The Inspection Connection 2

LATEST TECHNOLOGIES IN OPTICAL INSPECTION

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Optical inspection plays an important role in meeting quality requirements for printed circuit board (PCB) manufacturing. To achieve consistent quality, it is necessary to know what kind of defect is expected, where it can be found, and what type of optical inspection system is needed to visualize the defect. Inspection systems are directly integrated in the value-creation chain of PCB manufacturers, so it is critical to carefully consider the selection and purchase criteria.

Optical inspection systems, ranging from stereo microscopes to highly sophisticated, area-array inspection systems, have been fulfilling standard-control and process quality-control functions for quite some time. Unfortunately, these systems are partially limited in their use. Stereo microscopes cannot be used to inspect under connectors, inside hidden components, under BGAs, and other places where access is difficult. It is important that the geometries of microscopes allow inspection of large or oversized assemblies. Often, the optical focus must be readjusted when tilting the assemblies to enable a diagonal view, requiring additional effort and time.

One solution is to use a special auto-focus camera in connection with a highly flexible and self-balancing inspection arm, which stays put in the chosen position. The ability of this camera system to find the maximum focus within a few milli-seconds renders maneuvering the assembly, inspection, and subsequent documentation fast and efficient. The extended reach geometry of the arm facilitates the inspection of large PCBs, and allows for repair of large backplanes and rework tasks. Figure 1 shows the protected camera optics held above the solder joints at the best possible working distance, and the rework process can be observed and documented at high magnification. Installing such a system at hot spots within the line enables flexible operation.

Rigid Endoscopes – Old Acquaintances

Inspecting hidden or difficult-to-access solder joints requires more effort. Endoscope-based solutions offer decisive advantages with their wide range of application possibilities for the many requirements of today's electronic assemblies. In Japan, these patented processes were used in the development of new assembly and connecting techniques (CSP, μBGA) as early as the 1980s. Boroscopes have been known for decades and are primarily used in medical technology. Industrial endoscopes, on the other hand, require special geometries to meet the inspection requirements of BGA, μBGA, or flip chip components.

For rigid endoscopes, the inspection head — which holds the optic of the system — must be as small as possible to examine increasingly smaller components and packaging density. This selection criteria is important for meeting ROI requirements and avoiding costly follow-up investments.

At a magnification of 800×, and the ability to adapt the depth of field over a wide range without changing optical resolution, one company's* new flip chip endoscope* makes inspections of flip chips'

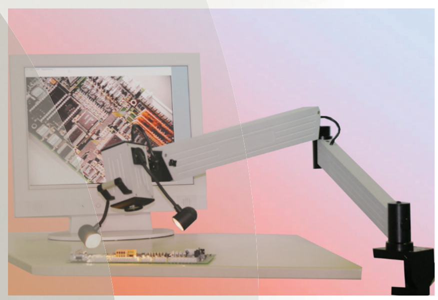

Figure 1. Reflow-Inspector during operation.

or chip scale packages' (CSPs) components feasible. The next generation* of this endoscope, currently under development, promises to allow focus on the complete depth of a flip chip. Figure 2 illustrates that the ability to focus over a large area (C) is not only important, but essential.

Space is extremely limited on electronic assemblies, and inspection is complicated by endoscopes with an unfavorable geometry. The given diameter of the endoscope refers to the whole height of the endoscope. Minimum specifications which are often only valid for the tip and not the rest are not helpful in the selection process for a suitable inspection system.

It is important that the system be robust — to reduce damage to the optical parts through accidental or bad handling, the bracket holding the optic must be designed to give and release at a pre-defined overload and act as a protection mechanism.

Rigid endoscopes offer a side view of the inspection objects (Figure 3). The outer solder joints can be inspected in area-array packages. Their surface properties can be evaluated, and evidence of

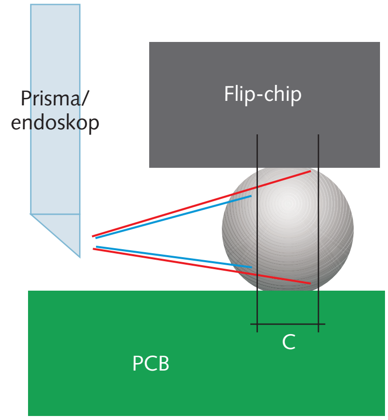

Figure 2. Area C (area of limited depth of field); only a small part of the ball can be focused.

solder bridges, micro-cracks, microballs, and flux residues can be detected. This is where the usefulness of rigid endoscopes for inspection of area-array packages ends — the vitally important central area of the package gets missed.

Soldering defects due to the drain of solder through-vias are hard to prove,

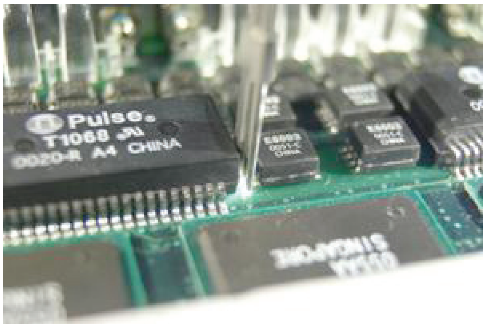

Figure 3. Connection between design height of endoscope and effectively usable range.

especially in the central area of the package. The view of single solder joints situated in the middle under the component is partially obstructed by neighboring solder joints. Popcorning of components with plastic casing always manifests as soldering defects under the BGAs. Microballs and flux residues are equally difficult to detect. Stabilization capacitors are frequently placed in the center under BGA components; particularly micro-processors where there are no pins in the middle. There is no way to tell whether these capacitors have been adequately soldered or whether tombstone or Manhattan effects have occurred.

Flexible Micro-endoscopes – New Companions

Flexible micro-endoscopes offer one possible solution for identifying these defects. These fiber-optical, flexible endoscopes are fed along the rows of solder joints and travel into the central area under the components. Although the image quality of flexible endoscopes is not as brilliant as rigid endoscopes; with a diameter of 0.32 mm, it is still more than adequate to illustrate defects.

Certain properties in flexible endoscopes are necessary to guarantee long-term and safe operation. The protection of the optical fibers plays a major role — unprotected or plastic-covered flexible endoscopes reveal damage to the outer protection sheaf after only a few inspection operations. A flexible steel capillary is required to protect flexible fibers from external damage through handling (feeding along the substrate of the BGA). This detail requires immense technical knowledge, but it saves on costly repair work and guarantees a long operational life of the endoscopes. One choice* offers much improved picture quality by using a 3-chip digital camera, Xenon cold light, and a series of flexible endoscopes ranging in diameter from 0.28 to 1.0 mm (Figure 5).

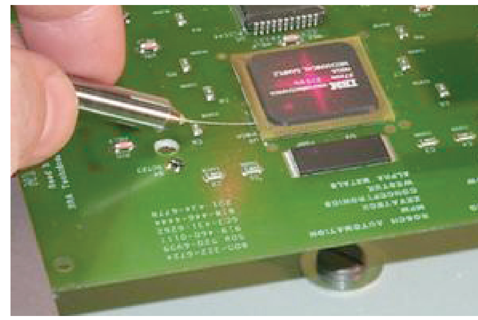

Figure 4. Flexible endoscope with steel capillary.

Modularity

Many inspection systems on the market are designed to serve only one defined purpose. Modular systems offer the possibility to complete the system at a later date when a particular optic becomes required. It is useful for the optical parts — macro lenses, microscopic lenses, and rigid/flexible endoscopes — to have a common interface to the camera system. This interface enables a fast change (<10 sec.) of the optical parts without using any tools, offering a high degree of flexibility. Additionally, a modular system helps reduce cost by being able to perform many different and complex inspection duties.

Processes

The transition to lead-free not only brings about changes in the alloy composition and its influence on wetting properties and surface finish, but also affects optical inspection and contributes to new evaluation criteria and methodology. The modifications which lead-free solder implies include a change in wetting properties. With the use of a pre-defined solder temperature during the soldering process, lead-free solder tends not to wet as well as tin-lead solder. The geometry of lead-free solder joints is mostly characterized by lower solder angles (flow characteristics, solder height). This is particularly interesting where AOI inspections are involved. Additionally, the partially higher surface tension of lead-free solders during melting can lead to a distinct increase in tombstoning and formation of microballs, depending on the solder stop mask used. The solder joint surfaces solidify first and often show dendritic structures, which become apparent in a coarse surface.

Optical inspection should take these changes into consideration and understand they may vary with a fluctuation in solder temperature. At the same time, all knowledge and standards for the optical evaluation of solder joints from the lead-era still apply for the lead-free technology.

One method of inspection involves lifting off BGAs with a tool in order to detect separations of balls from the substrate by the light shining through. Other methods of inspecting THD solder joints resulted in protruding wires, which needed to be cut off after soldering. In both cases, the solder joints are pre-damaged by exerting a non-defined force during the inspection process. It is much better to search for transient de-

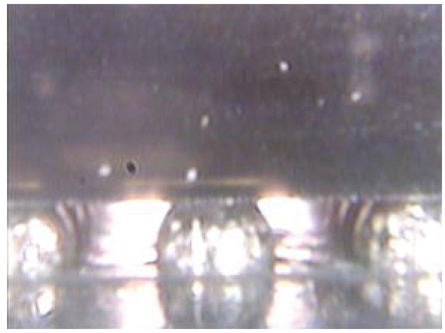

Figure 5. Flip chip inspection, color photo (the mean height of the ball is approx. 10 to 15 μm).

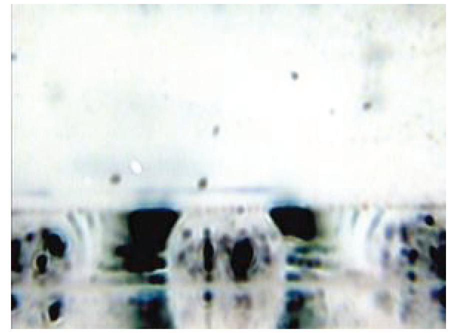

Figure 6. Flip chip inspection, negative picture supplies additional information.

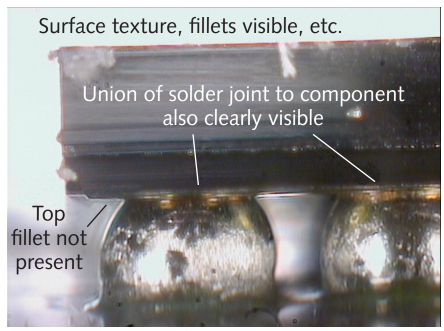

Figure 7. μBGA 800x, well-shaped solder sphere to an X-ray, but fails optical inspection.

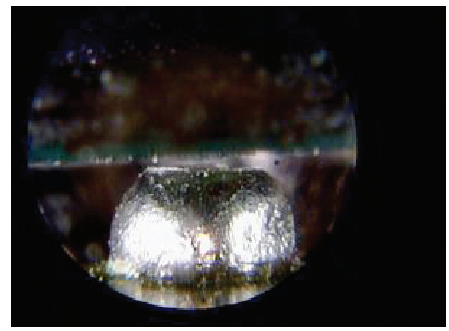

Figure 8. BGA, solder joint open at substrate.

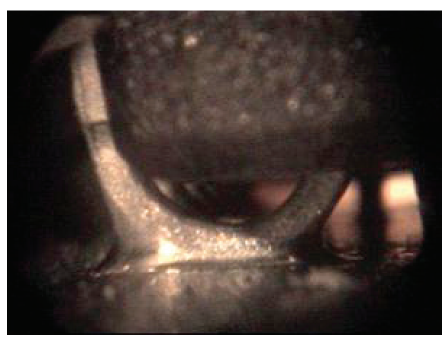

Figure 9. J-lead, lead-free solder paste, good wetting.

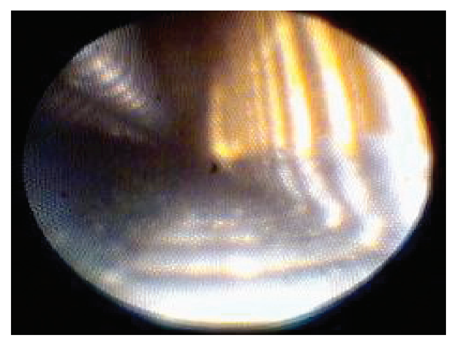

Figure 10. Gullwing inspection of heel fillet directly in situ with a flexible endoscope.

fects by means of temperature change tests, since the solder joints are subjected to an even and low load. Figures 5 through 10 demonstrate examples of modern inspection methods.

Inspection in a Lead-free World

The electronics industry has had to deal with the introduction of lead-free technology since the EU's WEEE and ROHS guidelines took effect. The worldwide trends in this branch of the industry are closely followed and directly influence the way future inspection tasks will be fulfilled. In the case of lead-free solder joints, inspection must be carried out quickly and efficiently. This task brings about new challenges through the changed composition of the alloy. Lead-free solder joints not only have different mechanical, physio-chemical, and technological properties as opposed to conventional Sn/Pb solder joints, they also have different surface finishes and a different appearance during optical inspection. In any case, inspection system companies should be ready for lead-free. **AP**

*SEHO/TechnoLab

*Micro-Inspector – "Mk.2"

*Mk.3

*Flex-Inspector

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