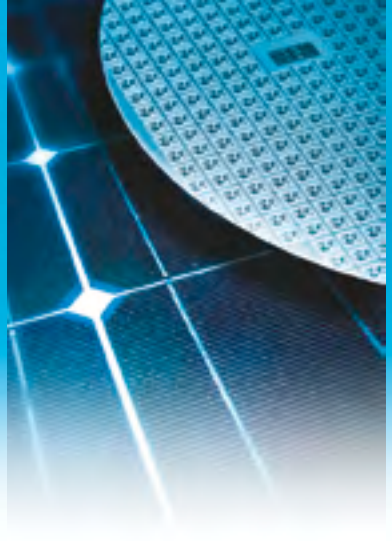
Microelectronics
Perspectives in Pure Water Analytics



8
News

THORNTON
Leading Pure Water Analytics

Need Quick Profiling of TOC?
Go Portable!

Multiple-point monitoring of total organic carbon can identify contamination sources in water systems. But full system profiling with fixed analyzers can be very costly. The new portable 450TOC analyzer is a convenient and easy to operate solution which can reduce system profiling time by 75 %.

Increasing demands on water purity

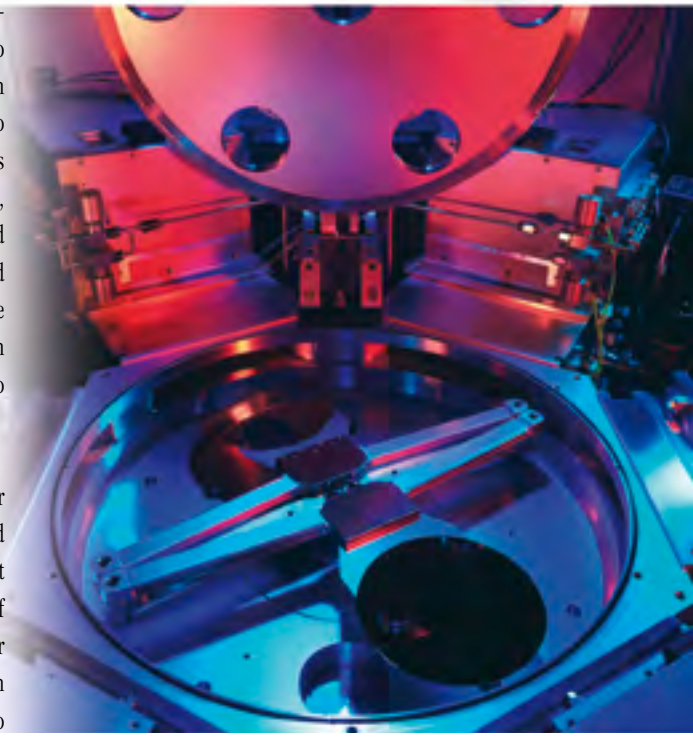
The microelectronics industry continues to move towards faster processes and higher production capacity while improving production yield. This requires ultrapure water (UPW) of increasingly higher purity. Such processes necessitate full profiling of the UPW system and continuous monitoring at multiple points to minimize production losses.

System profiling and monitoring

UPW is used in various segments of the industry, at different stages of the manufacturing process, and the level of organic impurities in the water needs to be constantly monitored to avoid any production losses.

Since 1992 the size of wafers being processed in fabs has grown from 200 mm to 450 mm. This translates to an increase in the number of chips per wafer from 150 to approximately 765. If these large wafers are contaminated during UPW rinsing, the amount of loss from just one rejected wafer is therefore substantial. This has led leading industry organizations to reduce the allowed limits of organic impurities in the water (see page 8), and companies to step up water monitoring.

For all high-throughput processes, water purity must be verified continuously and trouble spots fixed immediately. The most effective way to achieve this level of monitoring is to profile the entire water system and monitor total organic carbon (TOC) at multiple points throughout to



METTLER TOLEDO

ensure its compliance with purity requirements.

One of the challenges to achieving a full system profile and monitoring is the capital expenditure required to install fixed TOC analyzers at all the measurement points that should be checked. This has frequently led to facilities measuring only a few critical points of use along the system and extrapolating that data in the hope of estimating the full system profile. However, this still does not identify specific points of organic ingress or solve the issue of continuously monitoring along multiple points in the system to ensure water purity throughout the process.

To do that, a portable system is needed which can monitor quickly at various points in the system to provide immediate measurements.

The portable 450TOC – simple and convenient

The new, portable 450TOC offers quick and easy connectivity at multiple points. The analyzer can be used to quickly measure at points in the system not usually monitored due to lack of fixed analyzers for those locations. Rapid measurement technology allows immediate monitoring, providing first results 80 % faster than traditional methods. The 450TOC utilizes the same measurement technology as its fixed analyzer counterpart (5000TOCi), providing uniformity in measurement method, as well as fast results. With its portability and rapid TOC measurement technology, the 450TOC analyzer reduces system profiling time by 75 %.

The 450TOC has the ability to print the measurement data for easy documentation and profiling on the spot. It can also simultaneously store data on a USB memory stick for retrieval at a later time. This feature allows comprehensive analysis and monitoring at a central data collection point in a process control room.

Key features of the 450TOC include

- Provides first results 80 % faster than traditional methods
- Simultaneous data log and print means profiling and troubleshooting can be achieved on the spot as well as at a central data collection and analysis location
- Rugged design and ease of access to internal assemblies leads to low and easy maintenance

Find out more at:

▶ **www.mt.com/toc**

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Safeguarding Water Purity
in Flat Panel Display Manufacture

Flat panel displays (FPDs) can be easily damaged during production if rinse waters are not extremely pure. On-line, monitoring of critical parameters provides real-time determination of water quality, preventing out-of-spec water reaching points of use.

Organic contamination must be avoided

During FPD manufacture, 90% of substrate damage is caused by organic contaminants in rinse waters. Controlling organics via total organic carbon (TOC) measurement plays a significant role in maintaining high yields in FPD production. In addition, cleaning, etching and stripping of substrates, the thin-film transistor (TFT) array, and the matrix require pH and conductivity measurements also to limit contamination.

The rinsing and cleaning processes for FPDs relies on TOC and dissolved oxygen measurements and, most importantly, resistivity as this parameter determines when the cleaning operation is complete based on rinse water purity. FPD and semiconductor facilities rely on precise resistivity, TOC, pH, and flow measurements to ensure ultrapure water (UPW) is always available for production of TFTs and substrate cleaning.

High rinse water quality is crucial

During the manufacturing process, wafers and other products etched in hydrofluoric acid (HF) baths must be rinsed with UPW before further processing. The initial rinse water will contain substantial amounts of HF while the final rinse water should approach ultrapure water purity levels. The final rinse water contains extremely low levels of contaminants, but the conductivity sensor required to measure water purity needs accurate temperature compensation to ensure consistent measurements, while also being able to withstand the initial HF acid conditions.

Conductivity sensors with monel electrodes are ideal for such applications. They will tolerate exposure to HF as well as contact with dilute rinse water.

Control pH to protect RO membranes

As different reverse osmosis membrane materials require specific pH ranges for correct operation, it is critical to accurately measure pH to avoid damaging this expensive capital equipment. Moreover, with the use of double-pass reverse osmosis or high efficiency reverse osmosis (HERO) systems, the pH of pure water must be measured very accurately, which can be a challenge for some pH sensor technologies.

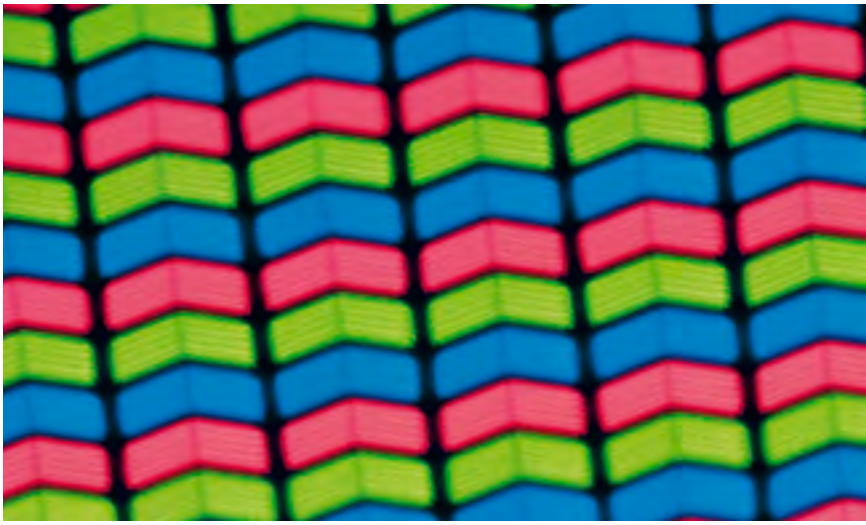
Measuring pH in a side-stream is a requirement for high purity water samples unless a highly pressurized electrolyte system is provided. For accurate and reliable measurements, a low pressure, low flow rate side-stream sample must pass through a grounded stainless steel housing to drain. It should also have a flowing junction reference electrode to ensure accurate measurements.

Maintain water purity levels to avoid being out-of-spec

METTLER TOLEDO Thornton's portfolio of sensor and transmitter systems will help you ensure water purity levels are maintained and eliminate out-of-spec situations in the FPD manufacturing process.

To find the right sensors for your applications, visit:

► **www.mt.com/pro-micro**



On-line Measurement Technologies
Improve Water Recycle / Reclaim / Reuse

As wafer size increases and circuit linewidth decreases, ultrapure water demand in fabs escalates. Questions regarding the viability of semiconductor manufacture in water-constrained countries are being answered with recycle / reclaim / reuse systems. On-line analytical measurements are central to system efficiency.

The growing requirement for water

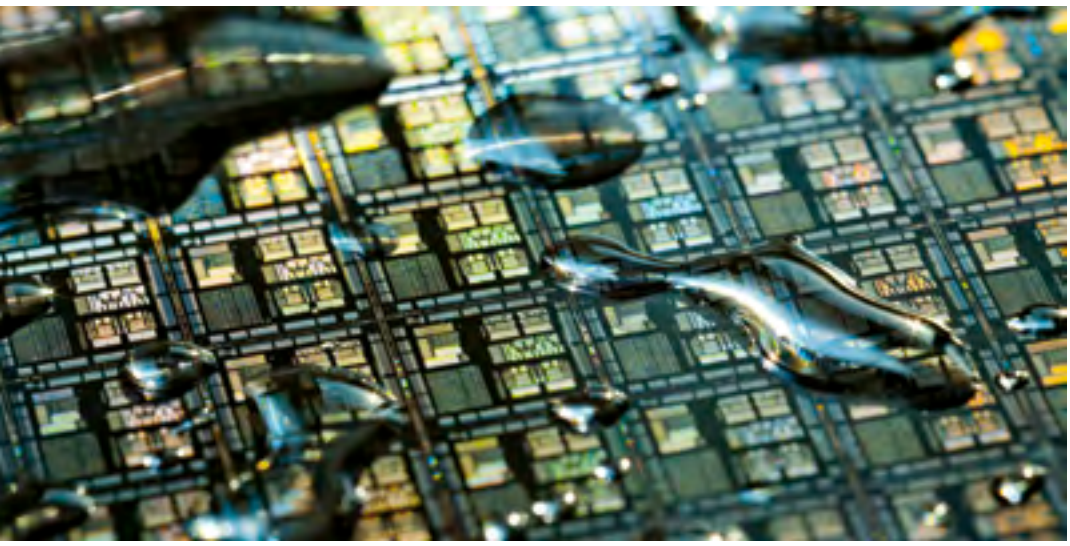
Semiconductor fabrication processes require a substantial volume of ultrapure water (UPW) plus considerable quantities of chemicals, to rinse and etch silicon wafers during processing. Combined, these liquids generate significant volumes of wastewater.

As the industry continues to expand and develop more advanced water dependent technologies, an even greater burden is being placed on limited water and sewer resources and local water support infrastructures. Each new fab or foundry will use 3,800 to 11,400 cubic meters of ultrapure water per day, solely for wafer processing. In addition, a reliable wastewater treatment and reclaim system is necessary to protect the environment and to conserve and reuse this highly valuable material.

Recycle / reclaim / reuse is becoming more important

In current locations with strained water resources, such as California, Taiwan, Singapore and Israel, serious questions are being raised about the long-term viability of semiconductor manufacturing. To try and counter these concerns, global corporations are implementing strategies to increase recycle / reclaim / reuse to over 80 %.

Modern techniques mean that it is now possible to achieve wastewater recycle / reclaim / reuse rates of up to 85 %. However, there exists a significant challenge in achieving these levels in the latest 300 mm and 450 mm wafer facilities where reduced linewidth technology demands higher volumes of UPW and process chemicals.



UPW is a costly material

Water conservation in the industry is not simply an environmental matter: production of UPW is very costly. For every USD 1 worth of water purchased by a semiconductor manufacturer, a further USD 20 is spent to bring it to UPW levels, and another USD 10 to treat it for discharge. It is therefore not surprising that recycle / reclaim / reuse is attracting increasing attention.

Analytical measurements are central to water management

In reclaim process systems, wastewater is segregated and dedicated to one of the following three recovery streams:

Recycle – Effluent discharged from a system or process is captured, treated (refurbished) and brought back to the same system or process.

Reclaim – Water that would normally go to waste is captured, reused or recycled.

Reuse – Effluent from a system or process is recovered, possibly treated, and then used for an alternative system or process.

In most fabs and foundries, streams from varying processes enter into the reclaim process system. As the streams combine, analytical sensors monitor the inlet quality, relying on the conductivity, pH, total organic carbon (TOC), and dissolved oxy-

5000TOCi Sensor

M800 Transmitter

gen (DO) measurement limits to divert the stream to the wastewater treatment plant or to the reclaim / recycle / reuse systems.

Historically, measurement and control of mixed waste streams utilized only conductivity, pH, and DO measurements. Facilities did not monitor TOC because of slow batch process measurement technologies or even less efficient off-line laboratory testing.

On-line TOC sensors complete the picture

Today, the METTLER TOLEDO Thornton 5000TOCi on-line TOC sensor, coupled with the multi-channel, multi-parameter M800 transmitter, is being utilized by semiconductor facilities globally to measure recycle / reclaim / reuse waters. The 5000TOCi's fast response, and continuous measurement and trending capabilities are providing swift, reliable, real-time TOC monitoring.

Real-time control saves processing costs as well as water

Microelectronics facilities are upgrading to the latest in analytical control technology to increase the volume of water recovered, to limit discharge, and to reduce processing costs for even greater efficiencies. In real-time control of the recycle / reclaim / reuse processes, METTLER TOLEDO Thornton's multi-parameter transmitters with conductivity, pH, DO, dissolved ozone and TOC sensors provide the accuracy and control technologies demanded by today's global microelectronics leaders.

Reasons for implementing an effective reclaim / reuse / recycle system:

- **Financial performance**
  Recycle / reclaim / reuse provides a positive return on investment. Ultrapure water used for semiconductor production is extremely expensive to produce. Recycling wastewaters to ultrapure water can cost less per liter than initial water purification steps.
- **Environmental performance**
  Water reuse and other green engineering technologies promote sustainability for the industry.
- **Community relationships**
  Recycle / reclaim / reuse demonstrates an awareness of the importance of water to the local community.

Find out more at:
► **www.mt.com/pro-micro**

Digital Sensors
Meet the Challenge of Resistivity Measurement

METTLER TOLEDO Thornton has once again advanced resistivity measurement technology and sensor calibration methods to optimize on-line detection of trace contamination in ultrapure water (UPW).

Increasing the value of resistivity sensors

Microelectronics UPW requirements continue to grow more and more demanding as linewidths of circuits are narrowed. This, in turn, is placing pressure on sensor manufacturers to increase the measurement capabilities of their instruments.

Conductivity / resistivity measurement has marginal sensitivity to detect trace impurities at levels that affect product yields in cutting-edge microelectronics manufacturing. Therefore, any improvement in accuracy significantly enhances the value of resistivity measurement. Described here are two recent developments that improve resistivity accuracy significantly: UniCond® sensors with Intelligent Sensor Management (ISM®) technology and direct sensor calibration to UPW.

Measurement issues with conventional analog sensors

With conventional analog resistivity instrumentation there are many variables in every installation, including signal wiring distance between sensor and transmitter, cable routing, and slight differences among transmitter measuring circuits for both resistivity and temperature. These factors all differ between factory calibration and the performance of equipment after installation, and each factor can contribute a small amount to the uncertainty of measurement.

This can sometimes be improved by a "system" calibration where the installed sensor, cable, and transmitter are calibrated as a complete system. However, this is cumbersome and time-consuming as temperature standards and trustworthy conductivity standards have to be made available on site.

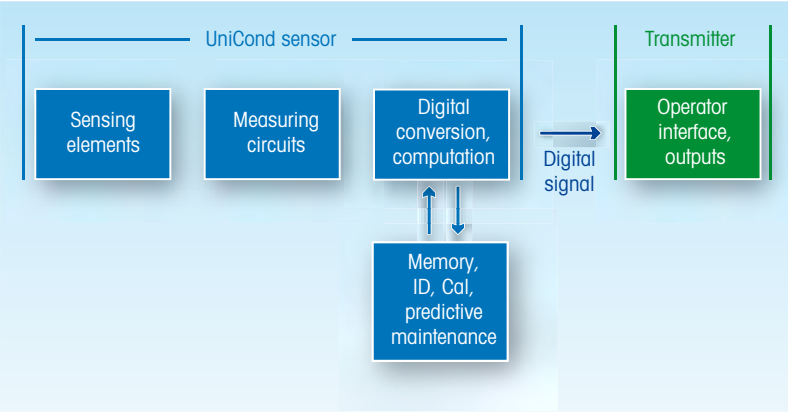


Figure 1 – UniCond sensor configuration

ISM technology removes sources of error

The introduction of self-contained measuring circuits within the new UniCond ISM conductivity / resistivity sensors eliminates all of the above sources of error. The resistivity and temperature sensing elements of UniCond sensors are inseparable from their respective measuring circuits and their calibration memory. The measuring circuits and all analog wiring are now extremely compact, fixed, and sealed within the sensor body. The factory calibration of the total measurement system is unaltered after installation, so factory accuracy can always be attained in the field. Even over long cables there is no degradation of the robust digital signal.

Figure 1 illustrates the configuration of a UniCond sensor. This contrasts with a conventional analog sensor which contains only the left-most block (sensing elements), with everything else located in the transmitter, and with analog signals passing between the sensor and transmitter. The UniCond sensor contains all measurement, digital conversion, and memory circuits and sends only a robust digital signal to the transmitter.

With the calibration data stored in the sensor memory there is no chance of errors when manually entering data into the transmitter or in swapping sensors without changing calibration factors. The sensor can only use its own calibration data for

measurement. Figure 2 shows a cut-away view of a UniCond sensor with its internal circuits visible.

Enhanced sensor calibration

To take full advantage of the improvements available with UniCond sensors, the factory sensor calibration system at METTLER TOLEDO Thornton has also been improved. In the past, our production UPW loop had shown excellent reliability in maintaining water purity. In fact, it was determined to be more consistent than the process of transferring calibration through laboratory sensors from ASTM standards.

Instead of performing the calibration of production sensors by comparison to laboratory sensors, Thornton production sensors are calibrated directly to UPW, which is a more stable standard. The water purity is verified by laboratory sensors which are calibrated to ASTM standards, so there is traceability to ASTM standards but the ultimate standard is the fundamental resistivity of UPW.

Experience with this procedure shows a consistent improvement in accuracy. UPW provides a standard with very tight tolerance – resistivity cannot go above 18.18 MΩ-cm, the maximum resistivity of water at 25 °C.

Conclusion

Further progress is available in resistivity measurement through better calibration capability using UPW as the standard coupled with digital sensor technology which ensures this accuracy will be delivered in a user's water system. These are two major steps toward meeting the on-line trace contaminant sensitivity needed in microelectronics manufacturing.

For your most critical measurements, an upgrade to UniCond sensors calibrated to UPW as the standard can enhance your capability for early detection of contamination to protect your manufacturing operations.

Find out more at:

► **www.mt.com/UniCond**

Figure 2 – UniCond conductivity sensor with cut-away view of internal measuring, digital conversion and memory circuits

Figure 3 – Automated conductivity / resistivity sensor calibration facility

New Standards for Ultrapure Water in the Microelectronics Industry

Guidelines for semiconductor manufacturing have changed: Reduced linewidths in modern fabs has lowered acceptable levels of contaminants. Monitoring ultrapure water requires instruments with greater capabilities than ever before.

Committees for semiconductor manufacturers

The International Technology Roadmap for Semiconductors (ITRS) is an evolving guideline which establishes future semiconductor industry goals and is sponsored by the world's leading semiconductor organizations. The ITRS committee consists of experts from the corporations that produce integrated circuits (ICs) and the suppliers of test equipment and components for the industry.

The objective of the ITRS is to ensure cost-effective advancements in the performance of ICs and the products that employ such devices, thereby continuing the health and success of the industry. The experts are chartered with the identification of possible risks and to propose potential solutions, encourage innovation, and to assist in the future of semiconductor manufacturing. ITRS works with other microelectronics industries (electronics, photovoltaic, and nanotechnology), so the effort is comprehensive and covers the spectrum of needs for research capabilities and product development.

In conjunction and cooperation with the ITRS committee, there is a semiconductor technical committee known as SEMI (Semiconductor Equipment and Materials International). This group includes manufacturers of equipment and materials used in semiconductor production, and is the clearinghouse for the generation of standards and guidelines. It also provides documentation for sustainable system design and operation which incorporates risk information generated by the ITRS.

Why revise the industry standards?

The transition to larger wafers (300 mm and 450 mm diameter) combined with reduced linewidths (currently at 14 nm and will be dropping to 7 nm), increases the need for stringent ultrapure water (UPW) requirements. Unlike the pharmaceutical industry, the standards in the microelectronics industry are not enforceable legal regulations but rather recommendations that microelectronics companies follow to produce high quality ICs.

For new larger wafers with tighter linewidths, the committee recommended that further definition of organics were required and therefore the new standards are as follows: critical organics < 1 ppb (non-volatile, boiling point > 200 °C), total organics < 3 ppb. Immersion photolithography is the one exception to this change and they still have a requirement of a TOC level < 1 ppb.

Resistivity and bacteria have recently been removed from the list of ITRS standards, and the TOC requirements have been split into two categories: critical and non-critical organics. The removal of resistivity and bacteria from the standards was based on the assumption that all of today's UPW systems meet or exceed these requirements. The UPW system fabricators objected to this change because resistivity and conductivity are critical measurements for monitoring and controlling the performance of a UPW system.

Flexible M800 Transmitter with iMonitor diagnostics utlity

Efficient monitoring of UPW systems necessitates a range of on-line analytical sensors. Multi-parameter, multi-channel transmitters streamline the monitoring task, and reduce training requirements.

A single METTLER TOLEDO Thornton M800 Transmitter provides inputs for analytical (resistivity / conductivity, pH,

M800 Transmitter

dissolved oxygen, TOC, O_3) as well as physical parameters (flow and temperature).

The M800 and associated Intelligent Sensor Management (ISM®) digital sensors, brings together a highly intuitive user interface, expanded measurement parameters and, most significantly, diagnostic maintenance capabilities. ISM sensors automatically communicate their identity, diagnostics, and calibration data to the M800 as soon as they are connected, significantly simplifying sensor handling.

Monitoring and control of TOC for today's semiconductor facility

UPW production requires the monitoring of organic contamination throughout the treatment process. The ITRS Roadmap indicates that TOC levels should be < 1 ppb for immersion photolithography and < 3 ppb for total TOC in the UPW system.

The new Thornton 5000TOCi sensor provides continuous, fast, and reliable monitoring of TOC levels to sub-ppb levels. ISM technology provides advanced sensor status and diagnostics data, turning reactive maintenance into proactive support. With on-line measurements that are both fast and continuous, the 5000TOCi and M800 system ensures TOC excursions will not be missed.

The importance of minimizing silica in UPW

Silica is the most prevalent element on earth and is in all water supplies. The presence of silica in UPW is largely responsible for water spot formation on silicon wafers. Silica dissolution during rinsing steps can add to the silica content in process baths, aggravating the problem. Water spots on ICs lead to reduced adhesion, poor contact resistance, compromised circuits, and other quality problems. Therefore, it is important that the silica content of UPW is monitored and minimized and any excursion identified immediately.

The removal of silica requires membrane separation with RO and / or ion exchange for its removal. Direct continuous silica measurement is the most effective means to detect the early exhaustion stages of anion resin and prevent silica contamination in the process water.

The METTLER TOLEDO Thornton 2800Si Silica Analyzer is an on-line instrument designed specifically for UPW treatment. The analyzer provides early detection of trace silica contamination with minimal operator supervision.

Expertise in water purity

METTLER TOLEDO Thornton is recognized globally as the leader in UPW measurements for semiconductor and microelectronics processing. Monitoring water purity helps guarantee that no contaminants endanger the final product, ensuring higher yield, faster cycle times, and improved economics of operation. Thornton instruments for resistivity / conductivity, TOC, pH, ORP, dissolved oxygen, silica, sodium, and dissolved ozone are specified in microelectronics manufacturing facilities worldwide to monitor and control critical UPW systems.

Find out more at:

► **www.mt.com/pro-micro**

2800Si Silica Analyzer

Confidence in Ultrapure Water Systems
with a Pure Water Optical DO Sensor

Eliminating silica oxidation at the surface of a wafer is vitally important in some areas of semiconductor manufacturing. The Pure Water Optical Dissolved Oxygen Sensor with Intelligent Sensor Management (ISM®) technology provides fast response, high accuracy, and increased stability in demanding low ppb-level ultrapure water applications.

Traditionally, dissolved oxygen (DO) measurement has been achieved using amperometric sensors. Although these measure accurately they often respond slowly to changes in DO and require frequent, time consuming maintenance.

The Pure Water Optical DO Sensor provides outstanding measurement performance with low detection limit, the fastest response available and minimal drift, and therefore significantly improves oxygen monitoring.

METTLER TOLEDO's proprietary OptoCap sensing element provides very accurate oxygen determination and easy maintenance without electrolyte handling. Additionally, the OptoCap eliminates the need for polarization, making the measurement system quickly available and reducing downtime.

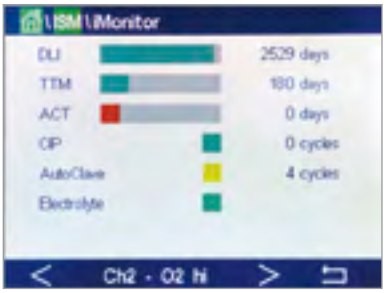
ISM simplifies sensor handling and provides diagnostic tools that predict the need for sensor maintenance before measurements are affected.

Find out more at:
▶ **www.mt.com/opticalDO**

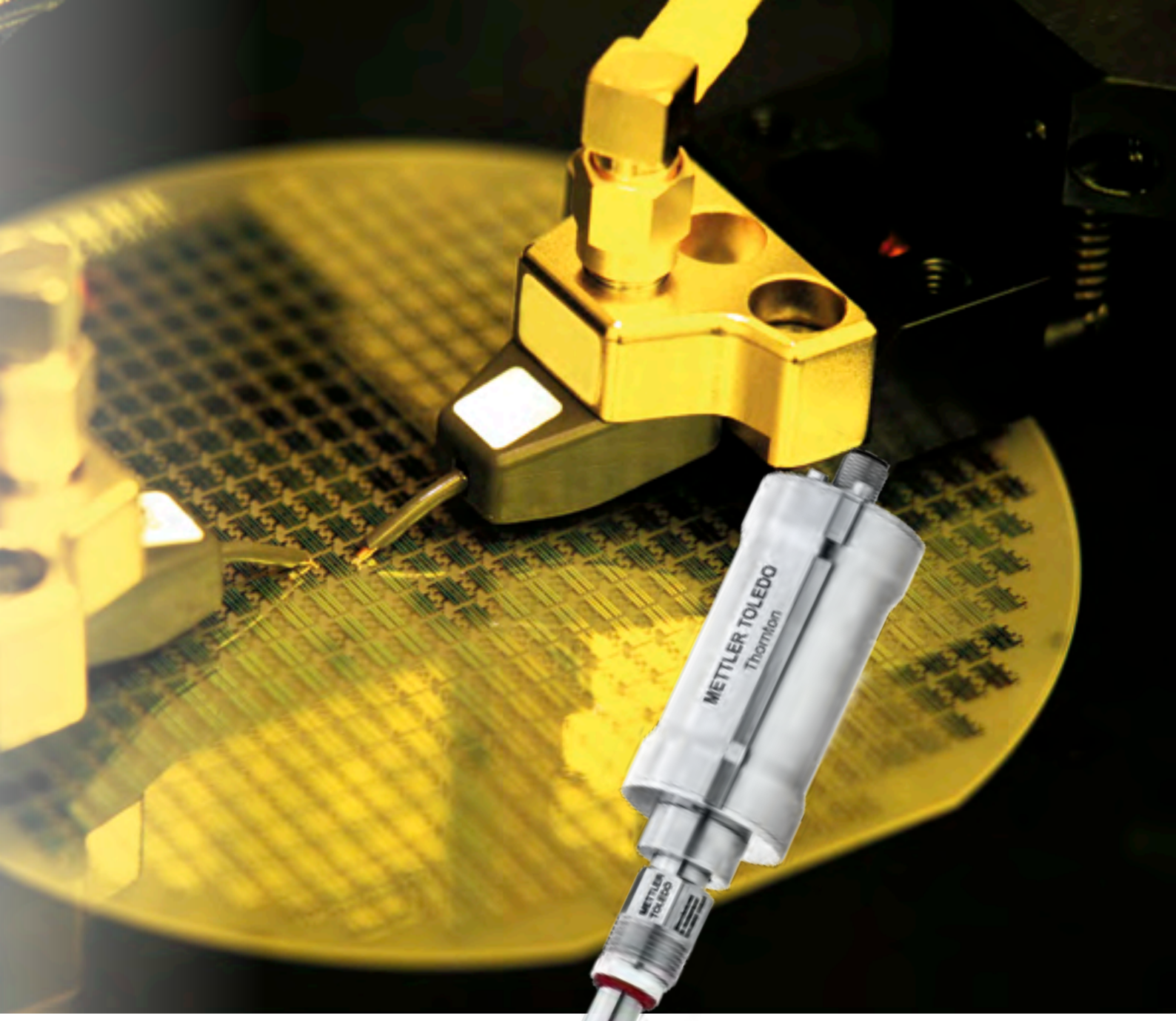
Your benefits

Fastest response
METTLER TOLEDO's proprietary Optical DO technology delivers the fastest response available providing confidence in the integrity of your ultrapure water system and equipment.

Reduced maintenance
No electrolyte or polarization eliminates the need for frequent, time consuming service.



Intelligent Sensor Management
ISM provides simple sensor handling, and predictive diagnostics for proactive maintenance.



Pure Water Optical DO Sensor

ISM

Get in-line with METTLER TOLEDO

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Microelectronics Competence Center

METTLER TOLEDO Thornton is dedicated to continuous improvement in producing instruments for the detection of impurities in microelectronics facility water systems. Our online resource keeps you informed as to our latest developments in monitoring and measuring pure water.

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