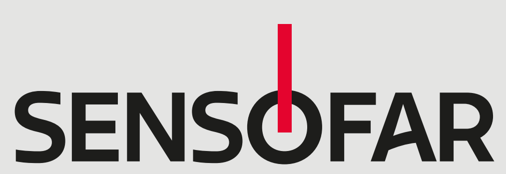
PCB characterization

Enhancing PCB Quality Control with Sensofar's 3D Metrology Solutions



Manufacturing a printed circuit board (PCB) involves many crucial steps that can significantly impact its final performance. The surface finish and critical dimensions of a PCB are vital factors that determine its functionality. As a result, the PCB manufacturing industry requires strict fabrication conditions, such as clean rooms and precise deposition and assembly methodologies.

Throughout the manufacturing process, PCBs are characterized using various techniques, including X-ray characterization, 2D inspection of defects, SEM imaging, and 3D optical metrology. With over 20 years of experience in 3D optical metrology, **Sensofar** has dedicated itself to providing the best solutions for PCB quality control.

Sensofar's optical areal microscopes offer an automated measurement and analysis process, eliminating the need for sample intervention. Sensofar showcases standard as well as specific solutions, like **SensoPRO** software, which can measure different pad shapes, whether they are regular or rare.

This document provides a detailed overview of these processes and highlights how Sensofar leverages its expertise in surface characterization, from acquisition to analysis, to ensure superior PCB quality control.

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COPPER PREPARATION

A PCB typically comprises a thin board of copper, fiberglass, and composite epoxy or other laminate materials. Following the attachment of the copper and fiberglass layers, the panel undergoes a chemical process aimed at altering the surface finish of the copper to enhance its adhesive properties. This step is crucial as it ensures that the photoresist attaches evenly to the substrate in the following step of the manufacturing process, the photolithography, to produce high-quality PCBs.

COPPER PREPARATION

Copper adhesion: enhancing surface finish for PCB panels

Interferometry is the most accurate technique for measuring flat surfaces on the nanometer scale. The combination of proprietary **Coherence Scanning Interferometry (CSI)** algorithms with a 50X Mirau lens can provide highly precise and reliable results.

With the help of an automation module, recipes can be defined to measure the roughness at different points on the plate. This allows to comprehensively understand the surface finish and identify any areas requiring further attention.

Roughness parameters, calculated following the **ISO25178 standard**, are essential to characterize adhesion. In fact, they provide information about the panel's surface finish, allowing the user to optimize the photolithography process and produce top-quality printed circuit boards. The different analysis tools available, **SensoPRO**, **SensoVIEW**, and **SensoMAP**, can provide automatic solutions for calculating roughness parameters. The choice of software will depend on the desired output and the expected analysis capabilities.

ISO 25178 / Height		ISO 25178 / Hybrid	
Sa	87.849 nm	Sdr	0.4269 %
Sz	1431.09 nm		

ISO 25178 / Height		ISO 25178 / Hybrid	
Sa	76.851 nm	Sdr	0.2832 %
Sz	1239.13 nm		

ISO 25178 / Height		ISO 25178 / Hybrid	
Sa	93.494 nm	Sdr	0.4555 %
Sz	1441.99 nm		

ISO 25178 / Height		ISO 25178 / Hybrid	
Sa	86.732 nm	Sdr	0.3664 %
Sz	1497.39 nm		

ISO 25178 / Height		ISO 25178 / Hybrid	
Sa	97.470 nm	Sdr	0.4821 %
Sz	1684.66 nm		

ISO 25178 / Height		ISO 25178 / Hybrid	
Sa	90.991 nm	Sdr	0.3827 %
Sz	1573.93 nm		

PHOTOLITHOGRAPHY (IMAGING PROCESS)

PCB manufacturers typically employ a photolithography or plating process to produce the inner circuit of an IC substrate. In the photolithography process, a layer of photoresist is selectively deposited on top of copper foil, which is then exposed to UV light using a mask. The areas of the photoresist that were not exposed to UV light are removed during the development process, after which the exposed copper is either removed (photolithography process) or deposited (plating process), depending on the specific method.

This method is essential for accurately ensuring that the PCB matches the schematic blueprints. Before proceeding to the next step, an examiner carefully checks the inner circuit traces, alignment features, and circular pads to ensure everything is in order.

PHOTOLITHOGRAPHY

Imaging through the resin: monitoring etching and plating processes

Right after the deposition of copper in the plating process or the copper removal after the etching, it is essential for the manufacturers to assess the height and width of the resulting copper traces. This applies to PCBs and IC substrates, but Sensofar has focused on measuring the latter.

By measuring at this stage, manufacturers gain the flexibility to monitor the copper deposition or removal, depending on whether it is plating or etching, at any given time. This flexibility is highly beneficial because, at this point, the developed resin has not been removed yet, allowing them to continue with the etching or plating until achieving the desired outcome.

Traditionally, one Integrated Circuit (IC) substrate had to be cut from each panel to evaluate the produced circuit tracks. This waste can be avoided using a non-contact profilometer that enables imaging of the copper through the resin without causing any damage.

Interferometry or **Confocal** technologies within the **S neox system** can measure through optically transparent films, like photoresist resins.

Interferometry technology works best with PP photoresist material, while Confocal technology is better suited for dry films. The reason of that lies in the thickness typically deposited for each photoresist: dry film layers range from a few microns to tens of microns. In contrast, PP photoresist thickness often comprehends from tenths of microns to several mm.

Interferometry
Confocal
1 µm
10 µm
100 µm
1 mm
Resin thickness

But that is not all. In this step of the process, where only half of the resin is developed, some areas of the copper are covered, while others are left uncovered. The uncovered area is where the copper has been deposited/removed.

Standard thickness algorithms can be confusing because they only image the covered areas of the topography, leaving out the data from the exposed copper. Both Sensofar's Interferometry and Confocal have a unique option to englobe the exposed and the unexposed regions, allowing us to characterize the height of the copper trace and achieve a better yield during the manufacturing process.

An interesting aspect to note is that resin suppliers also make use of optical profilometry to characterize the thickness of the resin to quantify it after the first development.

In terms of analysis, SensoPRO is a very powerful tool that provides rapid quality control software with plug-in-based data analysis algorithms that offer a high degree of flexibility and specificity.

SensoPRO's Traces plugin is designed to automatically detect traces and calculate parameters such as the height, width, and distance of the inner circuit tracks.

Interferometry

Confocal

Acquisition

Analysis

Traces

SensoPRO Plugins

1 2 3 4 5 6 7

H W WStd Tw

Bw X Y

H

20.745
20.73
20.715
20.7
20.685
20.67

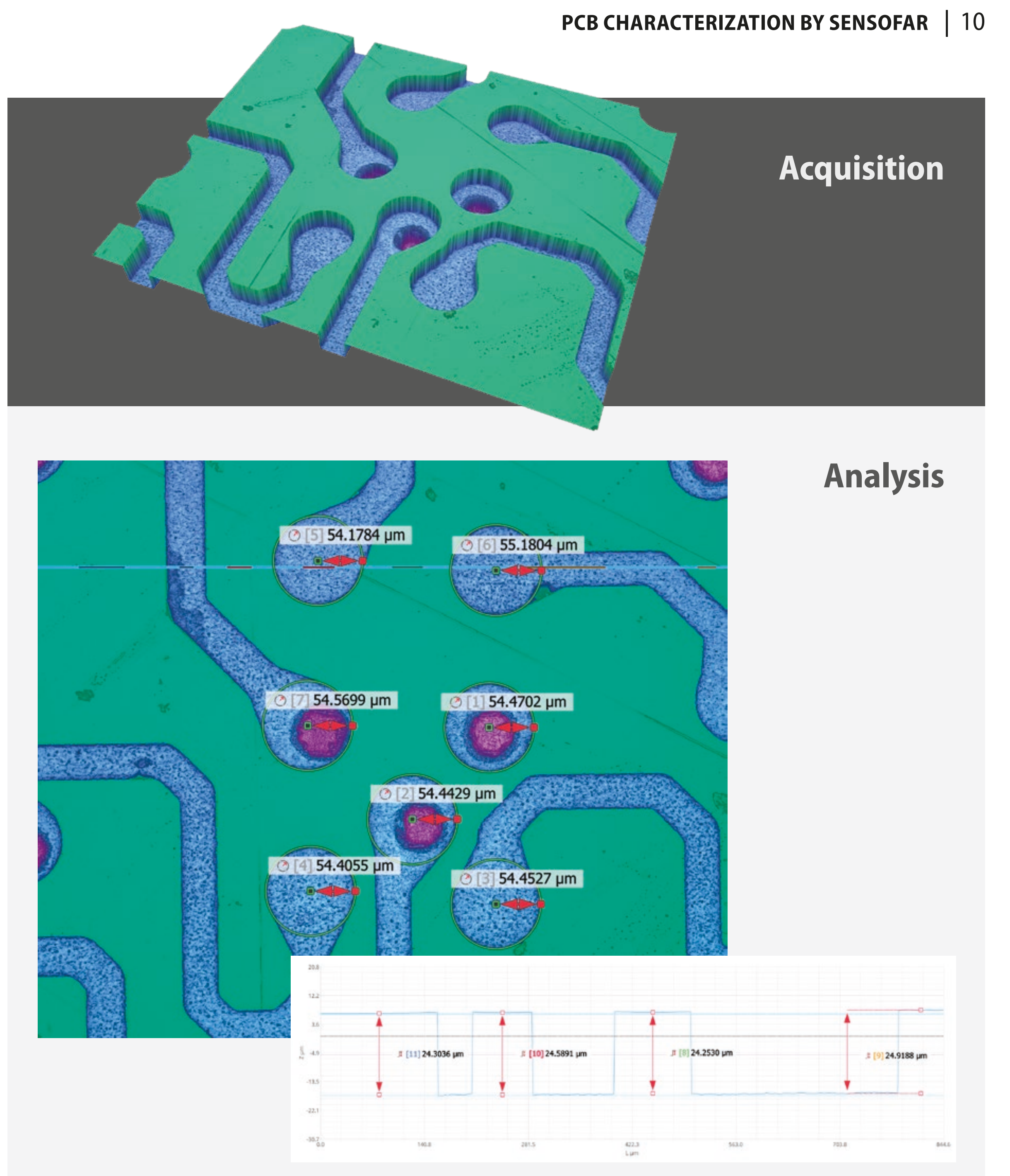
µm

PHOTOLITHOGRAPHY

Final verification after resin removal

Removing the resin during the PCB manufacturing process can have potential risks and impacts on the copper. On one side, the resin stripping must be carefully controlled because it can affect the integrity and quality of the copper traces. On the other side, it must be carried out effectively to avoid residues or contaminants from the photoresist material remaining on the copper surface. These residues can affect the adhesion of subsequent layers, cause electrical issues, or lead to reliability problems in the finished PCB.

The circuit is then optically imaged again to verify that everything is in order. The width of the traces, the radii of the pads, or the depth of them all are measured with **SensoVIEW**, a software that comes with all Sensofar profilers, provides a suite of tools for roughness and dimensional characterization. Its assist tools for dimensional characterization allow for a quick and versatile check into the contour (2D image) and the profile (1D).



Blind Holes

Through Holes

VIA DRILLING

The panel is perforated to create registration holes, essential for alignment, and vias, connections between layers and components.

Regarding the vias, Through Hole Technology (THT) and Surface Mount Technology (SMT) are the two most common ways of attaching components to a board. Specifically, through-hole vias are used for THT and go through the entire width of the PCB board. Blind vias, on the other hand, are used for SMT and only go a certain depth into the panel to connect different layers of inner circuits.

Sensofar optical profilometers have been utilized numerous times in characterizing the hole generation method and the holes made in the board, ensuring precise and accurate results.

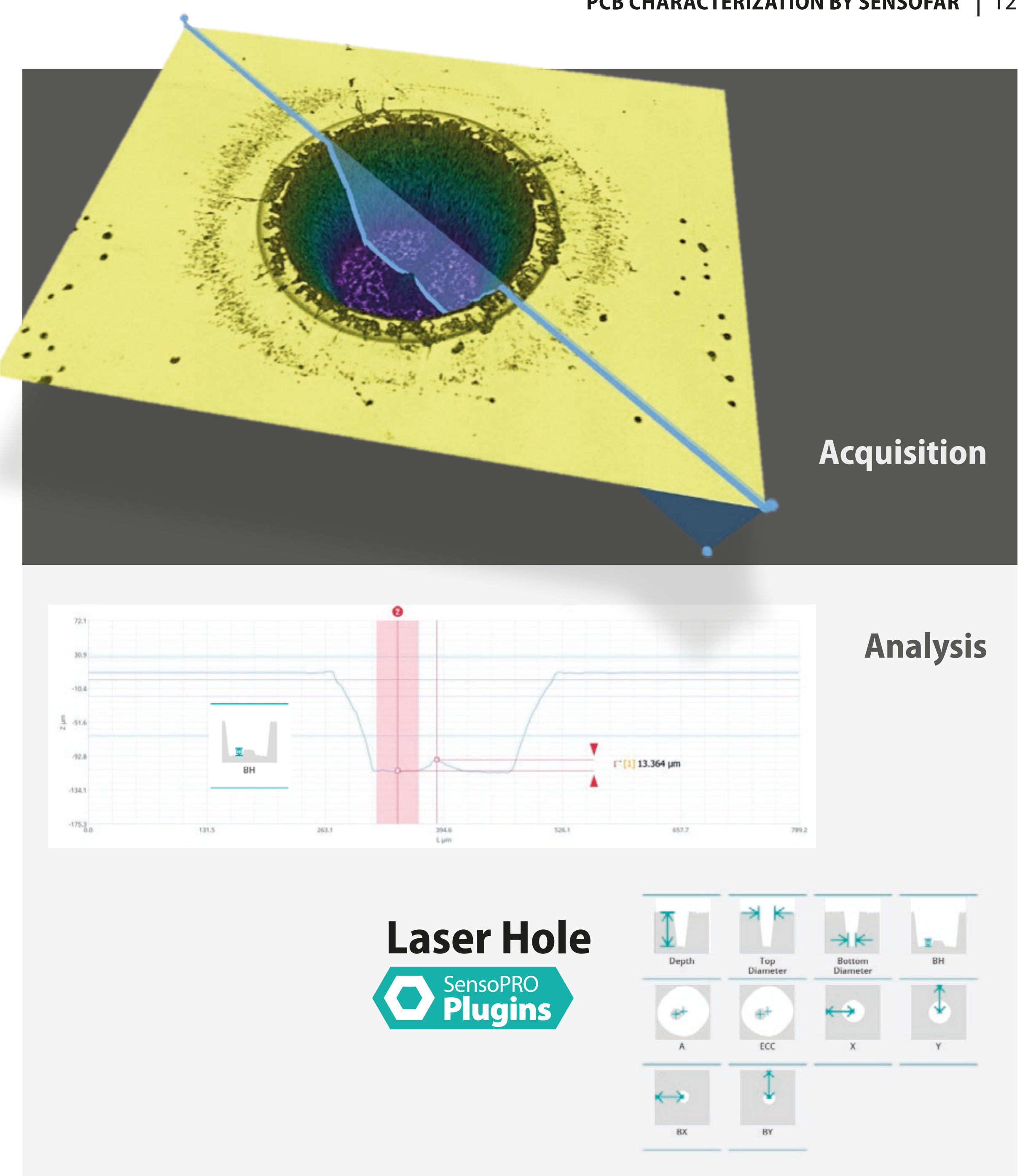
VIA DRILLING

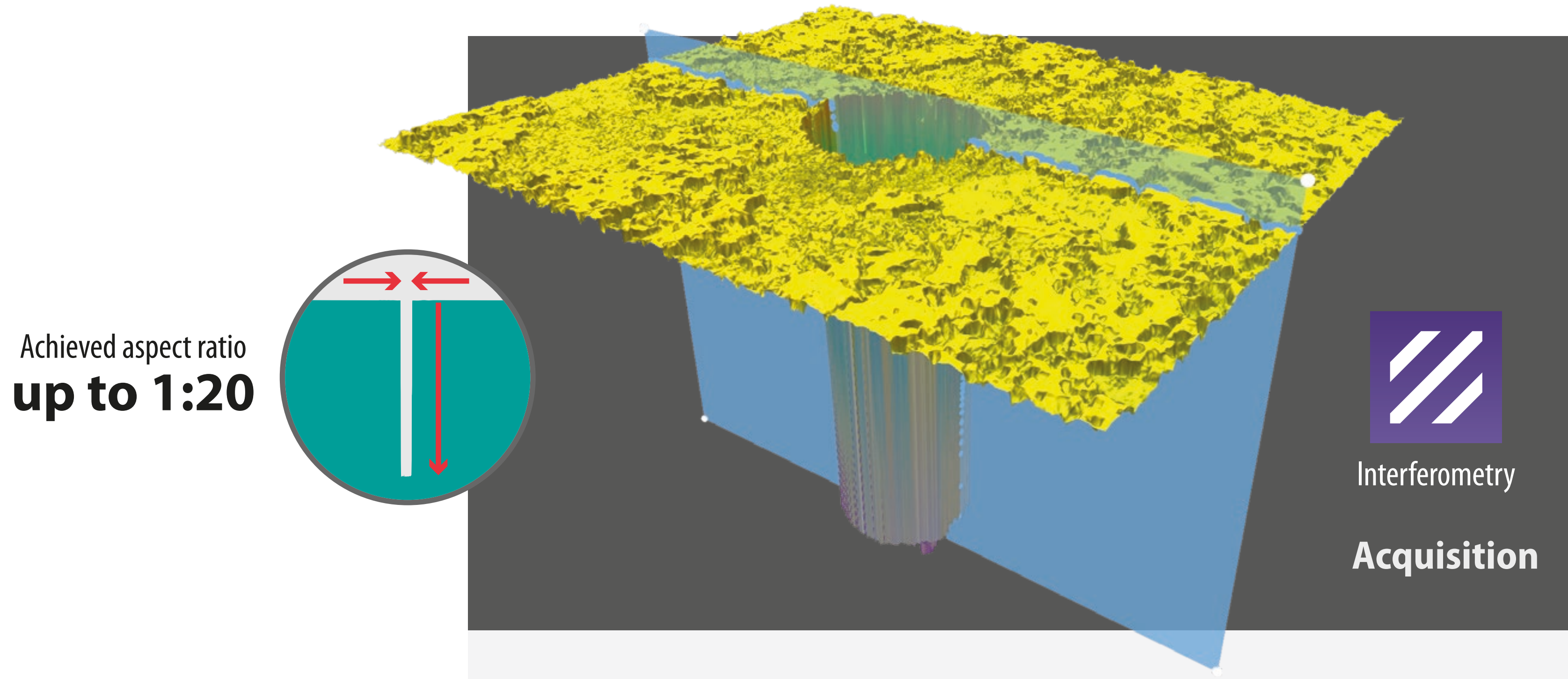
Laser drilling: is the laser well calibrated?

Both vias and registration holes are made using a drill or a laser. In the case of laser drilling, before operating in the PCB, test holes are made in a soft material such as plastic, where errors are more visible, to ensure the laser functions properly.

During the testing process, parameters such as the distance between the center of the top and bottom of the hole, as well as eccentricity, are calculated to verify proper alignment. In addition, the height of the dimple (or valley) at the bottom of the hole is evaluated to calibrate the uniformity of the laser power.

There is a specialized plugin called the **SensoPRO Laser Hole plugin** to aid in this process, which calculates all the previously mentioned parameters and more.

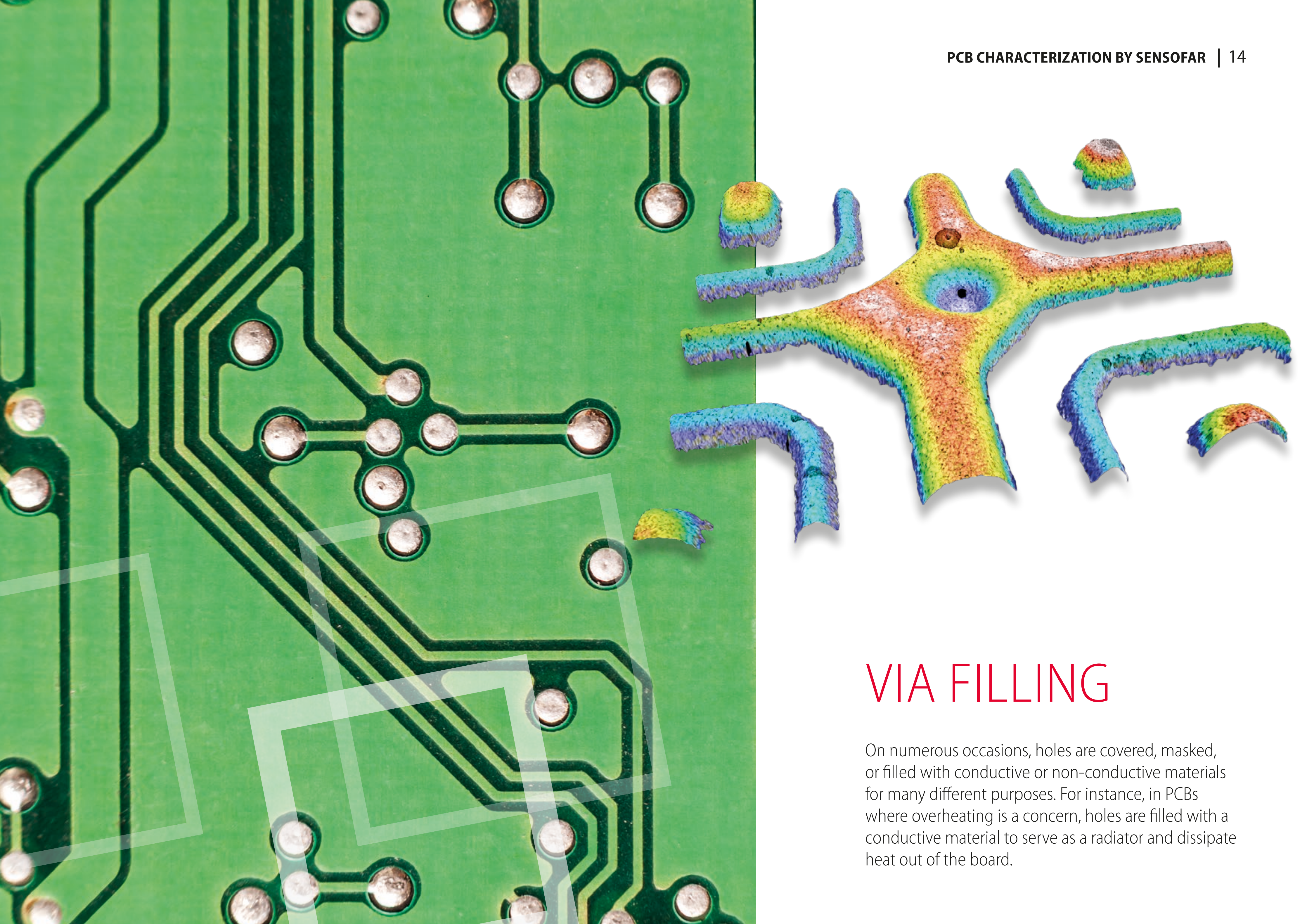




VIA DRILLING

Vias quality control: reliable and efficient connections

Technology selection for measuring through holes is based on sample roughness, whereas blind holes always measured with Interferometry. This optical technology showcases a superior performance in low reflectivity scenarios, which can occur when the aspect ratio is very high. In fact, the S neox has been able to measure a hole with an aspect ratio up to 1:20. On the analysis side, vias can be characterized with 19 parameters with the **SensoPRO Hole plugin**, and pass-or-fail reports can be obtained after setting tolerances.



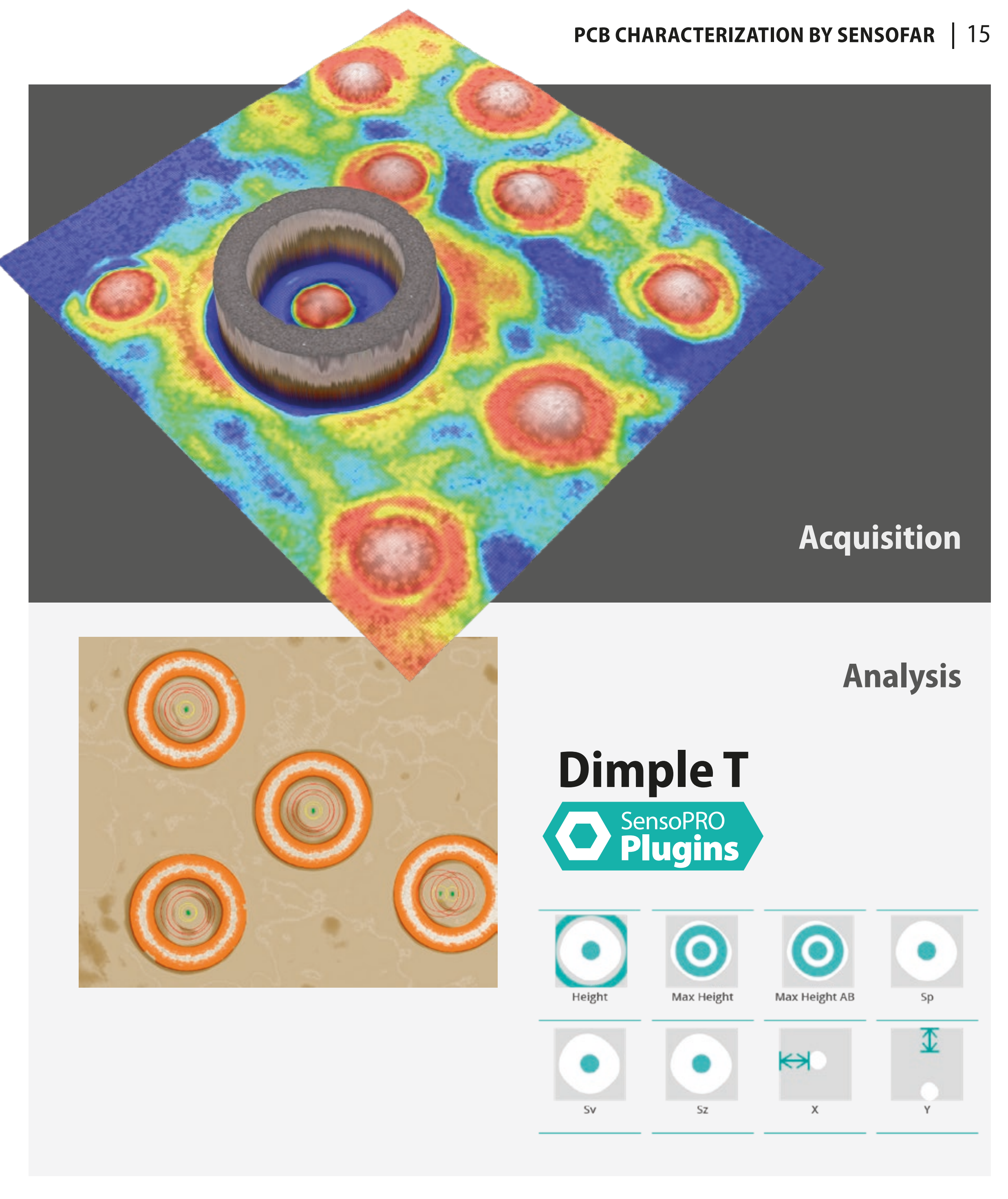
VIA FILLING

On numerous occasions, holes are covered, masked, or filled with conductive or non-conductive materials for many different purposes. For instance, in PCBs where overheating is a concern, holes are filled with a conductive material to serve as a radiator and dissipate heat out of the board.

VIA FILLING

Inspecting filled vias: dimple defects

When vias are filled, "dimples" can appear if there is excess or lack of filling material. The height of the dimples is critical for those filled holes that will be connection points. Since this is a pervasive issue in the PCB industry, Sensofar offers the **SensoPRO Dimple plugin** that automatically detects and provides the height of dimples. Also, the **SensoPRO Dimple T plugin** plugin can precisely identify and analyze the dimples within circles corresponding to connection points in the topography.



SOLDER MASK PRINTING

After the deposition of all the layers on the PCB, an isolating resin, commonly known as a solder mask, is applied to safeguard the board against oxidation and dust. The solder mask, typically green in color, is exposed to UV light to cure it, except in specific areas such as pads.

Post-Solder Mask Checkpoint: thorough verification of PCB elements

Sensofar offers a comprehensive range of solutions for automatically acquiring and analyzing various measurements after applying a solder mask.

Vias

Critical dimensions of vias are commonly re-checked at this step of the manufacture. The **SensoPRO hole** or **R hole** plugins are commonly used for measuring holes with rectangular or circular shapes, respectively.

Thickness of the depositions

By calculating the heights of uncovered areas of the PCB, our solutions like **Multiple SH plugin** can ensure that the deposited layers have the proper thickness, providing an extra level of quality control..

Solderless connectors

Premium connectors like solderless ones are characterized easily with the **Concentricity A plugin**. The dimensions of the circles composing the connectors and their concentricity are calculated guaranteeing a reliable connection.

Gold fingers

Gold fingers serve as connectors between the edge of PCBs and the motherboard. The roughness values of gold fingers are an indicator of their electrical performance. The **multiple recipe measurements (MMR)** functionality makes it possible to measure one field of view in each gold finger and export the data into the **SensoPRO surface texture plugin** for roughness calculation.

Solder mask paste

The solder mask paste between two pads is the element preventing the formation of solder bridges. The **SensoPRO resist bridge** plugin automatically recognizes and analyzes these structures.

Pads

A series of pad plugins available in SensoPRO can analyze the critical dimensions of various pad shapes, including the most common and specific ones: **Pad**, **L pad**, **R pad**, **X pad**, **Circle pad** and **Square pad** plugins.

Solder mask resin

The inner circuit of a PCB is thoroughly checked during the manufacturing process. One standard checkpoint is after the application of solder mask resin, which is effortlessly characterized by the **Solder Mask plugin** from SensoPRO.

LEGEND PRINTING

Laser marking is a common technique for printing labels on PCBs due to its high precision and permanence. Unlike traditional printing methods, laser marking uses a focused beam of light to create a high-contrast mark on the surface of the PCB. This mark is achieved by altering the color or texture of the surface material through localized heating, ablation, or melting.

LEGEND PRINTING

Laser-marked labels characterization

One potential issue from laser marking is the heat generated during the marking process, which can cause damage to nearby components or affect the performance of sensitive materials. In this case, topographical data from a non-contact optical profiler is fundamental to extracting the highest and lowest height within the label, which gives the information to ensure the quality of laser-marked labels.

[1] 24.3582 µm

[2] 14.3855 µm

ELECTRICAL TESTING

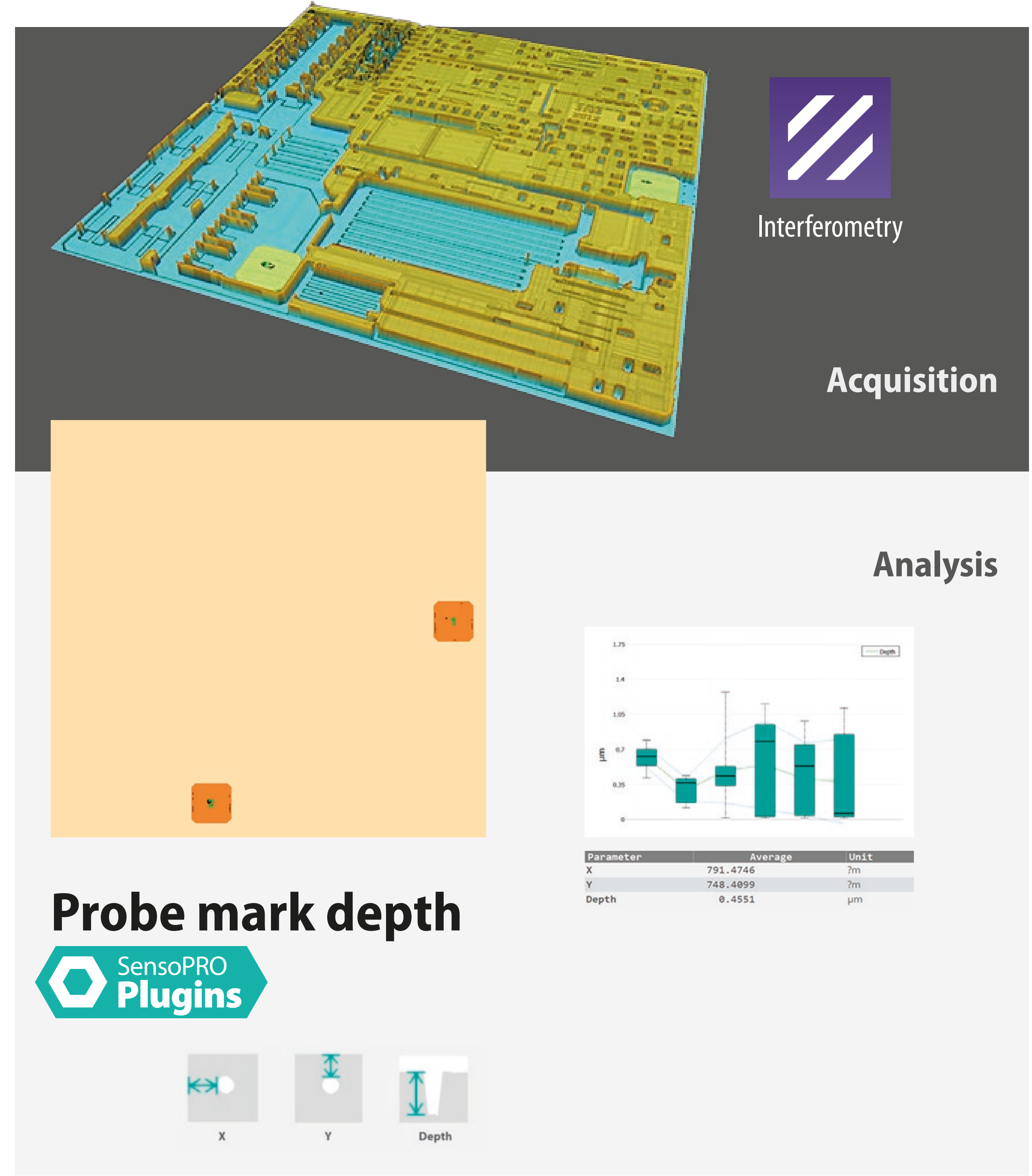
PCBs serve as the foundation for electronic devices and systems, making it essential to verify their electrical functionality and integrity. Electrical testing involves subjecting the PCBs to diverse electrical stimuli to assess their performance. To conduct this test, probes or test pins make physical contact with the test points or pads on the PCB surface. That leaves probe marks on the pads, whose depth and size depend on various factors, including the applied force and the hardness of the PCB surface.

ELECTRICAL TESTING

Detecting internal issues through probe marks

Probe marks on connection areas can result from the electrical testing process. If the testing probe applies too much pressure, it can damage the connection. To assess the damage level, the depth of the probe mark stands as an indicator. Since Z resolution is crucial in this case, **Interferometry** is the best technology for data acquisition.

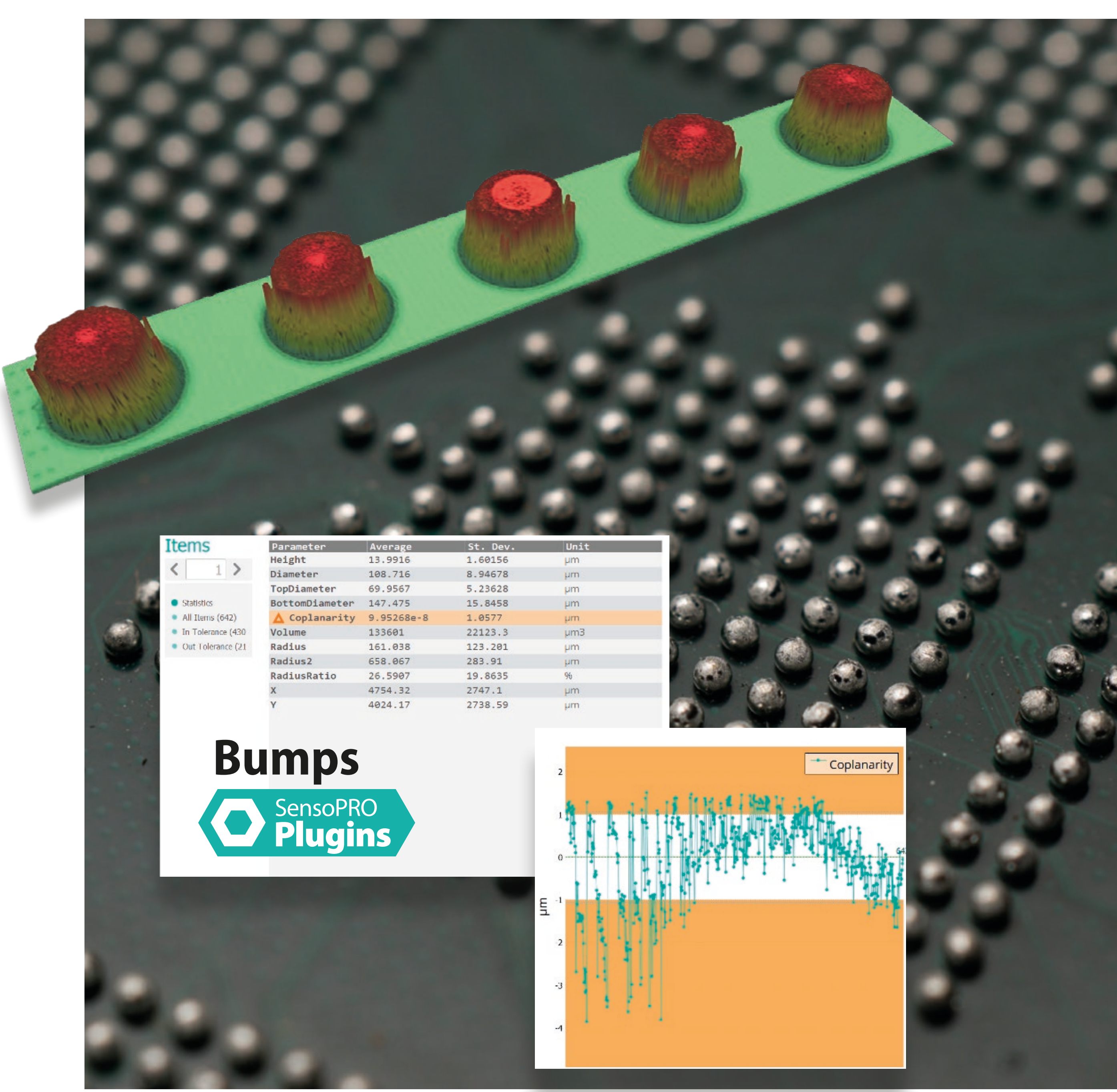
Depending on the scenario, there are different analysis solutions. The first is the **SensoPRO Probe mark depth plugin**, which identifies probe marks in rectangular and L-shaped pads and outputs the depth of the deepest pit.



Parameter	Average	Unit
X	791.4746	?m
Y	748.4099	?m
Depth	0.4551	µm

The second scenario involves characterizing a Ball Grid Array (BGA) connector. In this connector type, some bumps are electrically tested, while others are not. When probed, the bumps experience a decrease in height due to the pressure applied by the probing pin.

All pins must have a similar height to establish a connection. The coplanarity parameter in the **SensoPRO Bumps plugin** is designed to detect and calculate the height difference between the average height of all bumps and each individual bump, enabling measurement of the uniformity of the grid.



Parameter	Average	St. Dev.	Unit
Height	13.9916	1.60156	µm
Diameter	108.716	8.94678	µm
TopDiameter	69.9567	5.23628	µm
BottomDiameter	147.475	15.8458	µm
Coplanarity	9.95268e-8	1.0577	µm
Volume	133601	22123.3	µm3
Radius	161.038	123.201	µm
Radius2	658.067	283.91	µm
RadiusRatio	26.5907	19.8635	%
X	4754.32	2747.1	µm
Y	4024.17	2738.59	µm

COMPONENTS ASSEMBLY

The assembly process of a PCB involves several stages that ensure the structural integrity and electrical connectivity of the PCB assembly.

Chip attachment: Once the chip is placed according to the circuit design, glue is applied to provide mechanical support and ensure the stability of components during subsequent processes and throughout the lifespan of the PCB.

Wire bonding: In this step, the electrical circuits of the chips are connected to the conductive traces of the PCB. It involves using fine wires to establish electrical connections between bond pads of the chip and the corresponding contact points on the PCB.

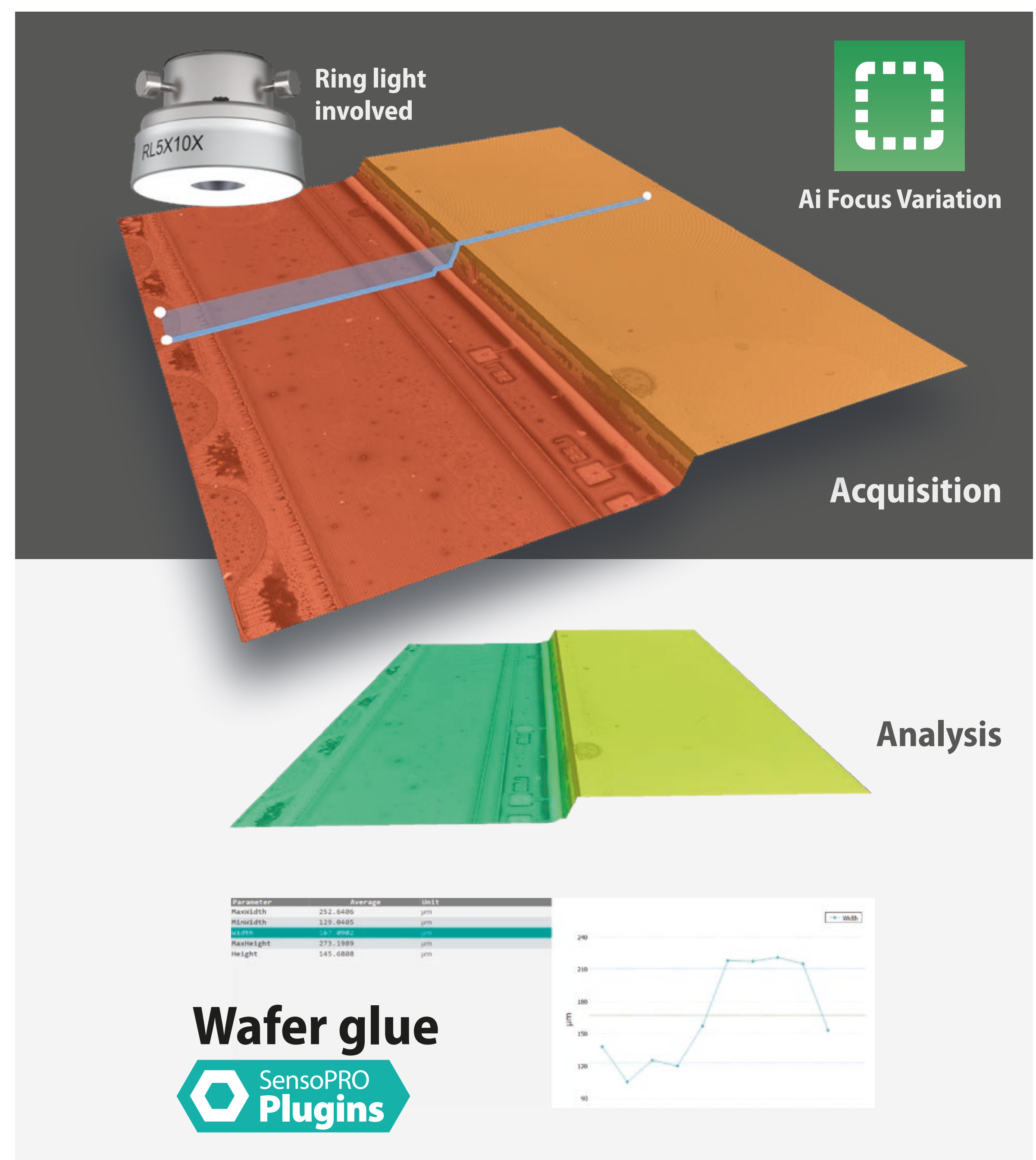
Encapsulation: When the wire bonding is complete, the entire assembly undergoes encapsulation or packaging. This process involves covering the components and wire bonds to safeguard them from external factors like moisture or dust.

COMPONENTS ASSEMBLY

Glue assessment between chips and the PCB

The height and width of the glue fillet play a crucial role in determining the device's optimal functioning. If the fillet is too high, it may affect the die's electrical performance. However, imaging a translucent sample such as glue, along with its high slopes (above 75 degrees), poses a significant metrological challenge. To address this challenge, the technology with the highest capability to image tilted parts, **Active Illumination Focus Variation technology**, is combined with a ring light that increases the signal, predominantly in the slopes.

As for analysis, the **SensoPRO Wafer glue plugin** searches for the glue between the die and the PCB board and calculates the width and the height of the fillet.

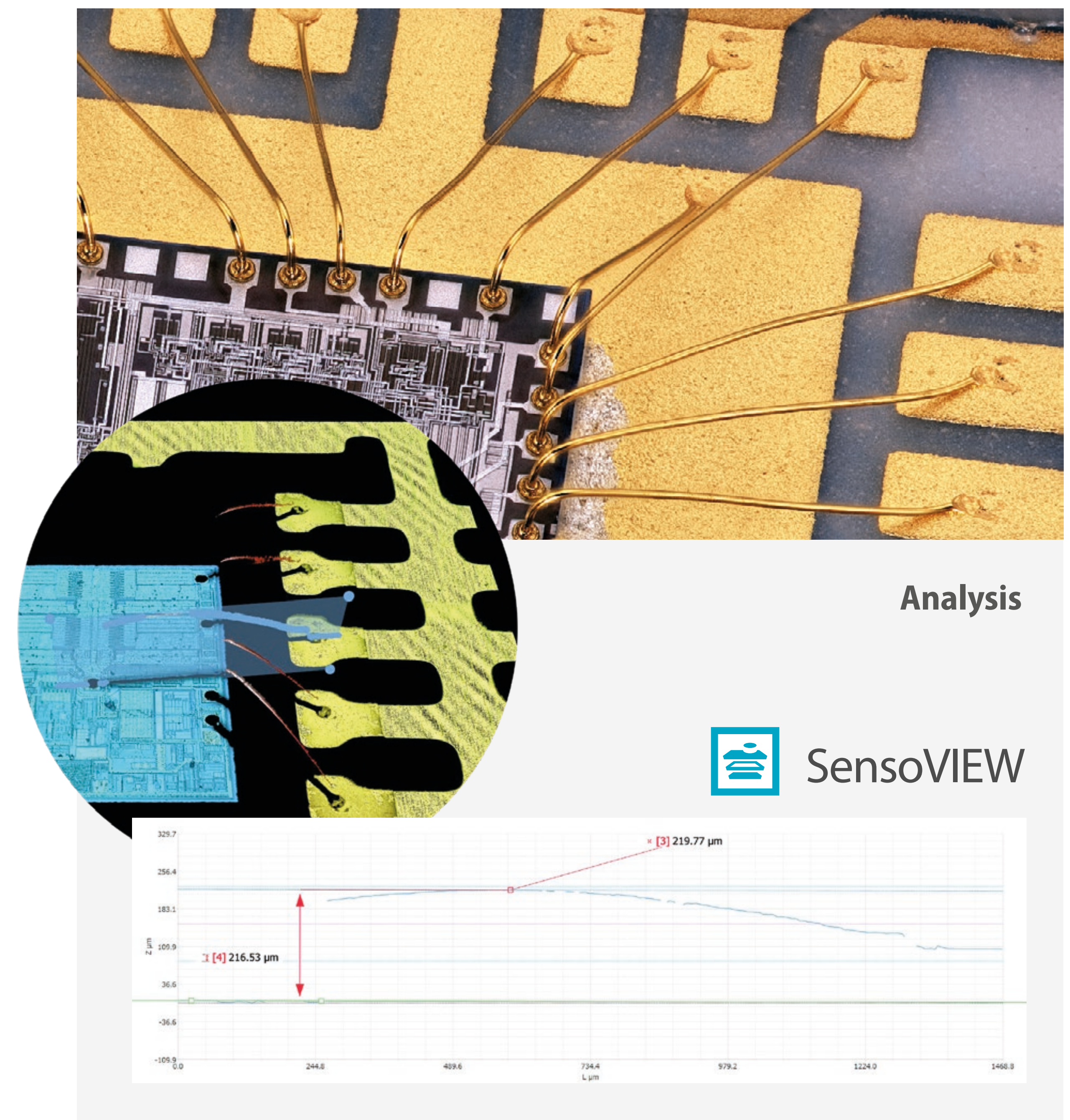


COMPONENTS ASSEMBLY

Wire bonding I: casing compatibility

Wire bonding is a critical process in establishing a good connection between components. As the chips and boards shrink, studying this process has become increasingly important. Due to the smaller sizes, imaging is now more challenging; only the highest magnifications can resolve the wire bonds. For instance, forefront technologies have successfully decreased the diameter of gold wires to 30 µm, significantly advancing in miniaturization.

Before the casing of the chip and after the wire bonding, there is a crucial factor to consider: the maximum height between the wire and the chip. It will advise about the possibility of the cable colliding with the case of the chip. **SensoVIEW** facilitates the creation of multiple profiles and precise measurement of critical dimensions, providing optimal performance and preventing potential issues.



COMPONENTS ASSEMBLY

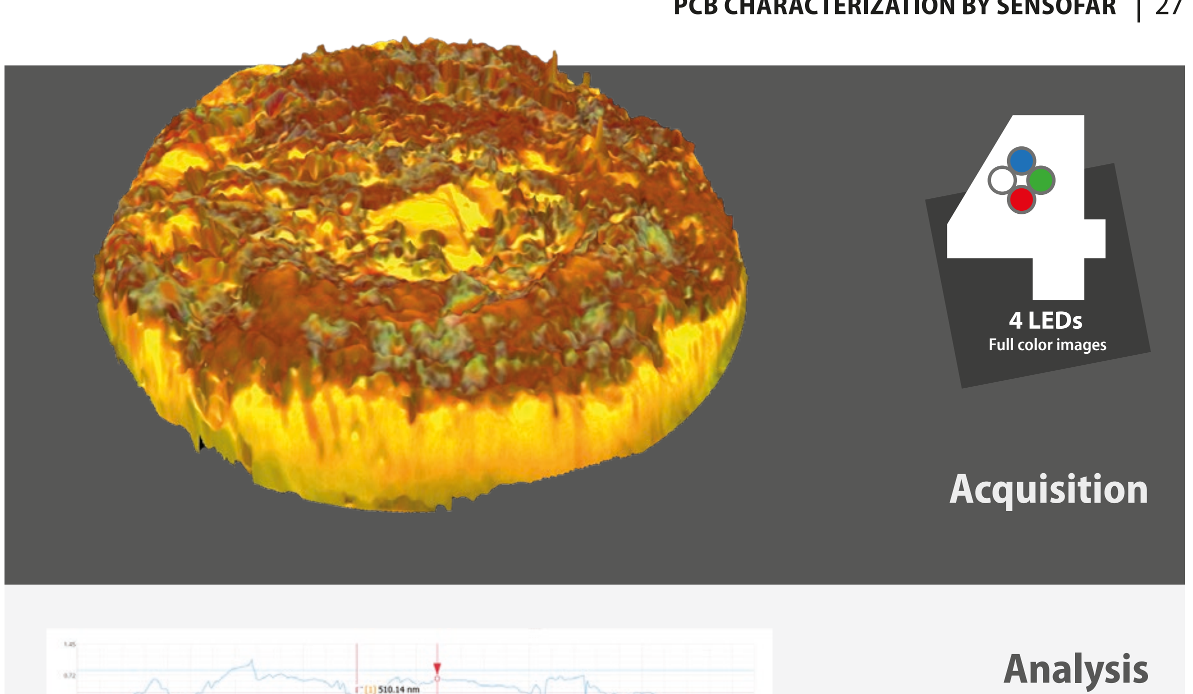
Wire bonding II: intermetallic Coverage (IMC)

During the bonding process, a cable and a connection area of the chip or board are assembled under pressure and heat. The result is the formation of intermetallic phases that ensure the two elements stick together. The intermetallic layers' thickness impacts on the connection's mechanical, electrical, and thermal properties. **SensoVIEW** is the best choice for analyzing the heights of the intermetallic layer within the connection area.

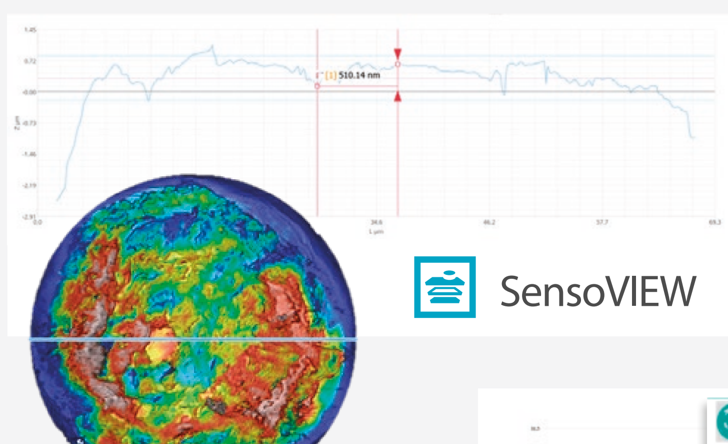
Furthermore, there is a widely used parameter to study the adhesion of the bonding process: the Intermetallic Coverage (IMC). The IMC is the ratio between the total area of the bond and the area covered by the intermetallic layer. Small IMC values may indicate mechanical and electrical malfunction due to weak bonds.

Color is an effective way to distinguish between the intermetallic layer and the connector's area. The **S neox 3D profilometer**, equipped with different LEDs, can obtain color information. The microscope scans the sample using three light sources (blue, red, and green), and what the algorithm does is weight the intensity of each color in each part of the sample, resulting in topography with height and color information.

The **SensoPRO IMCC plugin** calculates the IMC parameter by automatically detecting the intermetallic layer using the color information.

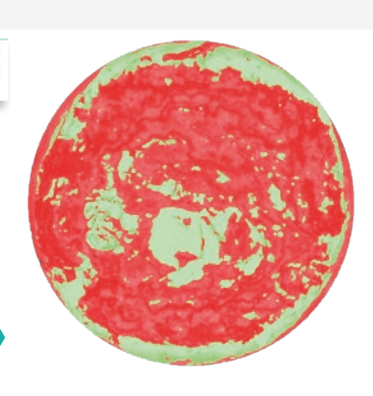


Analysis



IMCC

SensoPRO
Plugins



PACKAGE READINESS

The packaging readiness of PCBs is one of the latest steps in the extensive manufacturing process of PCBs. It refers to the stage where all the components are already attached, and the final step of covering or encapsulating the PCB is required to provide protection and ensure its optimal performance and durability.

PACKAGE READINESS

Flatness of the board

In scenarios where the PCB will be housed, it becomes essential to evaluate its flatness beforehand. By measuring the flatness of the PCB, manufacturers can verify its compatibility with the intended package, guaranteeing secure and reliable integration within the electronic device. Additionally, flatness measurements can also reveal any damage on the board.

Sensofar offers both **Fringe Projection** and **Interferometry** technologies to check the flatness of a PCB, with different resolutions and speeds according to specific manufacturer demands.

Fringe projection enables quick scanning of PCBs. For example, using this technique, the S wide Large Area 3D Profiler can scan a PCB in just 10 seconds.

The extended Phase Shifting Interferometry technique (ePSI) is recommended for those requiring highly precise measurements. The **S neox 3D Optical Profiler** can achieve a measurement noise as low as 0.1nm using this technique.

The flatness values are obtained using the **SensoPRO Flatness plugin**, wwhich follows ISO 12781, the ISO for flatness calculations in an area.

FAST

S wide | Fringe Projection

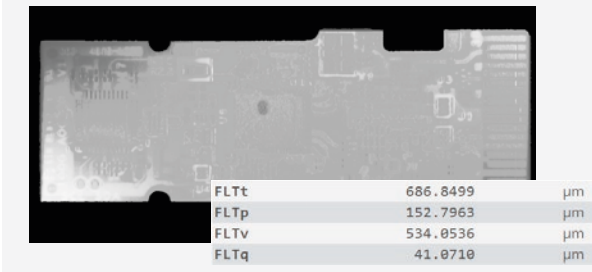
PRECISION

S neox | Interferometry

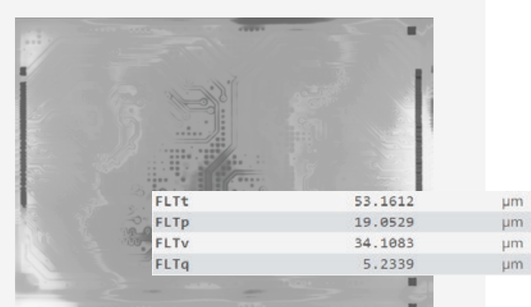
Acquisition

Analysis

This plugin is used to analyze the flatness following ISO 12781.

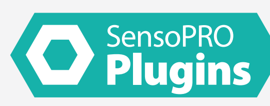


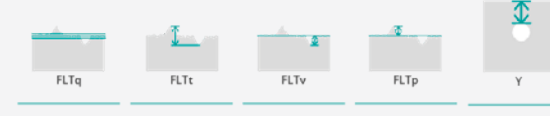
FLTt	686.8499	µm
FLTp	152.7963	µm
FLTv	534.0536	µm
FLTq	41.0710	µm



FLTt	53.1612	µm
FLTp	19.0529	µm
FLTv	34.1083	µm
FLTq	5.2339	µm

Flatness





Ai Focus Variation

Acquisition

Analysis

Glue

SensoPRO Plugins

Area | Feature Size | Feature Size Filled | Height | Width | X | Y

PACKAGE READINESS

Glue disposal optimization

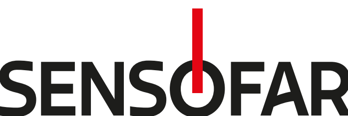
Certain companies handle the manufacturing of PCBs and their subsequent assembly into electronic devices, providing a comprehensive solution for customers. That can involve sealing the PCB inside a casing by applying specialized glues. A 3D optical profiler is used to determine the glue bead volume, ensuring that the correct amount of adhesive is dispensed. This information can help save money, with new alternatives in glue brand and dispensing speeds optimizing the amount of glue distributed.

The **SensoPRO Glue plugin** simplifies the analysis process. It measures the volume, height, and width of the bead in cross-sections across the bead. With this approach, the trends of any of these parameters can be observed along the measured length, making it possible to identify gaps in the dispensing process.

Sensofar displays a comprehensive range of solutions for automatically acquiring and analyzing the PCB process, offering endless possibilities.

SENSOFAR

Accurate and reliable measurements	Increased efficiency	Maximized yield	Customizable solutions	Improved product quality
Sensofar's automated solutions ensure that measurements are taken with the highest level of precision, reducing errors and improving the overall quality of the product.	Automating measurement processes reduces the time and effort required for manual measurements, increasing efficiency and allowing manufacturers to focus on other production areas.	The optical profilometers from Sensofar provide valuable data and insights for process optimization, enabling manufacturers to fine-tune parameters and enhance the yield and efficiency of the process.	Sensofar's solutions can be customized to meet the specific needs of manufacturers, allowing for greater flexibility and improved performance.	Accurate measurements help ensure that products meet the highest quality standards, reducing the likelihood of defects and improving overall customer satisfaction.



METROLOGY

SENSOFAR is a leading-edge technology company that has the highest quality standards within the field of surface metrology

Sensofar provides high-accuracy optical profilers based on confocal, interferometry, and focus variation techniques, from standard setups for R&D and quality inspection laboratories to complete non-contact metrology solutions for in-line production processes. The Sensofar Group has its headquarters in Barcelona, a European technology and innovation hub. The Group is represented in over 30 countries through a global network of partners and has its own offices in Asia, Germany, and the United States.

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