CCGA, are difficult to inspect because their solder joints are inaccessible.

CCGA solder joints are easier to reach, because space is less restricted. Inspection from the side is unsatisfactory, however, because surface area is quite large and the contact configuration (solder column) is evenly distributed over the entire underside of the component. In this case, flexible endoscopes with an external diameter of as much as 700 µm and more than 6,000 imaging fibers provide an opportunity to inspect the inner solder joints.


Figure 3 (left). This image shows a row of columns under a CCGA. Figure 4 (right). This image shows the central area under a CCGA.

A row of columns under a CCGA is shown in Figure 3. The outer solder joints are clearly visible. It also becomes clear that an inspection of the centrally located solder joints is problematic, because they lie partially hidden by the outer rows. The central area under the CCGA is shown in Figure 4. The flexible endoscope, ~ 700 µm in diameter, glides along the space between the columns and inspects two rows of columns at the same time. The optical angle, ~ 70 degrees, is brought about by a lens fitted at the top of the flexible endoscope. The relatively high number of imaging fibers (~ 6,000) delivers an adequate imaging quality. The upper and lower solder joints are clearly visible, at least through their reflection. Some columns in the central area have a modified surface appearance because of the changed properties of 90Pb10Sn, as opposed to eutectic alloy, and therefore reflect less than eutectic alloys. In the middle, between the columns, there is a through-hole that has a copper-colored reflection. The combination of the rigid and flexible inspection offers the best results for most applications (Figures 5 and 6).

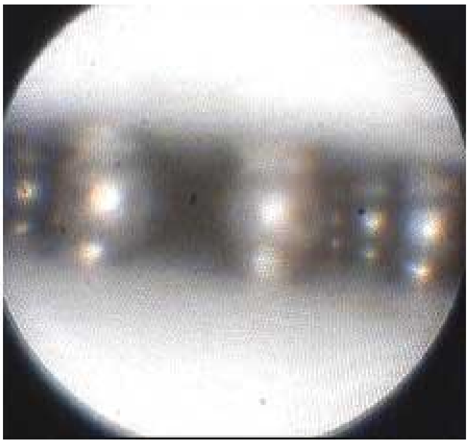



Figure 5 (left). This corner area of a CBGA shows that the surface of the upper solder joint is considerably rougher than that of the lower surface. The defect is the result of the wafer bumping process of the CBGA, in which the solder paste was not completely molten. Figure 6 (right). The image of this easily detectable defect was taken directly under the CBGA and shows the inner rows in the direction of the outer edge shortly before completely tunnelling the whole CBGA. The missing or at least considerably reduced reflection at the upper solder joints shows a deviation to the lower solder joints, meaning that the defect is also present in the central area of the CBGA.

The restricted space under BGAs necessitates the use of small flexible endoscopes. The slight loss of imaging quality implied does not impair inspection by staff. CCGAs, as well as the related PGAs or comparable components, can be inspected efficiently.

X-ray vs. Optical Endoscopic Inspection

An efficient optical inspection is essential in most of the areas of electronic assembly production. The investments costs for such equipment can be quite high.

Optical endoscopic inspection systems cannot replace X-ray systems but, rather, complement them. X-ray systems are more expensive than optical inspection systems, but diagnose defects effectively. The advantage of seeing an image, on the basis of which the information is interpreted, quickly makes an impact on working speed. In the case of X-ray inspections, the image information sometimes depends on the data processing method so that the image information varies with software and programming. This can lead to disturbances in connection with AOI systems and impair inspection. Today's X-ray inspection systems are unrivaled in the inspection of sealed areas such as the interior of ICs. They are also suited for in-line inspection. Optical inspection systems, however, are not well suited for serial inspection.

Conclusion

The ability to reach and see nearly inaccessible areas opens up prospects in the optical inspection of electronic assemblies. These niche products in the range of classical optical inspection can be an interesting alternative to costly X-ray inspection systems.

Endoscopic inspection can be applied in a far wider range than that of electronic assemblies. In the future, many more tasks will use the miniaturized endoscopes, as they respond well to increasing miniaturization requirements.

References

Please contact the author for a complete list of references.

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