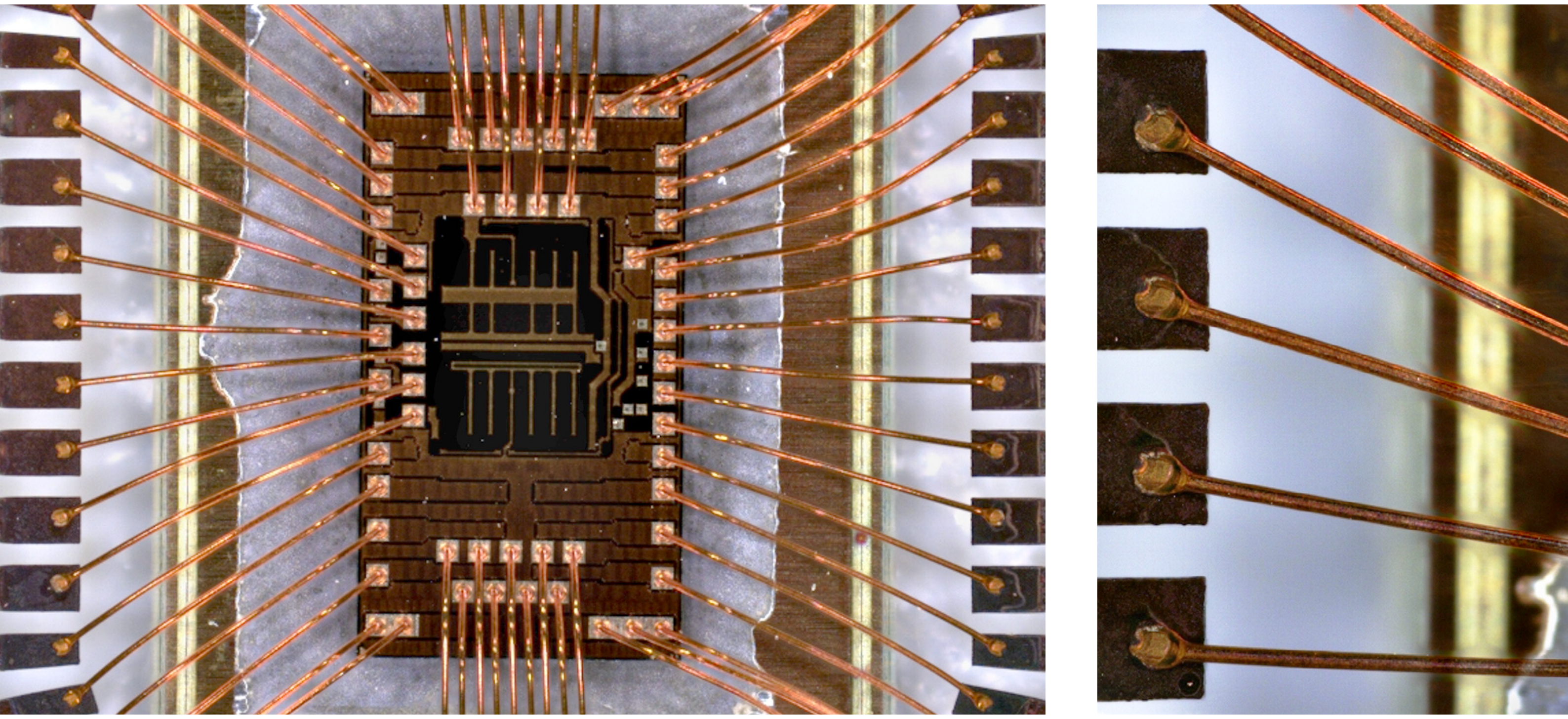
Application Note

Wire Bonding Inspection

by Digital Optical Microscopy



Seeing beyond

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Executive Summary

Microelectronics are used widely in all aspects of modern life, permeating from consumer products to the ever-critical applications like medical, defense and aerospace. Inside these devices are wire bonds providing interconnections to semiconductor chips. Being present in large numbers and small sizes, these make wire bonding inspection a challenging task. Digital optical microscopy (ZEISS Smartzoom 5) can help to alleviate some of these challenging issues and enhance the quality inspection process.

Importance of Wire bonding Inspection

In wafer packaging, wire bonding is a very important process to join microchips to the package. Wire bonding machines make the physical linkages by multiple short loops of fine wires made of typically gold, aluminum or copper. The process of wire bonding is very rapid, and involves the formation of metallurgical bonds in the form of balls or wedges, and then cutting at the end of the bond in order to start the next wire loop.[1]

In the production line, automated optical imaging (AOI) is employed to rapidly check for defects based on the overview of the wire bonded samples. Upon detecting a defective region, the sample is isolated from the production line, and transferred to an optical microscope to be further examined by an analyst to find out the cause of failure.

Defects in wire bonding would be detrimental to the performance of the microchip, and cause service failure and costly damages if left undetected. Thus, wire bonding inspection by optical microscopy is an important first step to characterize and understand cause of defects, in order to find solutions and preventing them from occurring again.

How can digital optical microscopy help wire bonding inspection?

Digital optical microscopes can greatly enhance the analyst's experience amid the heavy demands of wire bonding inspection, that traditional microscopes faces. In the following sections, common problems would be addressed.

Google Earth-like Experience

There is a need to check for both bulk defects (overall geometry, deformation, misplacement, etc.) & localized defects (cracks, tearing, etc.) at both wire loops and bond contacts. This means that the analyst needs to switch between low and high magnification, in order to thoroughly examine the sample. As the wires used gets finer in diameter and more in numbers, inspection can be confusing and exhaustive to the analyst.

Smartzoom 5 is equipped with an overview camera to image the sample in its entirety, without need for time-consuming stitching of individual images. With the overview image (Fig. 1), this would let the analyst have a Google Earth-like experience in locating the desired region of interest (ROI). Zooming in and out of the ROI can be done with the large 10× factor optical zoom engine. Geometry of wire loops can be examined at low magnification (Fig. 2), while the integrity of the bond contacts can be easily examined with the same objective at high zoom (Fig. 3, 4). Thus, a single objective can possibly allow the user to execute his task fully.

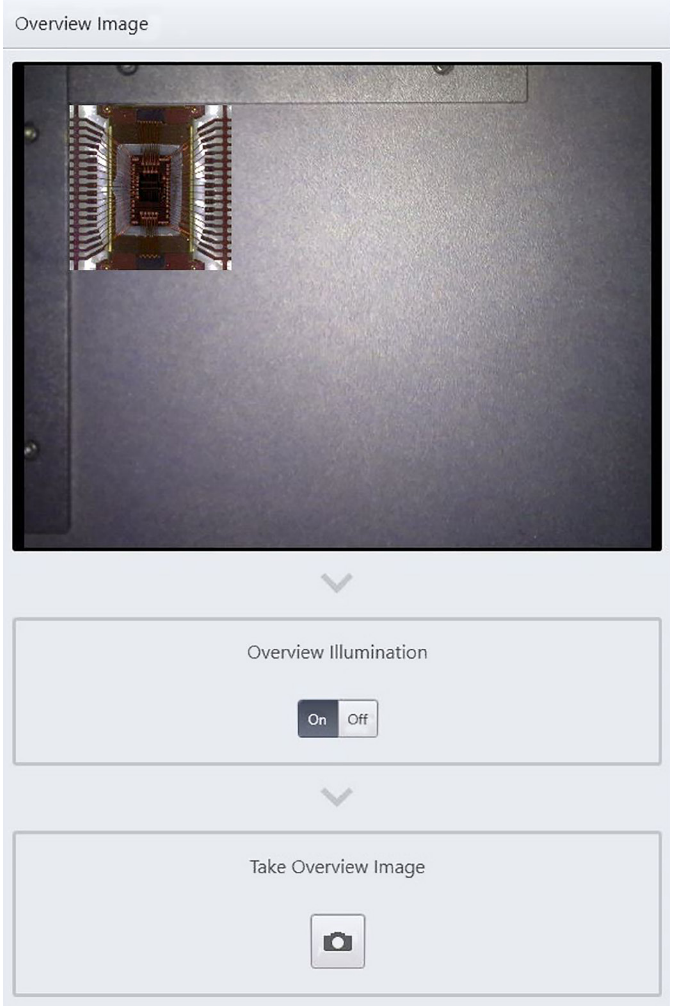


Figure 1. *Overview image of sample on stage to allow easy navigation*

In addition, the continuous calibrated, encoded & motorized zoom engine ensures that examination of the same bond contact or comparison between different wires loops can be repeatable, though the magnification is constantly being varied. To image a particularly fine defect at high resolution, the highest 10× objective with 0.6 NA can be easily swapped in via a quick objective changer process, that recognizes the encoded objective.

With an overview image, a defect can be easily related to the overall sample, to analyze any general trends of failure. For example, when misplacement of wedge bonds always occurs at the top left corners for many samples, it possibly might be indicating a bigger issue in the wire bonding machine.

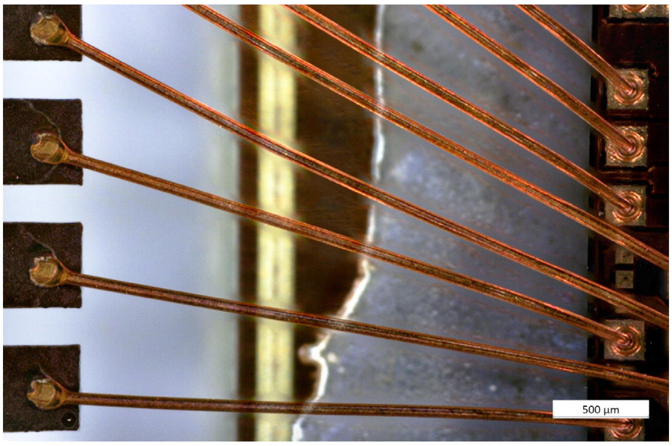


Figure 2. *EDF image of wire loops between ball bonds and wedge bonds. 5× objective. 101× mag.*

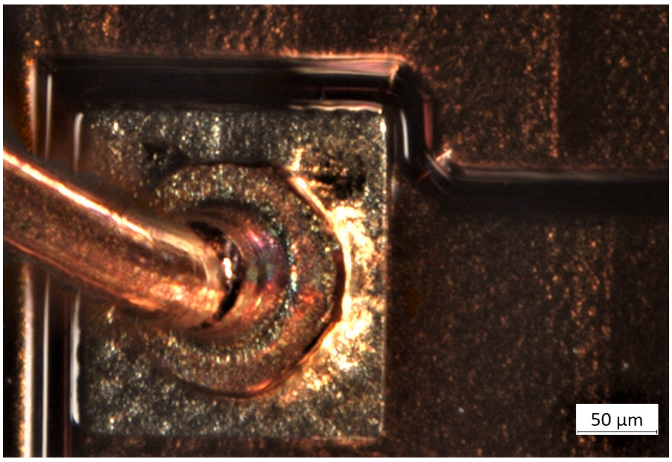


Figure 3. *EDF image of ball bond on bond pad. 5× objective. 1011× mag.*

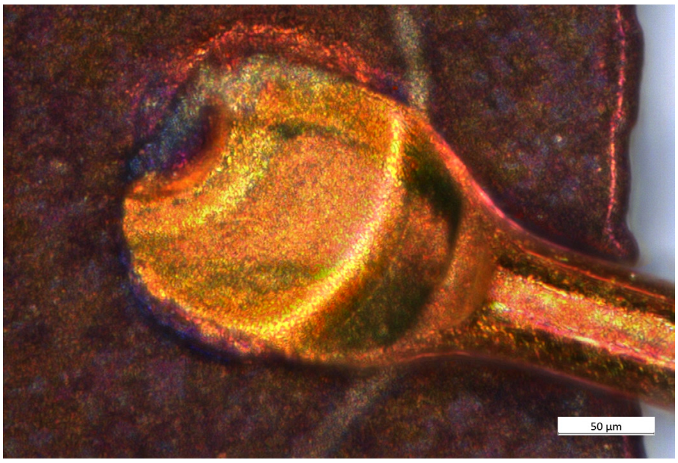


Figure 4. *EDF image of wedge bond on bond pad. 5× objective. 1011× mag.*

Reproducible High Angle Inspection

Due to wire looping, defects can occur at different positions and might be sagged. Thus observation angles need to be highly flexible in order to see the defects only visible at high angles. Smartzoom 5 is equipped with a large 90° angle automatic eucentric tilting (Fig. 5, 6).

The motorized stage automatically positions the sample focal point into an eucentric position, readying it for tilting. Tilting is performed easily with a one touch swing arm with continuously adjustable angles. The wire defect in question can be kept in center of viewing area, while tilting the optics with minimal compensation. As the tilt angle is encoded, thus high angle inspection is reproducible.

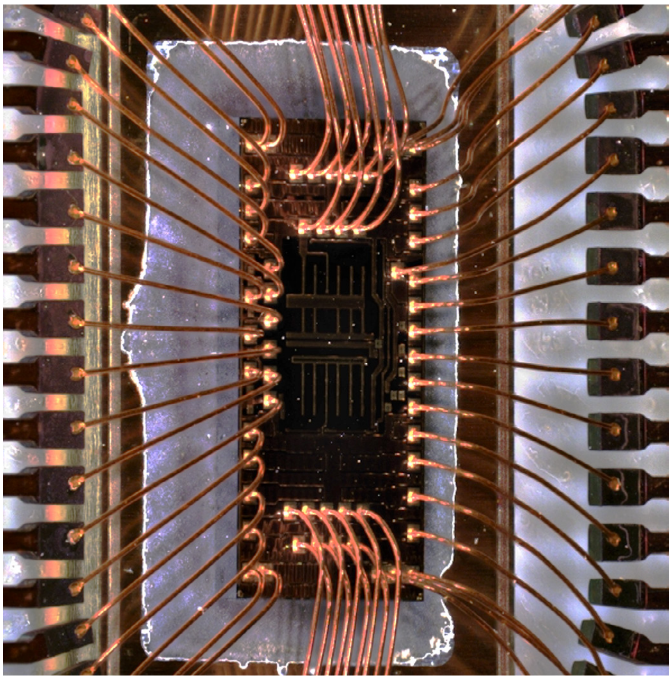


Figure 5. *Sample tilted at -45°. 1.6× objective. 34× mag.*

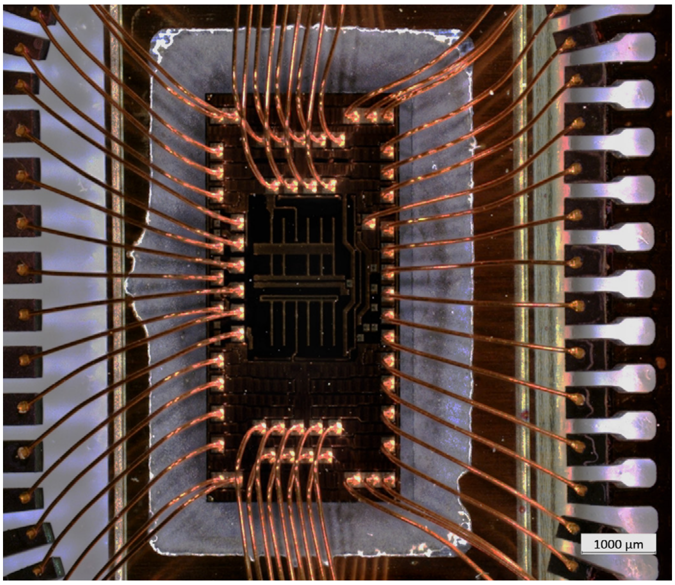


Figure 6. *Sample tilted at 30°. 1.6× objective. 34× mag.*

Accurate Defect Measurement and Metrology Functionalities

In the checking of wire loop geometry, or determining of defect size criticality, there is a need for accurate measurements. The low specified length measurement deviation of ≤ 0.5% makes SZ5 an accurate measurement tool.

Imaging of the height-varying wire loops require extended depth of focus (EDF), and having telecentric lens (1.6×, 5×, 10×) ensures that measurements are more reliable, as there is no distortion of non-flat samples. This means that samples can be observed in their true size, even with slightly different focus settings. The provision of ex-factory calibration makes SZ5 a working tool right out of the box, without any calibration needed at installation site. Basic 2D measurements to measure wire diameter, crack length, etc. can be done, while 3D height map can be easily generated and measured (Fig. 7).

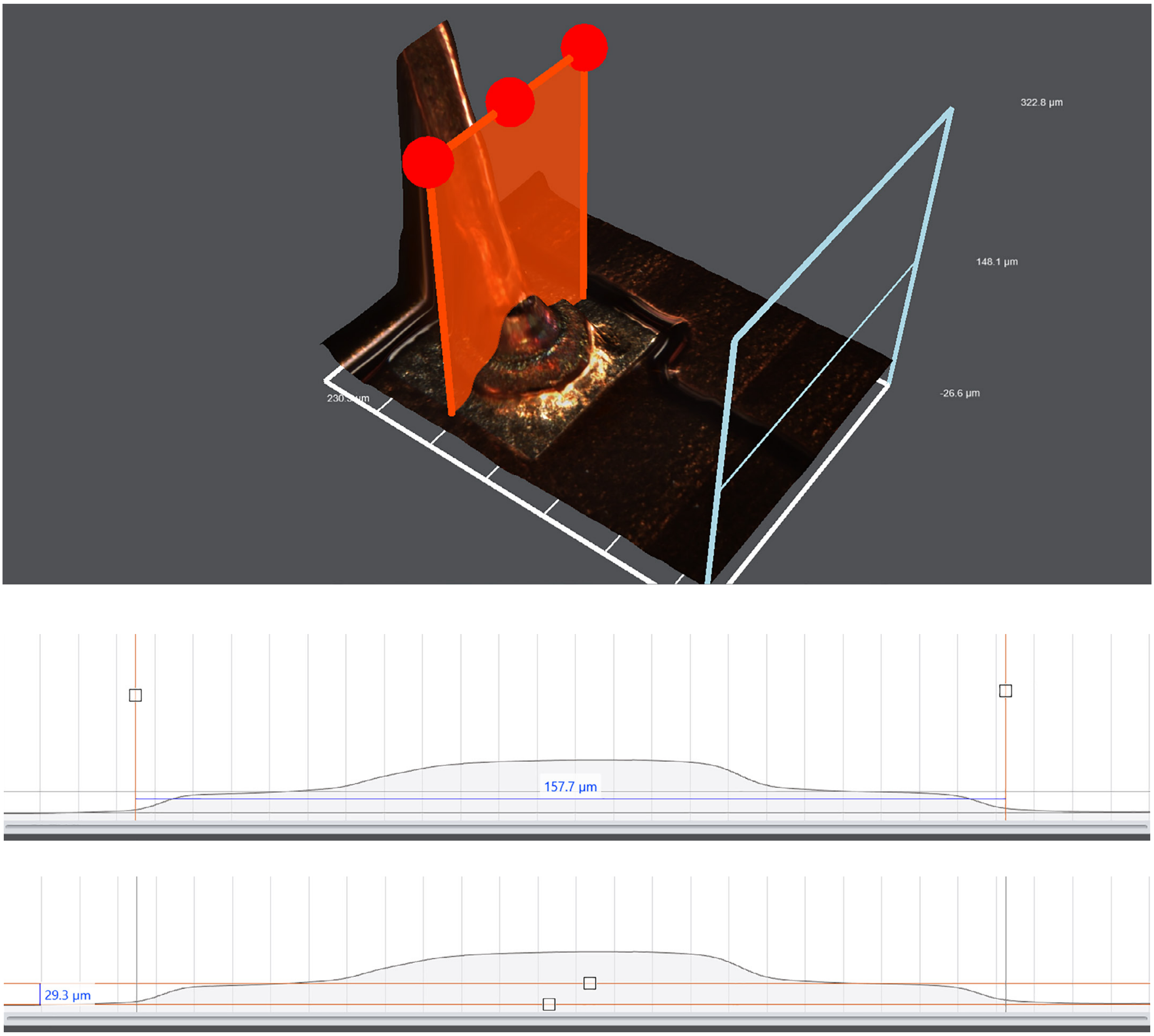
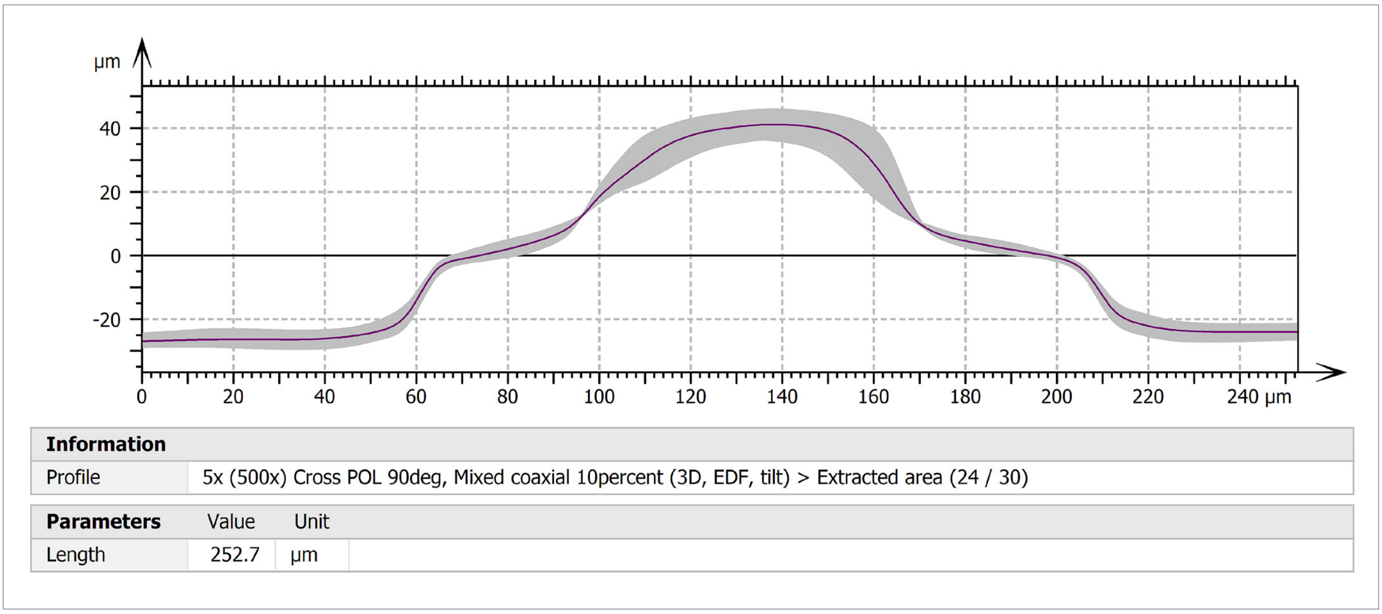


Figure 7. *3D view of ball bond. Cross-sectional profile showing diameter and height of ball bond on bonding pad*

For advanced requirements like generating of a more statistically correct mean profile, the dataset can be exported to our advanced software (ConfoMap) (Fig. 8).

Automated metrology dimensioning functions can be easily extended with NEO pixel (Fig. 9) or assess measurement data statistics and trends using PiWeb (Fig. 10) after measuring a few similar samples.



Information	
Profile	5x (500x) Cross POL 90deg, Mixed coaxial 10percent (3D, EDF, tilt) > Extracted area (24 / 30)

Parameters	Value	Unit
Length	252.7	µm

Figure 8. *3D dataset of ball bond exported into ConfoMap for further analysis. Mean profile generated from series of profiles.*

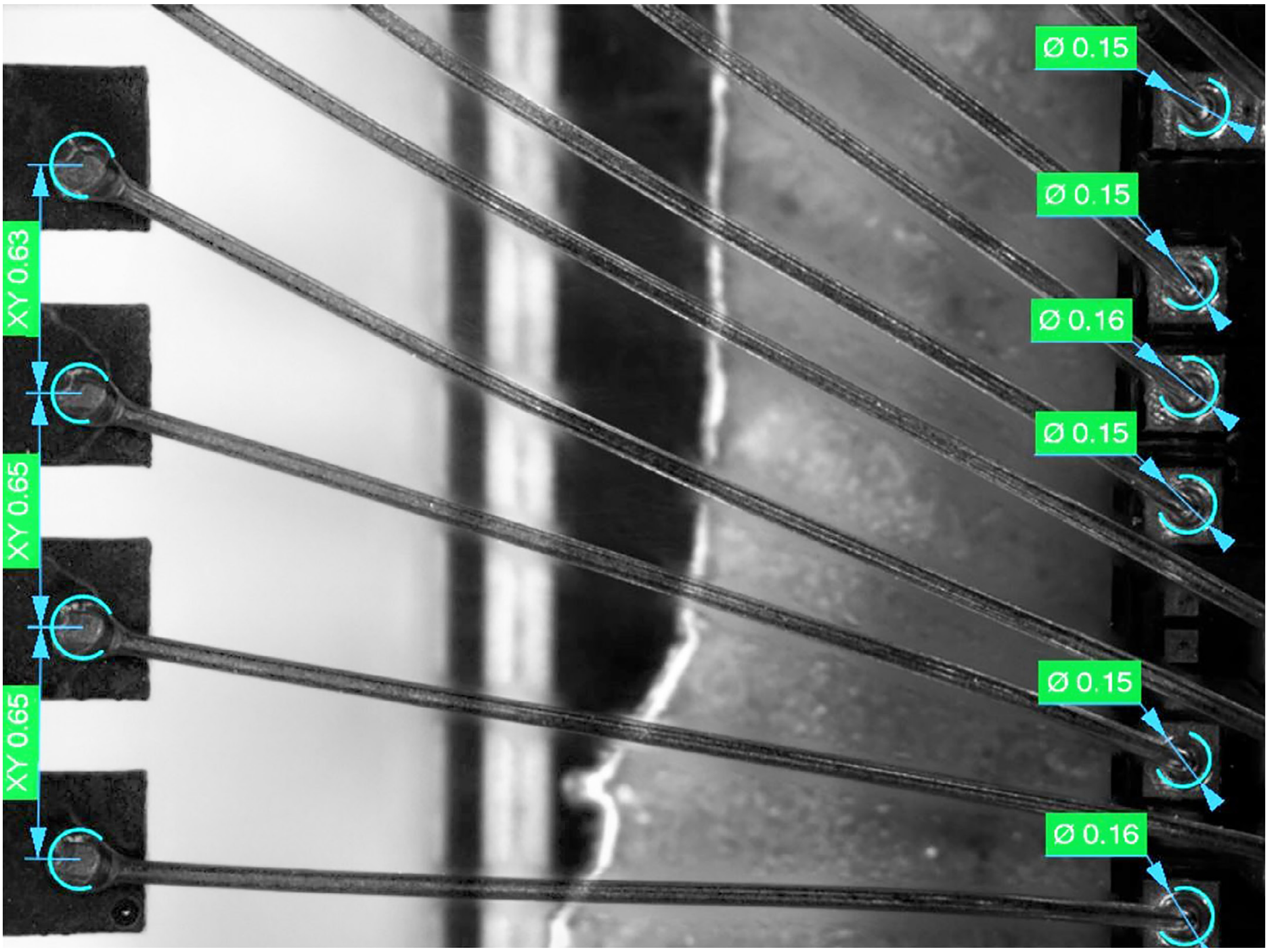


Figure 9. *2D EDF dataset exported into NEO pixel for automated metrology dimensioning*

ZEISS NEO pixel
2.4.0.161205
Process protocol

Date 9/23/2019 11:10:38 PM
Inspector
Measurements Last 200 measurements

	Nominal	Upper tolerance Lower tolerance	Value chart	Control chart	Histogram	Correction value
Ø Diameter (1)	0.16	0.10 -0.10				-0.01
Ø Diameter (2)	0.15	0.10 -0.10				0.00
Ø Diameter (3)	0.16	0.10 -0.10				-0.01

Figure 10. *Trend analysis plotted with PiWeb software*

Repeatable Job Sequence

If defect identification procedure is to be standardized, a job template (Fig. 11) can be created within Smartzoom 5. This step by step guide would ensure repeatability each time and make repetitive tasks less time consuming. Specific locations on the sample, based on stage, can also be stored in the job, and recalled for examination of the next sample. For example, this may include an examination of wire loops at low mag and high tilt, followed by high mag inspection of bond contacts, followed by 3D height measurement. Or multiple samples can be inspected at the same location consecutively. Thus, having a job template also ensures that no steps in the optical inspection would be missed.

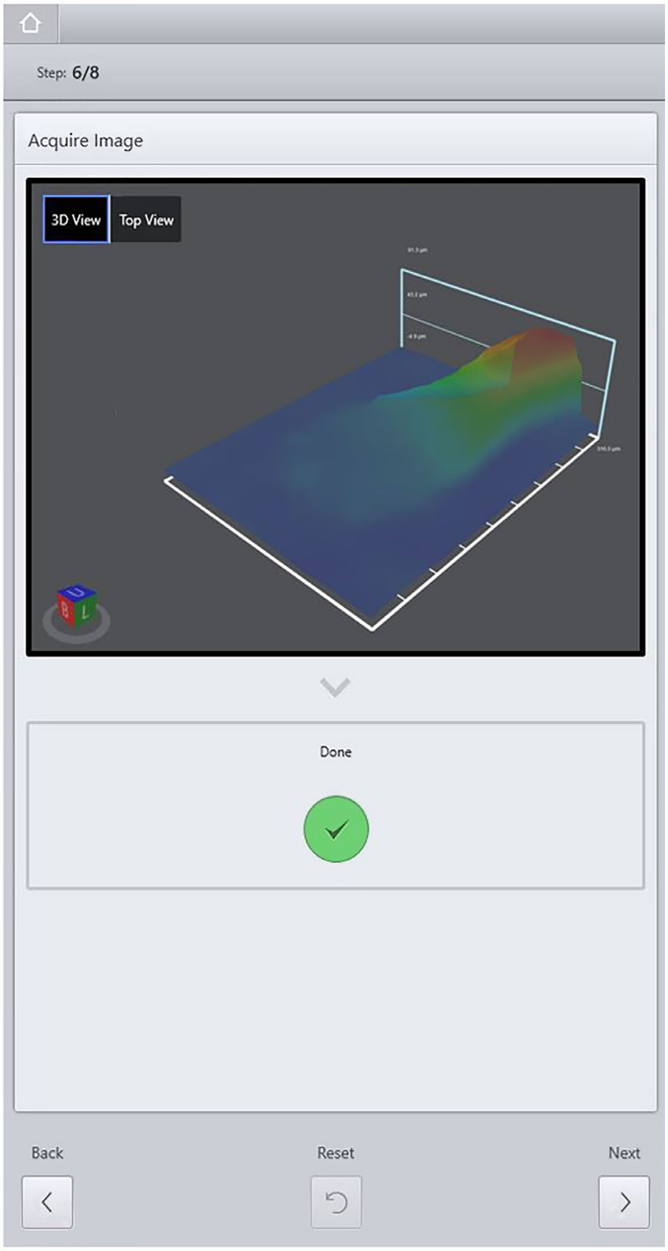


Figure 11. *Step by step job mode (showing 3D height map)*

Other Functionalities

Numerous other functions in Smartzoom 5 can also enhance the wire bonding inspection. Presence of touch sensor at the underside of all objectives can help to instill confidence in the analyst in microscope usage. This is especially so when using the 10× objective which is prone to collision with sample surface, due to the very small working distance inherent in high magnification objectives.

Best image functionality helps to quickly select the most relevant illumination methods out of the many available options (anti-ring glare, polarisation, HDR, oblique, coaxial, ring light, digital contrast, etc.). The selection of illumination methods can be particularly challenging, as bonding wires are highly reflective due to the metallic nature of almost pure gold and copper bonding wire, such that defects are difficult to detect. Correlative microscopy (Shuttle and find) extends the capability of optical inspection to electron microscope, where surface analysis techniques such as secondary electron imaging (SEI), backscattered electron imaging (BSE) and energy-dispersive X-ray analysis (EDX), would identify the presence of contamination, extent of intermetallic compound formation, and bond irregularities.

Summary

Digital optical microscopy by Smartzoom 5 is shown as a viable technique in wire bonding inspection. Smartzoom 5 digital microscope is a highly repeatable and connected optical inspection and documentation solution.

Reference:

[1] Wire Bonding in Microelectronics. 3rd Edition. George Harman. ISBN: 978-0-07-164265-1

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