3D X-ray inspection of LEDs for vehicle headlights

LEDs have experienced a real triumph in recent years and are an integral part of our daily lives. The automotive industry in particular has been relying on this technology for a long time and is constantly pushing it forward. LEDs have long been used in vehicles not only to indicate various statuses or to illuminate displays. They are an integral part of headlights, indicators and rear lights, or in combination with optical fibres they conjure up a pleasant ambience in the passenger compartment.

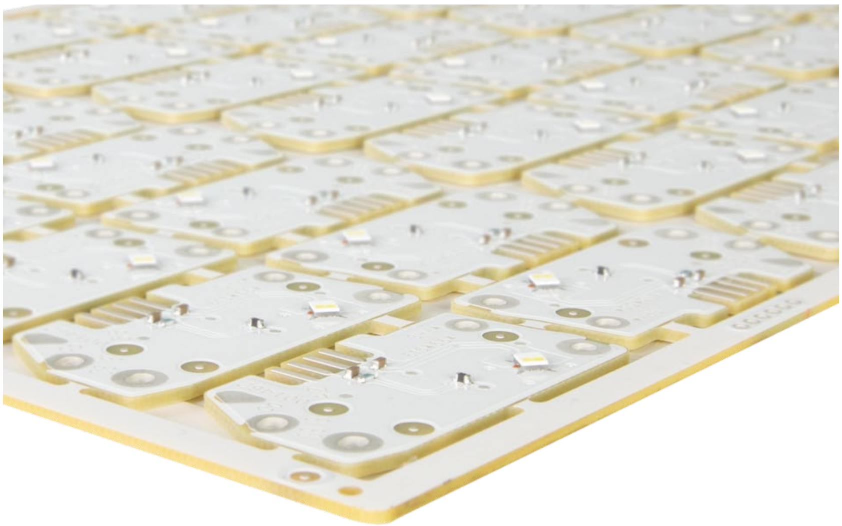

Fig. 1: LED board as multiple use for side indicators from vehicle

Light and warmth

However, LEDs emit not only light but also heat. Good heat dissipation is crucial for the service life of an LED. In earlier vehicle generations, LEDs were installed with a classic component body and lateral solder connections. Currently, LEDs are manufactured as chip-scale packages (CSP LEDs), for example. This package no longer has an enclosure that extends beyond the light source. The connections for the anode and cathode are located directly under the housing body. Additional connections for heat dissipation (so-called heat sinks or thermal pads) are also located under the LED and are not visible from the outside. This package reduces the LED form factor to a minimum, but requires new inspection concepts for optical inspection in the PCB or Board manufacturing process. Since the connections are concealed under the component, X-ray technology is the method of choice for inspection.

Press Contact:
GÖPEL electronic GmbH
Christina Schellbach
Göschwitzer Street 58/60
07745 Jena, Germany

Tel.: +49 (0)3641-6896-739
Fax: +49 (0)3641-6896-944
E-mail: presse@goepel.com
Web: www.goepel.com

2D vs. 3D X-ray inspection

Voids (gas inclusions) in the solder joints of an LED prevent the optimal dissipation of heat. The larger the void, the worse the heat dissipation - the shorter the service life of the LED. To date, there are no IPC limit values for the maximum permissible void content of an LED solder joint. According to the IPC, the limit value must be agreed individually with the manufacturer and the end customer. To ensure optimum heat dissipation, vias (heat-conducting vias in the PCB) are placed directly under the LED, among other things. If the LED is X-rayed using conventional 2D (vertical) or 2.5D (oblique) X-ray technology, the via and solder joint cannot be separated optically. A check for via content is thus not possible. Even if there are no vias under the LED, internal structures such as bonding wires themselves often interfere with the evaluation in the 2D X-ray image.

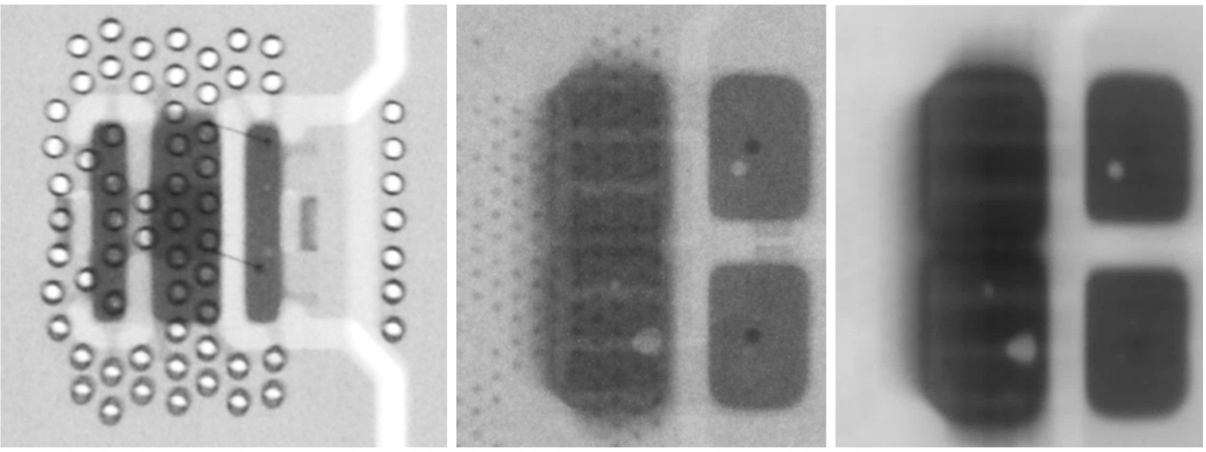

Fig. 2: Left: 2D X-ray image of an LED with underlying vias (circular). Void measurement is only possible to a limited extent. Middle: 2D X-ray image with interfering structures. Right: 3D X-ray image without interfering structures and with clearly recognizable voids.

The AXI system X Line - 3D from GÖPEL electronic GmbH uses fast, scanning 3D X-ray technology for inspection here. With 3D and the associated layer-by-layer inspection, the vias can be optically separated from the solder joints above them.

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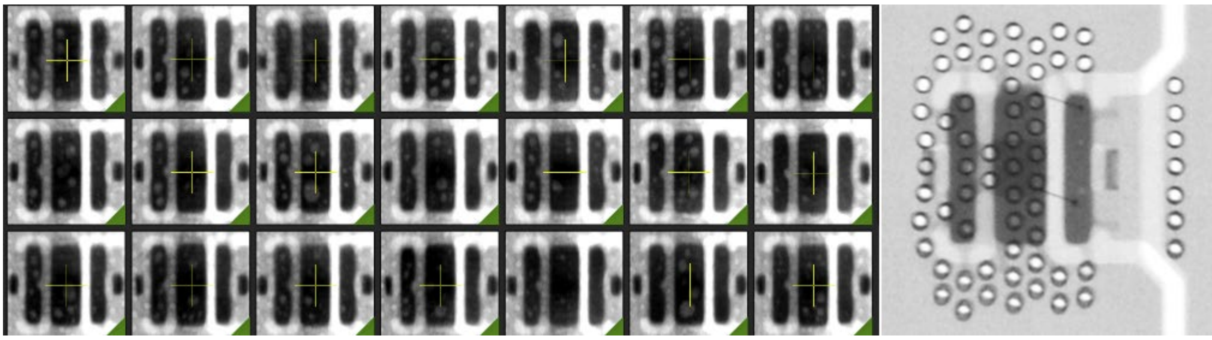

Fig.3: 3D X-ray image (slice image). The interfering vias are not visible. A void measurement can be carried out. Right picture: 2D image in comparison

The 3D layered image of the LED solder joint shows the voids without the disturbing influence of the vias or any bonding wires. The 3D reconstruction also eliminates the typical X-ray perspective and displays a geometry-calibrated image. On the one hand, this makes it easier to evaluate the voids and improves the accuracy of the measurement; on the other hand, it speeds up the creation of the inspection program. A uniform component library can be used to create the program.

What is being tested?

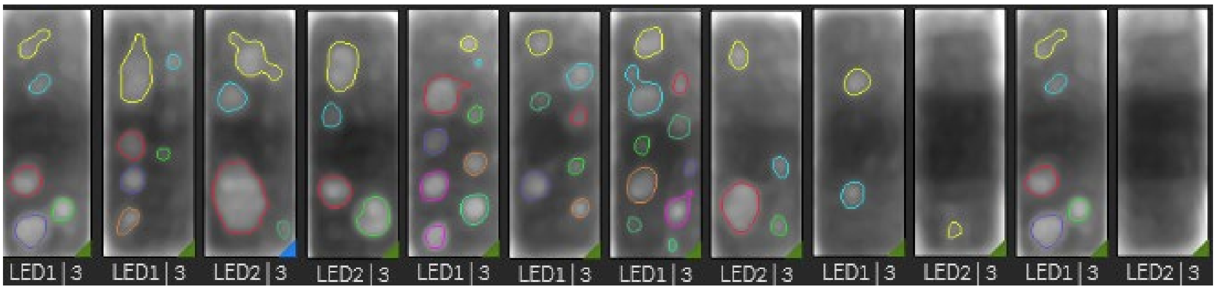

Fig.4: Automatic evaluation of the voids in the 3D X-ray image

In addition to void percentage, area of the voids in mm^2, number of voids, largest void, etc., further checks are carried out. For example, presence, position and rotation are checked. It is tested for short circuits and the insulation distance between the LED solder joints is determined. Solder balls located between the solder joints are thus detected even though they do not yet represent a short circuit. In addition, solder balls in the direct vicinity of the LED are detected.

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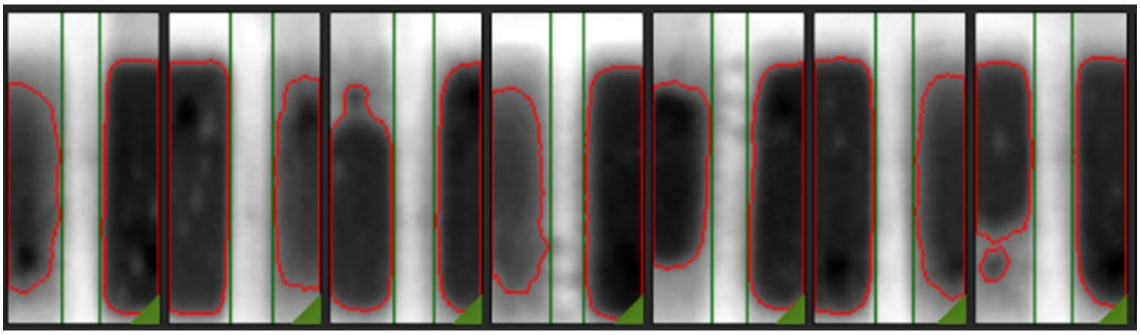

Fig.5: Checking short circuit and insulation distance. A minimum distance must be maintained between the two green lines.

Not all 3D is the same

A 3D X-ray image is calculated from several oblique X-ray images (so-called projections). The number of oblique images used for a 3D image reconstruction is a measure of the quality of the 3D slice image. The more oblique images are used, the "better" the 3D image. For LEDs, GÖPEL electronic typically uses between 8 and 16 projections at a resolution between 10 and 15 µm/pixel.

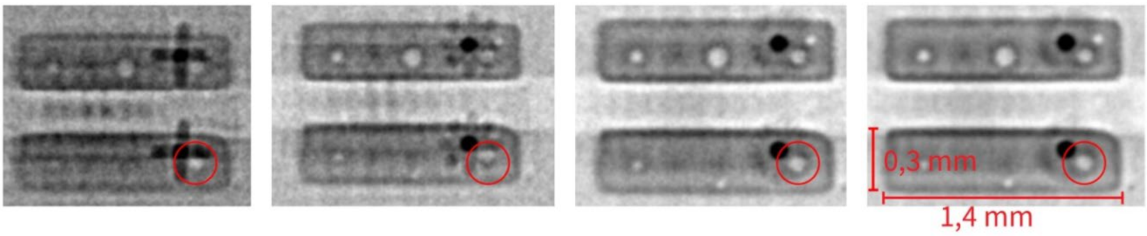

Fig.6: LED solder joints reconstructed with 4, 8, 16, 32 projections (void at bottom right becomes more visible with increasing number of projections)

This is where a weakness of the conventional stop-and-go image recording technique becomes apparent. For 3D image capture, a flat-panel detector is moved along a circular path to capture the individual oblique images. Each position must be approached individually. This costs time and results in long inspection times. For this reason, such systems usually use simple 2D and 2.5D images to evaluate the LED solder joints. However, due to vias under the LEDs and the inner LED structure itself, only a limited evaluation is possible in this way.

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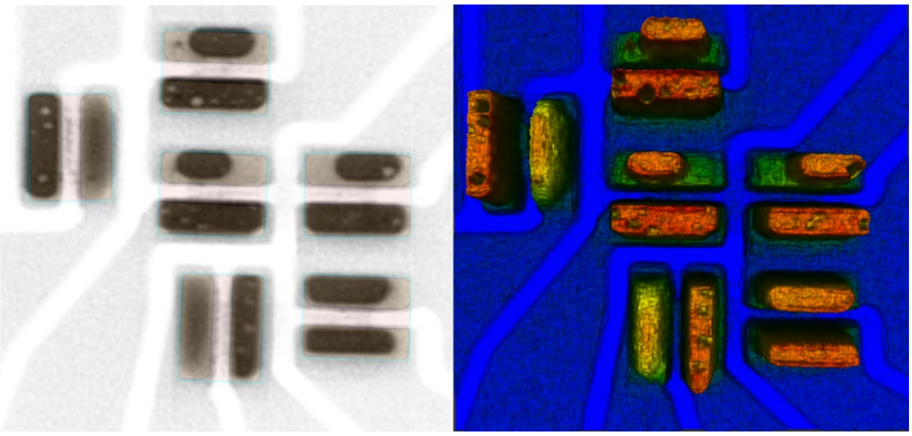

Fig.7: Left 3D X-ray image, right 3D visualisation with topoVIEW for easier assessment at the verification and repair site.

Advantage of scanning 3D X-ray imaging

The MultiAngle Detector 3 of the X Line - 3D does not rely on stop-and-go image acquisition with flat-panel detectors. This detector enables scanning 3D X-ray image acquisition. The oblique radiographic images are acquired by several digital line detectors in parallel directly in motion. The number of oblique projections for the 3D calculation can be freely selected. In this way, short inspection times can be guaranteed. The MultiAngle Detector 3 can also inspect in 2D in simple situations without overlaps. Another advantage results from the fact that LED boards are often designed for multiple use. Thus, several PCBs are contained in one scan strip. All components that are in the scan strip can be tested without affecting the cycle time.

Conclusion

With the X Line - 3D, LEDs can be X-rayed in a series cycle by means of a fast, scanning 2D or 3D X-ray image acquisition. The quality of the 3D image is scalable and can be adapted to the required cycle time. The advantage of 3D inspection lies on the one hand in the suppression of interfering structures due to vias and the internal structure of the LED, and on the other hand in the geometrically calibrated imaging of the LED solder joints and the thus more precise measurement of air inclusions. This 100% in-line inspection ensures the quality of LED PCB or Boards, guaranteeing their service life and preventing failures in the field.

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Fax: +49 (0)3641-6896-944
E-mail: presse@goepel.com
Web: www.goepel.com

Author:

Andreas Türk, AXI Product Manager at GÖPEL electronic GmbH

Press Contact:

GÖPEL electronic GmbH
Christina Schellbach
Göschwitzer Street 58/60
07745 Jena, Germany

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