



Powerful sensors for semiconductor manufacturing Wafer fabrication and quality control

Semiconductor technology is the cornerstone of all modern technology. The progress of numerous industries depends on microprocessors and memory chips. The key drivers are smartphones, cloud computing and Big Data, plus megatrends such as artificial intelligence, the Internet of Things and autonomous driving.

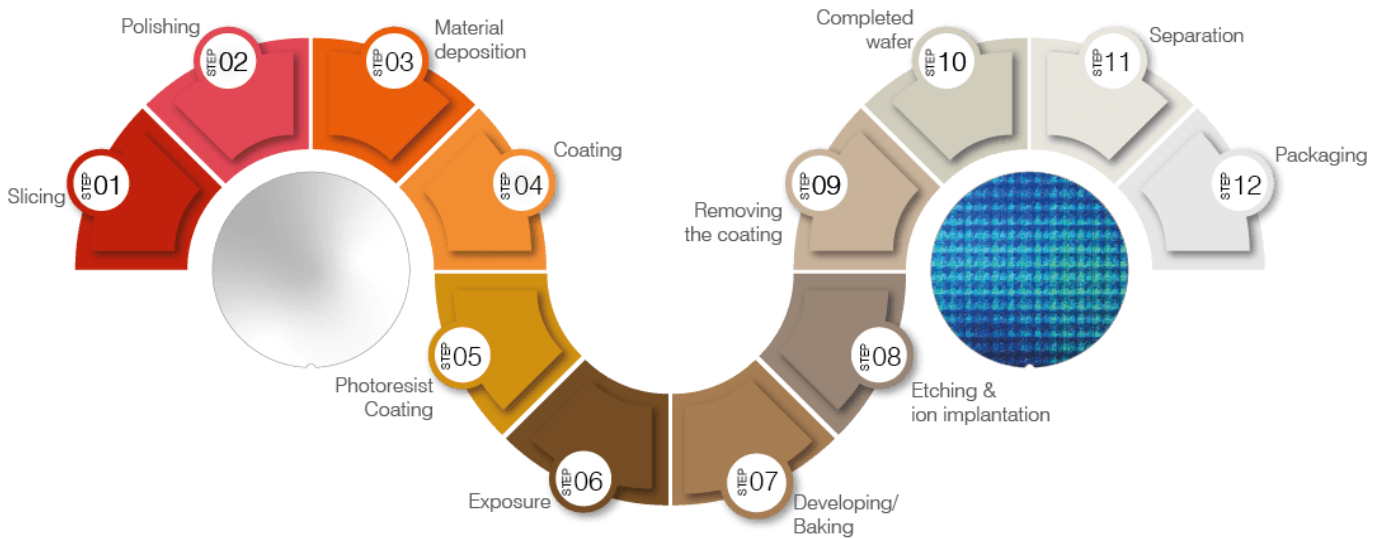
At the same time, the requirements for semiconductor production are extremely high. In order to make chips more compact and to fit even more functionality into the smallest possible space, all production steps in wafer manufacturing are subject to the most stringent requirements. This requires sensors that reliably monitor and control handling systems, machine parts, optics and the associated processes.

Micro-Epsilon is a reliable partner of the semiconductor industry. Decades of experience and cooperation with leading companies in the semiconductor industry enable us to offer the right solution for the measurement task at hand and to develop customized sensors if required. Our high-precision sensors and measuring systems are designed and built based on semiconductor-compliant manufacturing technologies and suitable materials. Therefore, they are ideally suited for use in vacuums and ultra-high vacuums.

This white paper shows application examples of Micro-Epsilon sensors in different process steps and application areas.

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Essential processes from wafer production to separation: Sensors from Micro-Epsilon are used in all important processing steps to reliably monitor critical measured variables.

Sensors with More Precision - Ready for Semicon

Due to the high demands in semiconductor manufacturing, all sensors and systems from Micro-Epsilon are put through rigorous manufacturing and testing processes. This includes the selection and placement of electronics, mechanical manufacturing, and special process technologies.

In addition, special manufacturing processes and application-specific sensor materials are used to meet the highest quality requirements. This enables us to manufacture individual sensor solutions that prove themselves in precision mechanical engineering due to high performance and precision as well as robust design.

Manufacturing process for high-precision displacement sensors

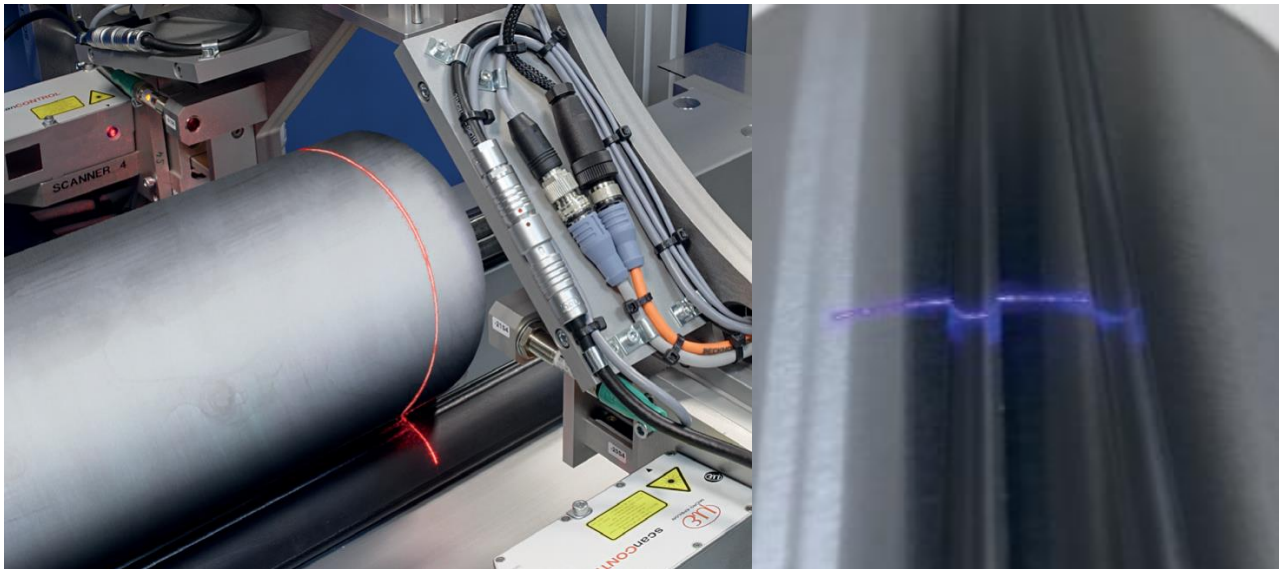
- USP laser technology
- High-temperature vacuum soldering
- Precision manufacturing
- Burn-in tests
- Fully automated potting systems
- Passivation and coating of components and switching groups

Adapted sensor design for use in clean rooms and vacuums

- Low outgassing
- Suitable for use in vacuums
- Cleaning possibilities
- UHV-compliant technologies
- Connection technologies
- Semiconductor compliant labeling and packaging
- High quality standards

Measurement tasks in wafer production

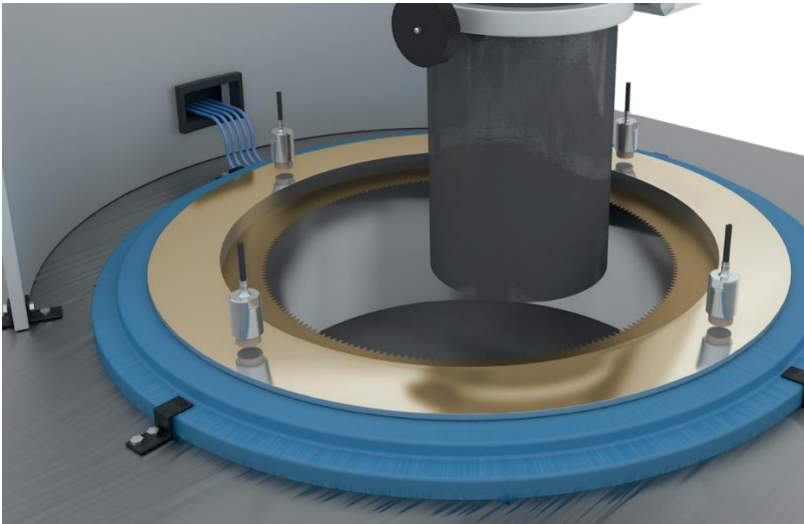
Ingot sawing requires high precision in processing. During sawing, the single crystal rod is cut into thin wafer slices using an internal hole saw. Wire saws, on the other hand, allow several slices to be cut from the bar at the same time. Non-contact sensors from Micro-Epsilon are used to monitor the sawing processes.



Dimensional inspection of silicon ingots

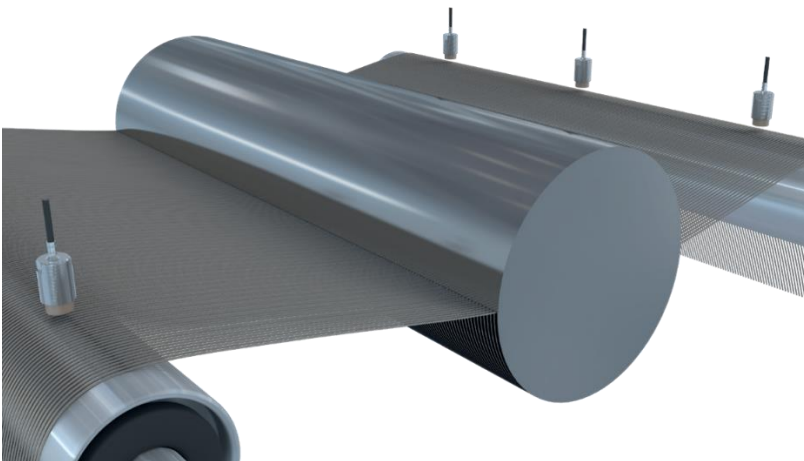
Initially, laser profile sensors measure the complete geometry of the silicon rod. To do this, the ingot passes a measurement station with several laser scanners.

In a second step, the scanners check the dimensional accuracy of the orientation notches, which are later required for the exact alignment of the ingot. Blue laser scanners are used for this purpose, which generate a highly precise and interference-free measurement signal.



Monitoring the axial movement of internal hole saws

In the inner hole sawing process, wafers are sawn out of the silicon block. As eddy current sensors monitor the axial movement of the saw blades. Since eddy current sensors are insensitive to dust and dirt, they provide precise measurement results even in adverse environmental conditions. The eddy current sensors measure the distance to the saw blade support without contact and so are wear-free. The result is a homogeneous and uniform cut of the silicon wafers is the result.

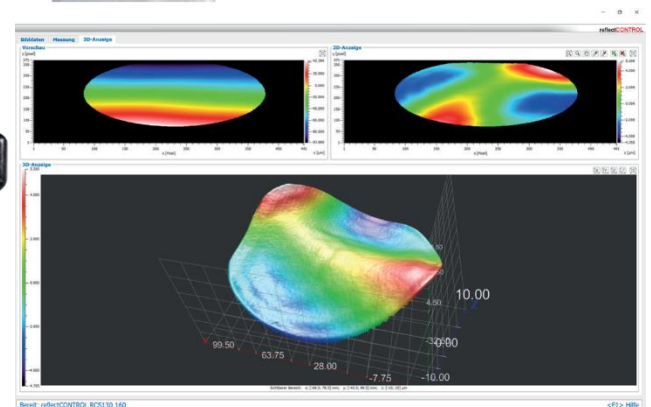
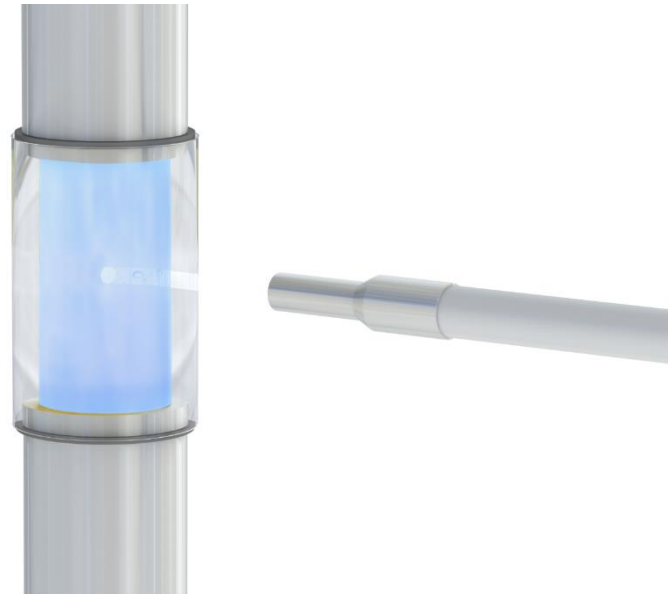


Monitoring the deflection of wire saws

In wire sawing, several wafers can be cut from the silicon ingot simultaneously. The thin wires have a diameter of just over 100 μm . Due to abrasion, the wire wears out and loses about 5-10% of its diameter. Therefore, wire wear must be monitored continuously. Here, too, eddy current sensors are used, which record both the wire height of the wire and wire sag.

Color measurement when cleaning wafers

For cleaning wafers, ozone is added to the cleaning liquid. Color sensors from Micro-Epsilon are used to permanently determine the concentration of the contained ozone. These monitor the color of the liquid and from this detect the ozone concentration. Even the smallest color deviations of the concentration are reliably detected in the process.



3D shape measurement of wafers

The wafer slices created during sawing must be planar. Deflectometry systems from Micro-Epsilon record the flatness of the wafers with just one recording. 3D sensors project a striped pattern onto the wafer surface for this purpose. Integrated cameras record the reflected fringe pattern, and the included software subsequently enables quick and easy evaluation. Distortions of the wafer would cause an equally distorted striped pattern. A highly accurate 3D representation enables the detection of such deviations at the micrometer level.

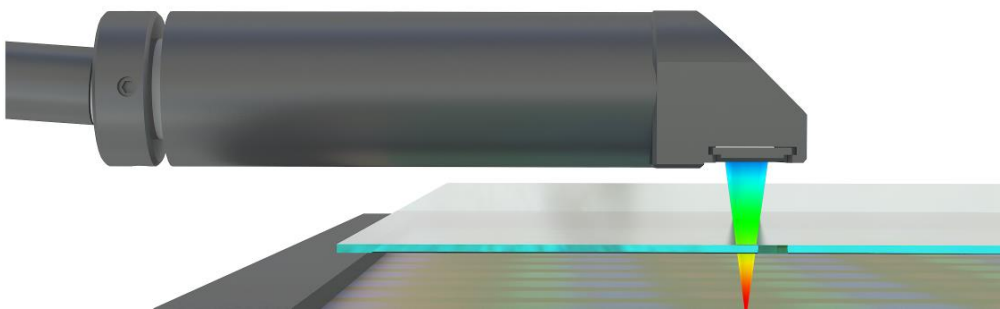
High precision distance measurements in lithography

Photolithography is a central step in the wafer manufacturing process. In the exposure process, the image of a photomask is transferred to the wafer surface. A photosensitive photoresist layer was previously applied to the wafer. After stabilizing this resist layer, the actual exposure begins.

Wafer lithography - especially EUV lithography - is one of the most complex industrial manufacturing processes. In order to deposit structures in the single-digit nanometer range on the wafer, the machine and optical elements must be positioned and aligned with correspondingly high precision. Sensors from Micro-Epsilon take on a decisive role here: nanometer-precise distance measurement in the positioning of the mask, the lens system and the wafer stages.

Positioning of the mask (reticle)

High-resolution and long-term stable measurements of the machine movements must be made when feeding and positioning the lithography mask. Capacitive displacement sensors are used in this process to monitor mask alignment, meeting precision requirements in the nanometer range. The modular design with multiple sensor channels and the vacuum-compatible components enable use in numerous measurement tasks.



Confocal sensors are used to check the parallel alignment of the mask. The gap between the glass and the substrate is detected using just one sensor. The rectangular design of the sensors also allows installation in confined areas. In this version, the sensor requires only a minimum of installation space.

To achieve maximum measured value resolution, white light interferometers from Micro-Epsilon are used. These generate absolute readings with sub-nanometer accuracy and achieve accurate photomask alignment. Special evaluation algorithms and active temperature compensation ensure high signal stability. Similar to confocal sensors, the white-light interferometers are available in vacuum-compatible versions.

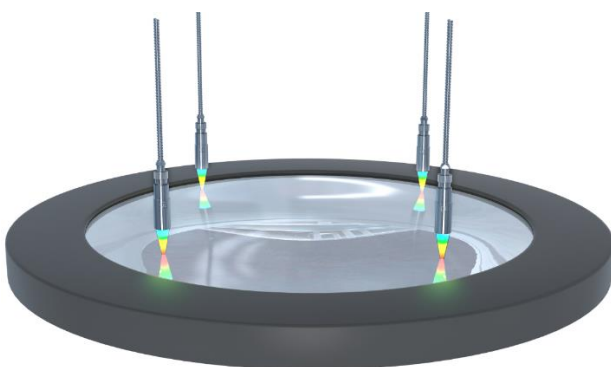
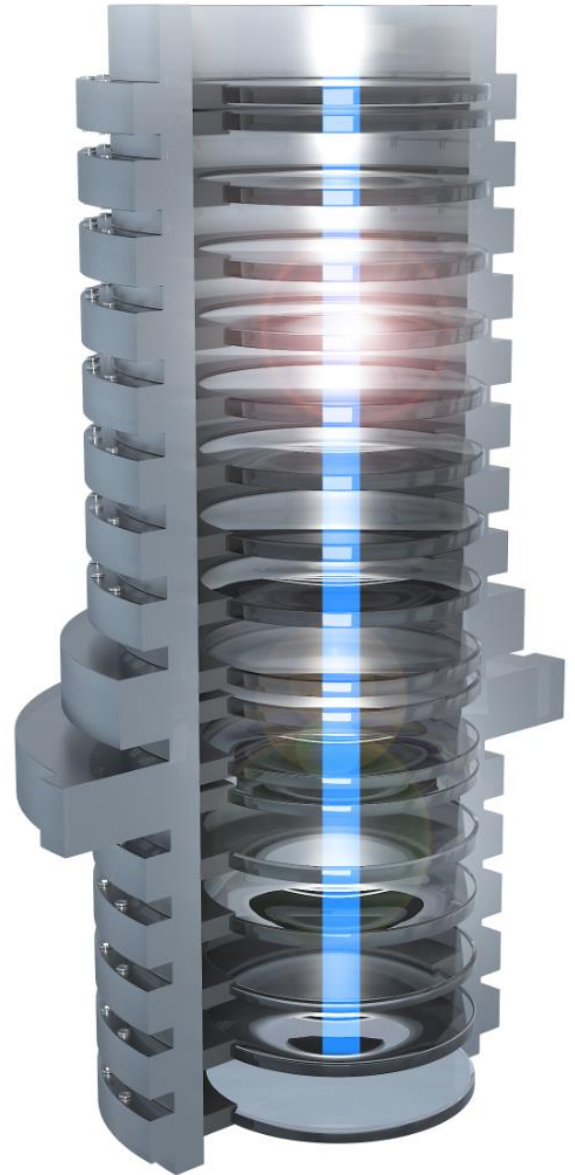
Alignment in the lens system

High-precision mirror optics are indispensable in lithography in order to achieve the highest possible imaging accuracy. To ensure that they function properly, the mirrors, lenses and lens carriers must be positioned precisely. In the same way, the horizontal and vertical movement of the individual optical elements must be monitored.

The alignment of the optics is measured using confocal chromatic sensors. This involves the nanometer-precise detection of the respective lens tilt. For use on glass, the confocal chromatic sensors and white light interferometers are the ideal choice.

The positioning of the lens carriers is monitored using capacitive displacement sensors. High-precision capacitive sensors check the tilt to nanometer accuracy. Several sensors measure onto the metallic carrier, which ensures exact positioning and thus reproducible light projection onto the wafer.

Non-contact eddy current sensors also measure the position of lens elements. Depending on the lens system, displacement sensors from Micro-Epsilon are used to detect movement and position in up to 6 degrees of freedom. Thanks to the high frequency response, even highly dynamic movements of the lens systems can be monitored.



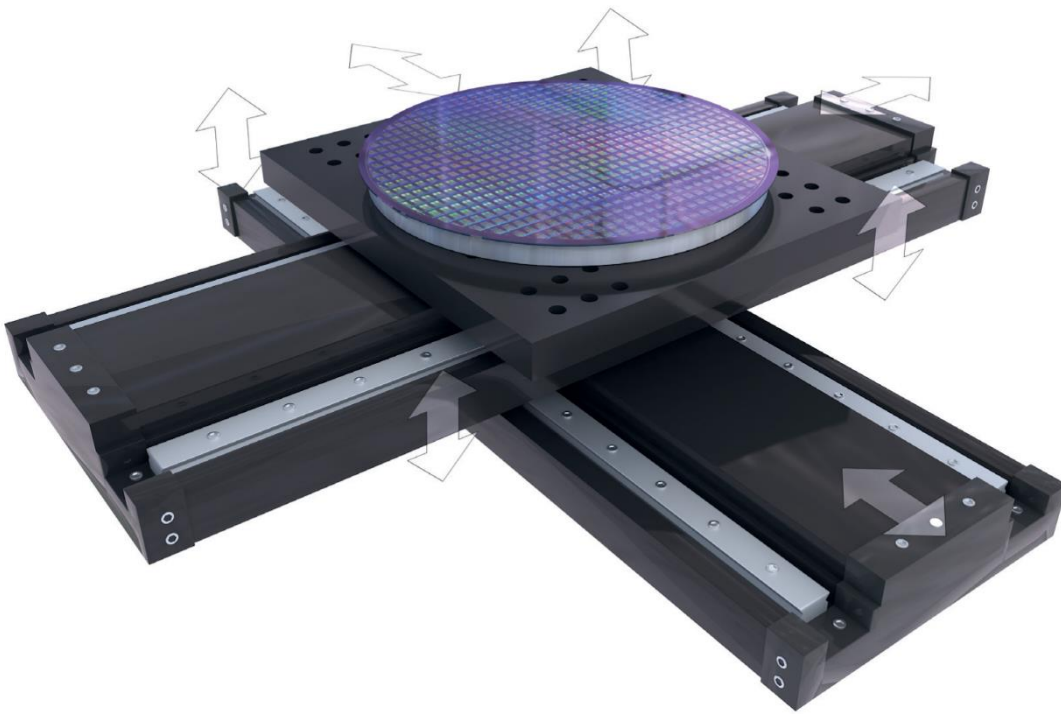
Left: 4 confocal sensors detect the tilt of the lens



Right: 4 capacitive sensors measure the tilt of the lens carrier

Position monitoring in the wafer stage

White light interferometers and eddy current sensors are used to monitor the position of the wafer stage or wafer platform. There, they measure the XYZ movements of the stage, where extremely high accelerations occur. The high-precision optical interferometers achieve sub-nanometer resolution and ensure that the wafer is optimally positioned for exposure. Vacuum-compatible measuring heads and insensitivity to strong magnetic fields enables the high-precision sensors to be used in demanding environments.

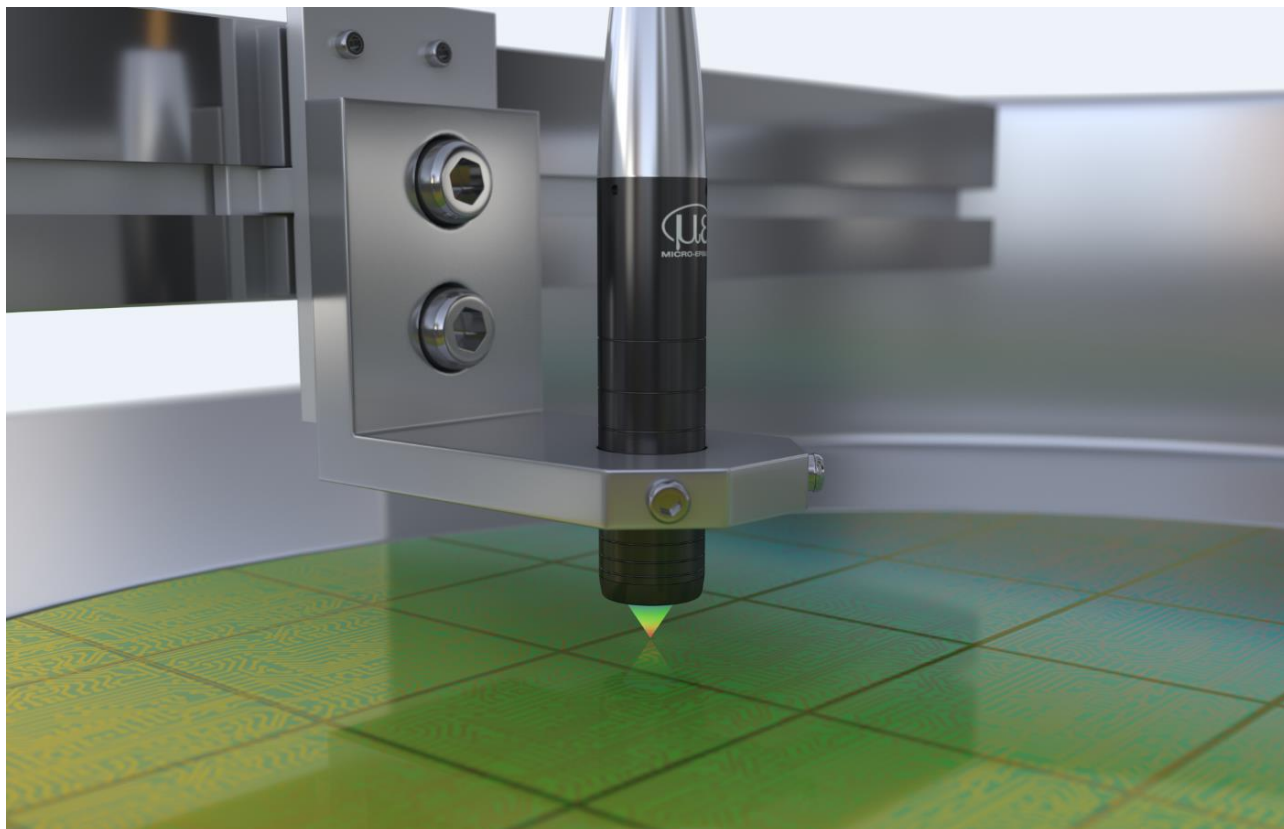


High-resolution measurements under extreme conditions: UHV, magnetic fields and high accelerations are among the requirements for displacement sensors

Capacitive displacement sensors are used for fine positioning in the wafer stage. They measure the position of the stage at various points, which is particularly necessary for fine alignment. Thanks to their triaxial design, the sensors are insensitive to electromagnetic fields and achieve a resolution in the nanometer range. In addition, they achieve extremely high long-term stability. The non-contact sensors are suitable for both vacuum and UHV.

Inline wafer quality control

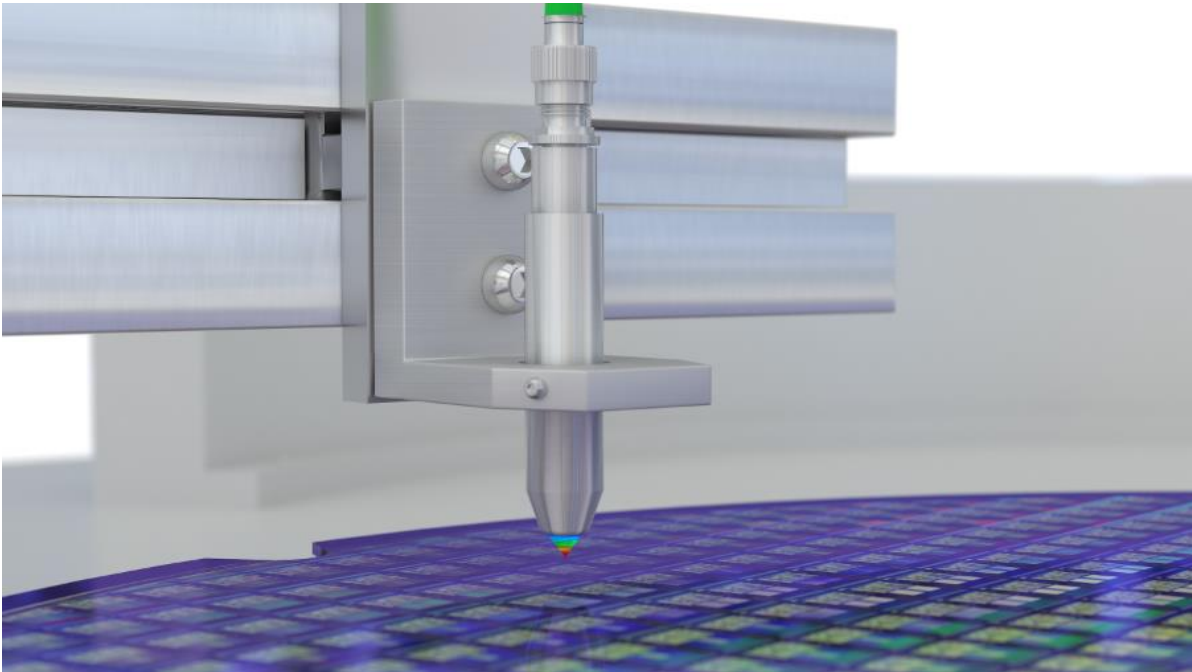
For quality control, sensors from Micro-Epsilon are used in various areas, for example, for testing the coating thickness, for monitoring the deflection as well as separation. In addition to high precision, a high measuring rate is also required to support the high speed manufacturing processes.



Confocal sensors are used for numerous measurement tasks in quality assurance

Single-sided thickness measurement of transparent coating layers

Confocal chromatic sensors are used for one-sided layer thickness measurements. The confocal measuring principle enables the evaluation of several signal peaks, allowing the thickness of transparent materials to be determined. Thanks to multi-peak measurement, even the thinnest layers are reliably detected. With just one sensor, the thickness of protective and paint layers, for example, are detected with micrometer precision.



Monitoring of wafer bow & warp

The larger the wafer, the greater the risk of deflection. Confocal chromatic sensors scan the wafer surface to detect bow, warp and distortion. With a measuring rate of 70 kHz, the confocalDT controllers enable highly dynamic measurements. This allows the wafers to be inspected in short cycle times.

Total Thickness Variation

Two confocal chromatic sensors measure the wafer thickness from both sides. The thickness profile of the entire wafer can also be used to determine the curvature and deflection of the wafer. High measuring rates enable thickness detection of the entire wafer in short cycle times.

Bumps

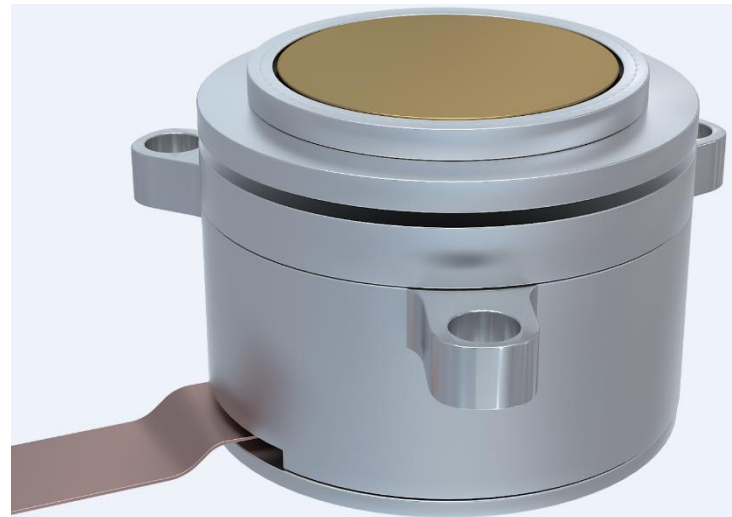
Confocal chromatic sensors from Micro-Epsilon measure precisely on shiny and textured wafer surfaces to determine the height of bumps with micrometer accuracy. Thanks to the focused light spot, a high lateral resolution of 4 μm is achieved. In this measurement task, 3 sensors are moved above the wafer. From the three tracks, both the spherical shape and the height can be calculated exactly. This is possible because the controllers are connected via Ethernet and trigger input and thus perform a synchronous measurement. In order to measure the high number of chips and therefore the bumps in the shortest possible time, Micro-Epsilon sensors offer an extremely high measuring rate of 70 kHz.

Checking the saw marks, cracks and break-offs

Confocal chromatic sensors from Micro-Epsilon are used to detect cracks, saw marks and other defects on the wafer. They reliably detect surfaces with varying reflection characteristics due to a fast surface compensation feature. An extremely small light spot and high resolution enable the reliable detection of the finest of anomalies on the wafer. The confocal sensors ensure reliable detection of the saw marks and other depressions in the wafer.

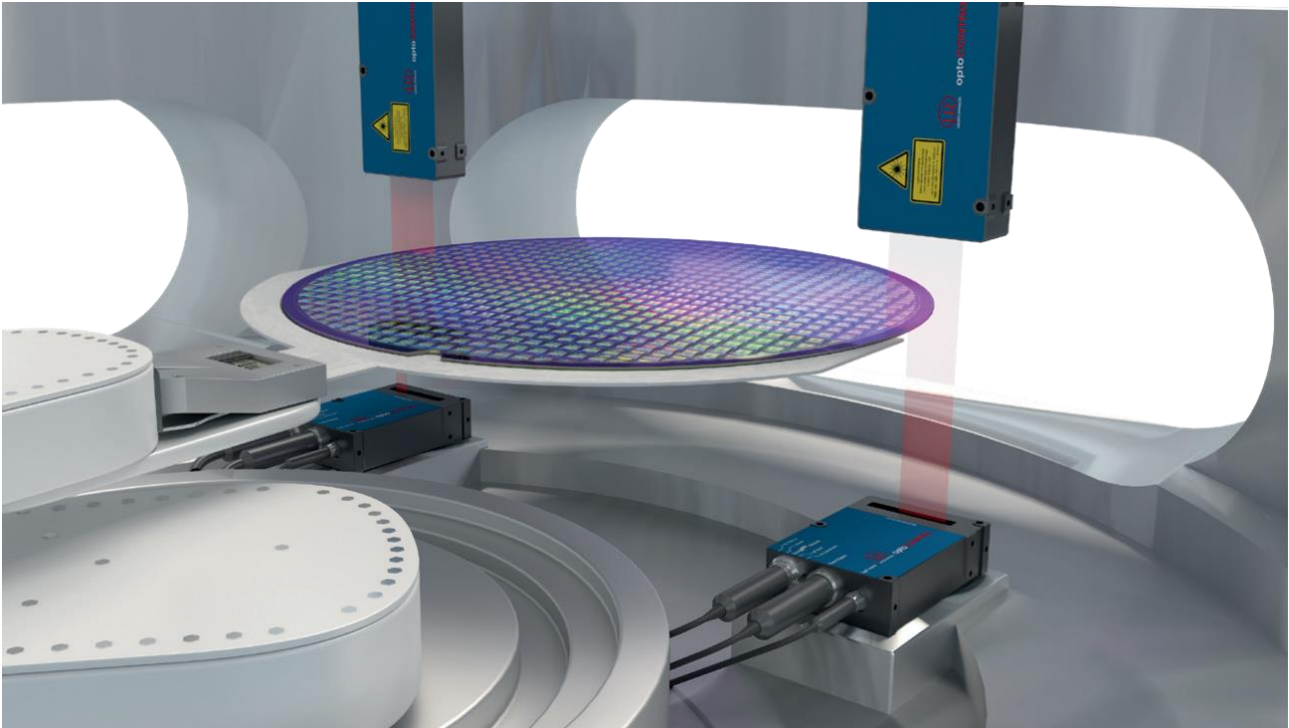
Highly integrated actuator systems for demanding environmental conditions

The Fast Steering Mirror from Micro-Epsilon is equipped with optimized non-contact displacement sensors. This micro-mechatronic actuator system is used for applications in the semiconductor industry to monitor the rapid tilting of the mirror, for example, in beam stabilization and laser dicing.



Precise monitoring in wafer handling

Wafers must be automatically removed and fed to the appropriate processing step throughout the manufacturing process. Accurate positioning is just as important as fast, and reliable movement. Sensors from Micro-Epsilon ensure exact alignment and safe transport in every process step. The clean room suitability of the wear-free sensors is a basic requirement for their use.



Precise edge detection of wafers with laser micrometers

Determining the position during wafer handling

When handling wafers, exact and repeatable positioning is crucial. During the infeed of wafers, two optoCONTROL laser micrometers inspect the diameter and thus determine the horizontal position. Thanks to the high measuring rate and accuracy, these micrometers provide reliable position information.

Tilt angle measurement of wafers

When feeding wafers, white light interferometers are used to measure their horizontal tilt. The interferometers provide absolute distance values at nanometer resolution. The measurement ensures the greatest possible positional accuracy when picking up and removing wafers.

Why choose Micro-Epsilon?

In-house production
with state-of-the art
equipment for short
delivery times

Long-term
experience and
industry expertise

High delivery
capability and
reliable cooperation

Well-conceived
sensor design for
easy cleaning

Experience in
applicable standards
and laws

Material variety,
e.g., Titanium, Inconel,
Invar, Kovar

Vacuum-suitable
solutions
including UHV

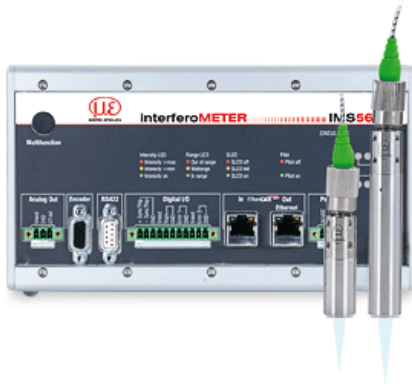
Clean-room
suitability

Low-outgassing
materials for sensors
and accessories

High-precision sensors for the semiconductor industry

Micro-Epsilon offers high-performance sensors and measuring systems, particularly for areas where high demands are placed on precision and reliability. The sensor products are used in almost all areas of the semiconductor industry and convince with their high accuracy, durability and stable measurement results. Below are 4 sensors that can be run as standard for semiconductor-specific environments.

Absolute measuring white light interferometer



The innovative white light interferometers from Micro-Epsilon set a benchmark in high-precision distance and thickness measurements. These sensors enable stable measurement results with sub-nanometer resolution, offering a comparatively large measuring range and offset distance. The white light interferometers are used for measurement on wafers as well as for monitoring small machine movements, such as those in the reticle stage.

Special features:

- Absolute distance measurement with nanometer accuracy
- Precise thickness measurements, regardless of the distance from the sensor
- Best-in-Class: Resolution < 30 picometers (IMS5600-DS)
- High signal stability due to new evaluation algorithms and active temperature compensation
- Vacuum-compatible sensors, feedthroughs and cables

High precision confocal chromatic sensors



The confocal chromatic sensors enable high-resolution distance and thickness measurements. The confocalDT sensors consist of passive components and do not emit heat. Especially for use in vacuums, Micro-Epsilon offers sensors, cables and accessories that are adapted to the respective environment. The sensors are primarily used for measurement on wafers and masks.

Special features:

- Distance and thickness measurements with high resolution
- Almost surface-independent, ideal for mirrors and glass
- Extremely small constant measurement spot for detection of the smallest of objects
- Passive measuring system and vacuum-compatible components
- Fastest controller worldwide for dynamic measurement tasks

Capacitive sensors with high resolution



Capacitive sensors are designed for non-contact displacement, distance and position measurement tasks. Thanks to the high signal stability and resolution, capacitive displacement sensors are used for measurement tasks in the semiconductor industry for high-precision monitoring of machine movements, e.g. for high-precision position monitoring of wafer stages as well as for the alignment of optical components and masks.

Special features:

- Non-contact measurement of displacement and distance with sub-nanometer resolution
- Maximum temperature stability
- All sensors, cables and controllers are compatible with each other and interchangeable without calibration
- Vacuum-compatible sensors, cables and feedthroughs

Robust eddy current sensors with high precision



Eddy current sensors from Micro-Epsilon are designed for non-contact displacement, distance and position measurement tasks. The sensors are used in applications where the highest precision is required under demanding environmental conditions. On the one hand, the robust measuring principle enables measurement tasks during sawing, polishing or grinding of wafers. Another area of application is the position monitoring of wafer stages, as well as vibration compensation in semiconductor machine construction.

Special features:

- High frequency response for dynamic measurements
- High resolution in the submicron range
- High linearity and temperature stability
- Customized adaptations, also for UHV
- Measurement on ferromagnetic and non-ferromagnetic targets

[Further application examples for semiconductor manufacturing can be found here](#)

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