Optical Sensors conquer 3D Surface Measuring Devices

3D measuring technology for electronic components: cameras, optical sensors, confocal microscopes.

How does the 3D measurement of electronic components work? At first glance, the measuring machines used here look like their relatives from the mechanical world, the high-end coordinate measuring machines. Bridge and portal designs are also the prevalent types here. Yet much is different and it starts with the name: We speak of 3D surface measurement systems for microelectronics or microsystems technology, for precision engineering or for the tool industry; and the all-rounders among these can offer several sensor systems. Optical sensors are taking over the lion's share of the measuring tasks. Up to four different measuring systems can be found on the sensor carriers of the cyberTECHNOLOGIES 3D surface measurement device.

A surface view

In quality assurance, the focus is increasingly on the surface properties of electronic components, in addition to their actual basic dimensions. These properties include roughness and evenness, but also the step heights and layer thicknesses of coatings, co-planarity and global thickness variation. The latter is also known as TTV (total thickness variation).

The production of electronic components involves very large quantities with simultaneous traceability of each individual component, so a 100% inspection is not an option. This naturally has consequences for in-process quality assurance, since the quality check of a control group cannot and must not take a whole day where 70,000 high-quality electronic components are manufactured daily for a smart phone. No company today can risk as many potential rejects – the longer the feedback time, the greater the risk of rejects.

Several methods can be used to minimise feedback time as much as possible. The easiest – but also the most expensive – is the parallel placement of several measurement systems to check production lines in parallel. Less costly but more technically challenging is the acceleration of the measuring process through parallel measurement processes and the optimisation of individual measurements by specialized sensors.

Depending on the task they have to perform, 3D surface measuring devices have an ensemble of measuring systems consisting of different technologies that are specialized for their respective roles. A camera system is always present for easier operation. The measuring section is defined by means of simple marking, using the live view of the sample. In automated measurement procedures, the camera is also used to automatically align samples and to compensate for offset and distortion.

This enables the measuring devices to be used directly in production. Measurement data is recorded with maximum repeat accuracy and quickly – no user intervention is necessary. 3D white light interferometers are used in parallel here. In the world of technical measurement, they play in the top league and are the first choice when it comes to roughness (e.g. on wafers) and when resolutions of less than one nanometre must be attained. Just like white light interferometers, confocal microscopes are surface sensors with resolutions in the nanometre range and typical measuring surfaces of less than one square centimetre. They are also very often installed in surface measuring devices. Line or point sensors are available for the scanning of larger surfaces, making the combination of both technologies interesting.

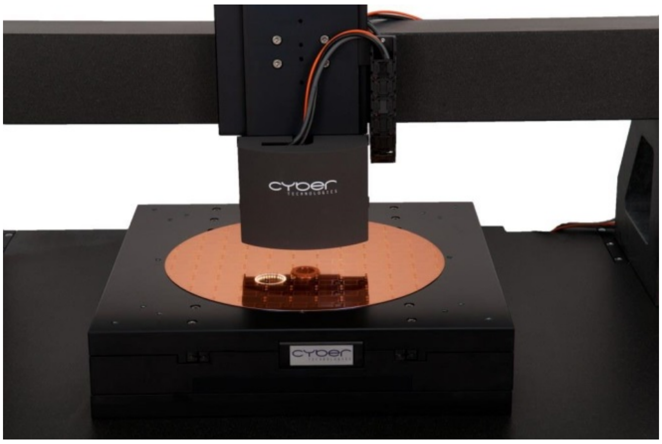

Image 1: The sensors of a 3D-surface measurement device: Camera with ring light, chromatic-confocal sensor.
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Chromatic-confocal speed rush

When it comes to speed, the new chromatic-confocal line sensors are number one. Instead of one single measurement point, they have a line of them, i.e. a line of adjacent measurement points. Depending on the number of measuring points and the length of the line, significant measurement time savings can be achieved. The CLS Line Sensor supplied by Precitec Optronik in Neu-Isenburg and installed into the 3D surface measuring devices at cyberTECHNOLOGIES in Eching-Dietersheim is faster by more than a factor of 100 than the comparable point sensors from the same company, according to the assessment of Frank Kemnitzer, Head of Sales at cyberTECHNOLOGIES. This speed advantage is achieved through the parallel readout of 192 measuring points, which can be arranged on a measuring point line of between 1 and 5 mm, so the CLS Line Sensor can scan much larger surface areas than conventional point sensors within comparable timeframes. The chromatic-confocal measurement technology used here has other advantages as well as the contact-free measuring principle: Thanks to its high level of dynamics and its excellent signal/noise ratio it can tackle all kinds of materials, including polished and reflective surfaces. This is very important when components and substrates have to be measured. Bumps, for example – contacting elements for mounting bare semiconductors – are usually made of highly reflective, almost mirror -like materials; and these surfaces are difficult to measure for conventional optical systems.

In the case of systems which have a point sensor and a confocal microscope, the point sensors not only take over the scanning of larger surface areas, they are also good distance sensors. For table movements in the XY direction, confocal microscopes need an active distance control for the Z-axis, since the typical viewing distance between the microscope objective and the measurement surface is only one millimetre. Even at high speeds, a chromatic distance sensor with a working range of around 20 millimetres can also verify that the objective of the confocal microscope cannot collide with the component to be measured and that the required distance is maintained. Continuous distance control is especially important for automated measuring processes, with which customer-specific measuring programs can be taught. The customer can create the relevant programmes himself. Equipping the system is either done manually or by means of an automated handling system (robot).

For what are 3D surface measurement systems used in practice? This can be easily exemplified using the example of the production of electronic components.

Image 2 A measuring system for wafers, consisting of a handling cell (robot) and a measuring machine. © cyberTECHNOLOGIES

1. Wafer inspection

A first step in the manufacture of electronic components is the inspection of the wafer, where the roughness, bow & warp and the TTV are especially important. At the beginning of the production of a wafer, the silicon disc is cut then polished until it is optically reflective. The surface roughness may only amount to a few nanometres in thickness to enable further processing. To ensure this, the roughness is examined before the next process steps and the highly reflective surface is closely inspected to detect the smallest defects. Non-contact 3D surface measuring instruments are the optimal solution here and 3D white light interferometers are used due to the sensitive surface and low degree of roughness. They enable non-destructive, rapid and relatively large area 3D measurements with a height resolution in the sub-nanometre range for accurate roughness monitoring.

In addition to the roughness, the smallest possible degree of bowing and warping is crucial for the next process steps. Mechanical stresses in the wafer will be the result if these quality criteria are not adhered to and errors can then occur during the dicing of the wafer. The wafer surface is therefore scanned with a confocal white light sensor before the next production step and the degrees of bow and warp are measured.

At the same time, however, the thickness or TTV of the wafer must be inspected. Wafers are usually attached to a thin film (dicing tape) to enable better handling. An infrared sensor can then measure the wafer thickness through the dicing tape. If infrared cannot be used, the thickness of the wafer is measured by two sensors positioned opposite to one another. Both of these sensors detect the height data in synchronised and precisely localised manner.

They must be exactly aligned axially in order to ensure an absolutely precise differential thickness measurement. The speed advantage of line sensors is also particularly exploited for double-sided thickness measurement by incorporating two sensors positioned opposite to one another. With this arrangement, TTVs can be determined in the shortest possible timeframe, even over large scan areas.

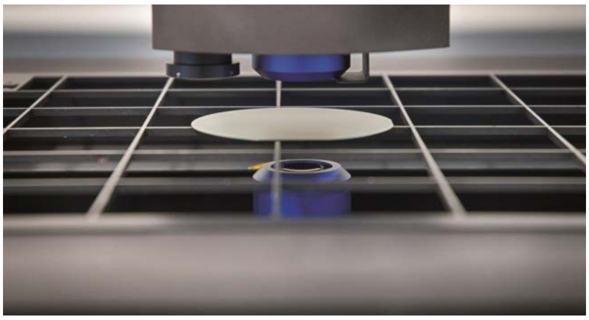

Image 3: TTV measurement over large areas by means of sensors positioned opposite to one another (double-sided thickness measurement).
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2. Measuring component alignment and position

In the next step, the singulated chip is applied to a substrate or to a lead frame. Adhesive is often used for this purpose; it is applied to the substrate in a stencil printing process. In the direction of the blade, excess adhesive, so-called dog ears, amasses at the end of a depot and these elevations can lead to the tilting of the chip. Now the 3D surface measuring devices come into their own: They monitor the layer thickness of the adhesive and the dog ears. If the values are outside the tolerance limit, the printing parameters are corrected.

The chip and the substrate are connected by means of wire bonding, which creates wire connections between the chip and the lead frame. The decisive factor in the positioning of the component is that the chip must be applied to the lead frame or the substrate without any tilting being involved. Any erroneous application would cause problems in the subsequent bonding process, resulting in rejects. This processing step must also be constantly monitored to avoid errors here. A measuring system with a chromatic-confocal white light sensor automatically measures the tilt of the silicon chip. If the degree of tilt is too great, the software immediately sounds the alarm. Production can then be stopped and process parameters corrected. A white light point sensor only requires around 40 seconds for the overall measurement of all the chips on a lead frame, so it makes sense to provide additional support for the measurement system through a handling system that handles the lead frame feeding and removal. Inline measurement can also be performed as an alternative.

3. Measuring thickness

The next important process is moulding. It is used to encapsulate the sensitive silicon chip. Here the chips connected to the leadframe or substrate are protected with plastic. The thickness of this protective layer must be measured since it has to be as thin as possible and as thick as necessary. Now the contact-free point sensors can shine! An optical sensor can neither perform a through measurement of a component made of different materials, nor can it determine the component’s layers. Two sensors positioned opposite to one another can do this, however and they are used for this step. Both sensors detect the height data in synchronised and precisely localised manner. They must be exactly aligned axially in order to ensure an absolutely precise differential thickness measurement. The measurement procedure here is similar to that of wafer thickness measurement before and after moulding and the layer thickness is determined by subtraction.

4. Laser Marking

Components are marked after the moulding process to help identify them clearly. A data matrix code is often used for permanent direct marking. It is applied to the components by means of laser during production and can be read by special reading devices. At 1,000 characters per second, this writing process called “laser marking” is very fast, requires no consumables and does not create static electricity. When set correctly, the laser writes structures that are only a few micrometres deep into the surface of the component. However, if the process parameters for the Laser Marking are set incorrectly, the laser can damage the chip beneath the moulding, so 3D surface measurement systems control the depth of the written characters as part of quality assurance. A line sensor is used for fast measurement in this case.

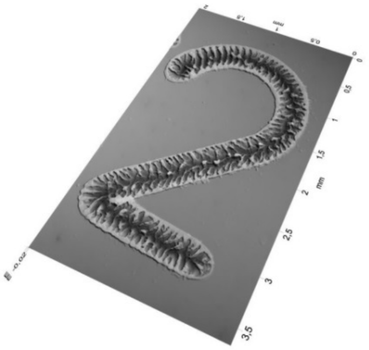

Image 4: Structures created during Laser Marking are only a few micrometres in depth. © cyberTECHNOLOGIES

Summary

As you can see, 3D surface measurement devices differ significantly from conventional coordinate measuring machines. Scanning sensors, as they are known in the mechanical world, no longer exist here – the industry relies totally on optical and consequently contact-free sensors instead. Chromatic-confocal white light sensors, white light interferometers and 3D confocal microscopes are taking over the measurement tasks for 3D surface measurement devices. They guarantee the precise and non-destructive measurement of evenness, contour, thickness, layer thickness, step height, roughness and other common 2D and 3D measurements. Extremely powerful designs include contact-free surface measuring devices that measure double-sided components and are equipped with CHRocodile line sensors by Precitec Optronik. These measuring machines are mainly characterised by the fact that they can carry out large-scale scanning, precise 3D measurements, 2D profiles and 3D raster scans of upper and lower surfaces in the shortest possible time. The two worlds still have one thing in common, however: The accuracy of high-end coordinate measuring machines and the equipment of cyberTECHNOLOGIES are not only ensured by the sensors, but by the machine itself to a large extent.

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