X-Ray And Endoscopic Optical Inspection

by Marco Kämpfert, TechnoLab

The desire to perform optical inspections of inaccessible places, to be able to see areas normally hidden from the eye, is as old as technical endoscopy. While a well-known German manufacturer of technical and medical endoscopes has patented products since the early seventies, only now have endoscopes been applied successfully for optical inspections for electronic assemblies. And their greatest advantage in comparison to the well-established X-ray systems gains ever-increasing importance: cost. The cost of an optical inspection system is about 1/8 to 1/10 that of an X-ray system.
The decisive question now is: which system is able to carry out an inspection at the lowest possible cost?

Up until today, technical endoscopy for the inspection of electronic assemblies has mostly been used for special applications and with custom-built devices. The development of ever smaller rigid endoscopes has made it possible to optically inspect electronic assemblies for defects. With endoscopic inspection systems the user has a true-colour and true-geometry picture, which is decisive for a quick evaluation. Therefore this instrument gives a valuable contribution to the inspection of hardly accessible or hidden areas on the assemblies. The inspection of the metallic surface of connectors is thus easy and quick. And the quality of solder joint surfaces under a BGA can also be quickly assessed – at least that of the outer rows.

Optical and x-ray inspection

The ability to visualise surface phenomena which cannot be assessed with an X-ray inspection system is what distinguishes optical inspection from X-ray inspection. The latter, however, does offer the benefit of "seeing" through the inspected object. It should not be forgotten either that an X-ray system can be easily integrated into an in-line concept, whereas the optical inspection systems of today are rather laboratory devices and can hardly be used in serial inspection. However, this is not the place to discuss the advantages and disadvantages of these two complementary systems. In practice, the decision to be made is which system is most suited for a particular application?

Table 1 gives a brief insight into what is involved. The decisive issue is the problems that need to be solved. It is quite useful to X-ray a BGA with more than 500 I/O during the assembly process. An endoscopic inspection would be far too time-consuming. But the endoscopic inspection also gives the user important information about the soldering process (temperature, wetting, flux residues, blobs/microballs, etc.) which can only be partly or not at all ascertained by X-ray inspection.

Practical examples

Figure 1 shows the solder joints of a CBGA. The angle of view under the component in this case is 45° relative to the transverse and longitudinal axes, which means that the hard ball in the foreground is

Table 1 – Advantages and disadvantages of X-Ray and endoscopic, optical inspection systems

System	*Advantage*	*Disadvantage*	*Value creation*
X-Ray	*-fit for automation -fit for in-line applications -radioscopy -fast*	*-expensive -requires specially trained personnel -high maintenance costs -interpretation of results necessary*	*Only within in-line production process, quality assurance, introduction of new processes.*
Endoscopic, Optical	*-WYSIWYG -low cost -true picture -no security measures necessary -broad and diversified information (flux residues, surface, etc.)*	*-hidden areas remain invisible (rigid endoscope) -limited picture resolution with PAL*	*Quality assurance, introduction of new processes.*

on the corner of the array. It is clear in the picture that the solder joints on the top of the balls are not completely molten. Here the solder paste displays a rough surface structure which indicates that heat management during the solder process was incorrect or disturbed.

Figure 2 shows an open. The soft ball is not connected to the solder depot beneath. This can have many causes: twisting or warp of the plastic casings is as possible as is gassing from the solder joints. This case should be closely looked into. The main advantage of optical, endoscopic systems is, as stated above, the ability to deliver a true-colour and true-geometry picture containing much additional information (roughness of solder joints, flux residues, contamination, etc.). With a 2D X-ray system on the other hand, only the blackening (by the solder joints) and the geometry of the sectional view can be used for evaluating the quality of solder joints. The additional information mentioned above is lost. Since the blackening is determined mainly by the solder volume with the lead content, it is hardly possible to find opens with a 2D X-ray system, for the radioed solder volume does not change in the inspection axis. The same applies to the badly soldered example in Figure 1.

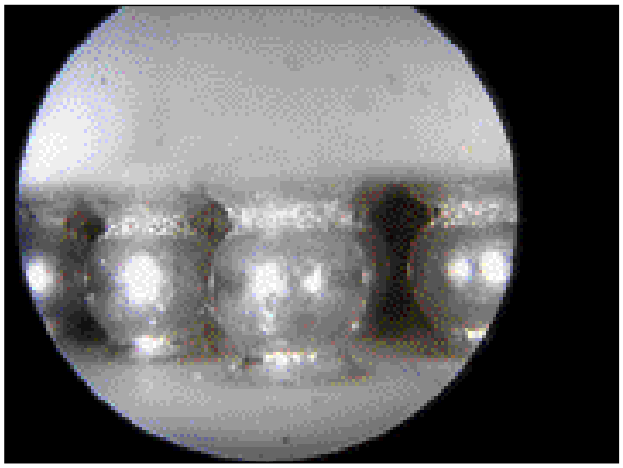

Figure 1 – CBGA, solder not completely molten

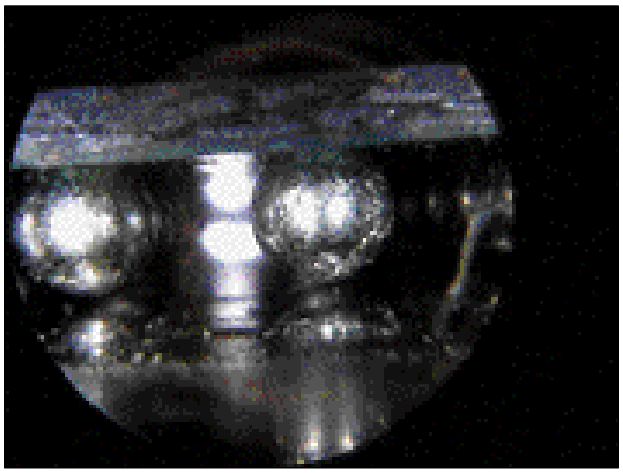

Figure 2 – No-wetting (ball)

The 2D X-ray pictures are far more difficult to interpret than the pictures from optical inspections. The blackenings (in this case the black dots) represent the solder joints. The solder bridges between some solder joints are very easy and moreover very quickly to locate. Some blobs/microballs are easily and quickly detected as well. The main advantage of the X-ray method is the ability to "look into" the solder joints (inclusions, gas pockets, voids in the solder joints) in the middle (small light dots). Such deficiencies are only discernible with an X-ray inspection.

The examples given above illustrate how the two inspection methods for electronic assemblies do not compete but ideally complement each other. Depending on the application, one or the other system is best suited.

A versatile optical inspection system

Within the family of inspection systems ranging from simple stereo microscopes via modern incident light microscopes to specially developed vision systems for electronic assemblies, endoscopy for technical applications plays an increasingly important role. The following examples highlight this importance.

Figure 3 shows an extended solder joint under a PBGA 352 which has probably risen during the soldering process. Figure 4 illustrates the separation of a solder ball from the BGA substrate. These photos were taken by a highly miniaturised rigid endoscope with side view. Since the diameter of this endoscope is only 2.2mm, there is hardly any area on an electronic assembly which it cannot reach, even with the densest placing.

The endoscopic principle which has been known for more than thirty years is only now getting increased attention due to the problems involved in the inspection of miniaturised components such as BGAs. In this context it is especially important to have an endoscope with a very small diameter in order to reach otherwise hardly accessible areas. When choosing an endoscope, it is essential to know how much free space there is alongside the BGA, and whether the endoscope must be placed directly against the BGA to get a well focused picture, or whether it is necessary to leave some space between the endoscope and BGA in order to achieve this. The area of application is not limited to the inspection of BGAs, however. Endoscopes can also inspect hardly accessible or hidden connectors, already mounted high frequency shielding plates and much more.
Furthermore, optical inspection with a rigid endoscope is highly

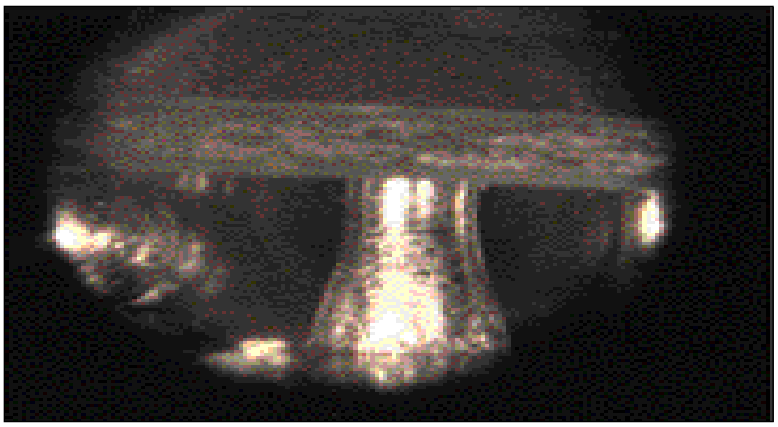

Figure 3 – Extended solder joint

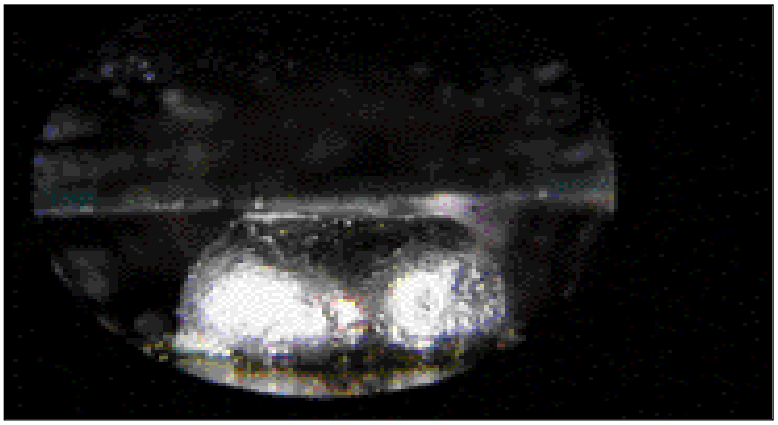

Figure 4 – Break of the solder joint (top)

suitable for quality control at every production step. The endoscope can be used to control solder paste printing, soldering results and even rework, contributing in many ways to the creation of value.
Developing successful solutions means placing the priority on the special requirements of the customer and offering custom-made systems. For this reason an inspection system was developed which - thanks to its high flexibility - meets practically all optical inspection challenges. The A_IS system by TechnoLab has been modularly designed to give the user the opportunity to decide for himself how many components of the system he needs. The complete system with all attachments covers the total range of requirements for optical inspections and quality control in electronics and related branches.

Inspection under a BGA

The A_IS is the only system on the market which enables inspection directly under a BGA. This is also done with endoscopes. These endoscopes are not rigid, however, but semi-flexible, so that it is possible to insert them under a BGA and inspect the solder joints there. The decisive factor here is the diameter of the endoscopes. Seho has succeeded in developing an endoscope with a diameter as small as 0.28mm.

This endoscope has 1600 light guides each of which has a diameter of just about 1 µm – very close to the physical limits of light transmission. Seho also offers endoscopes with a diameter of 0.32mm and 0.42mm (with integrated light). The use of these optical systems for BGAs is limited by the BGAs' pitch and stand-off, since diameter cannot be reduced any further. The range of applications for the flexible endoscopes is as wide as for the rigid ones. The flexible endoscopes originally developed to inspect closed relays were further miniaturised to also inspect BGAs.

A wide range of options

The inspection system is supplemented by different optical attachments for overviews. The developers took great care in choosing usefully graded focal lengths in order to achieve a complete magnification range from 1:1 to 1:1000. The complete system offers the user a versatile inspection tool from which only costs a fraction of other additive optical systems and which operates in stand-alone mode or ideally complements an existing X-ray.

The microscopic attachment which can go to a scale of 1:1000 is able to distinctly show the finest structures as can be found for example on semiconductors. This optical attachment is very important if a company does not yet have any microscopes or if the microscopes present do not have costly colour camera connections and matching software.

State-of-the-art inspection

The differences between the X-ray and the optical inspection systems described above make it clear that the systems do not directly compete with each other. Each of the systems has its advantages and disadvantages, and the user has to make his choice on the basis of his requirements, quality objectives and the nature of the problems that need to be solved. In the future, cost efficiency will weigh more when considering which system is best suited to the company's needs, and this will lead to a shift from classical, cost-intensive inspection methods to comprehensive and integrated systems. There is definitely a tendency towards the use of low-cost X-ray systems coupled with innovative optical inspection equipment. This combination offers a cost-efficient solution to the problems of quality control and contributes to a solution that creates value.