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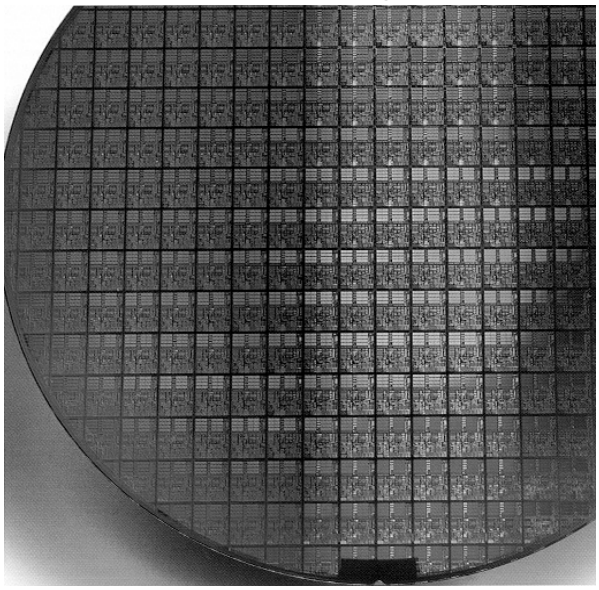
Application Bulletin

The impact of TOC in UPW systems for the Electronics Industry



"Water, water everywhere...Nor a drop that's pure".

Water is the most common reagent used by mankind. Ultrapure water is the most voracious and aggressive solvent employed by the Electronics industry in the cleaning and production of wafers.

During the past four decades the electronics industry has exponentially increased the number of circuits that are etched onto silicon chips. The increase in the number of circuits has significantly decreased the line-widths. Thereby, increasing by magnitudes the requirements for accurate and continuous measurement of the UPW system.

Semiconductor manufacturing processes have some of the most stringent specifications for ionic and organic contamination in pure and Ultrapure water systems. Managing and measuring these contaminants in their UPW systems has enabled semiconductor manufacturers to improve product quality and maximize yields. Advances in water purification technology and innovations in instrumentation for monitoring these contaminants have played a significant role in improving and measuring the quality of Ultrapure water. These advances, in turn, have driven lower specifications for all contaminant levels in UPW systems.

Total organic carbon (TOC) analysis is a powerful technique for monitoring organic contaminants in Ultrapure water and the 'health' of the UPW system. Over the past few decades, specifications for TOC have decreased by several orders of magnitude, resulting in specifications in the low-parts-per-billion range and moving to the parts-per-trillion detection level. As future-generation chip technology is projected to reach narrower line-widths, the semiconductor manufacturers continue to demand their Ultrapure water not only contains ever-lower levels of organic and ionic contamination, but the instrumentation is capable of accurate and fast detection and response.

Organic Sources in Water Systems

The major source of organics is the make-up water. Surface waters have higher levels of naturally occurring organics than ground waters. But ground water sources are being depleted in many areas. As a result, there is greater reliance on surface water, reclaimed water and even municipal wastewater as the raw water source. A further complication is that surface water sources typically have significant seasonal variations

in concentration and types of organics. A treatment system that produces water with low organics during one season may be seriously challenged in another season.

Even greater changes in source water composition impact a treatment system if it must alternate between surface water high in organics during wet seasons and ground water high in minerals in dry periods. There are a number of unit operations that can reduce organics in make-up water including improved flocculation, membrane processes, final oxidation, and others. Treatment must be tailored for the specific water composition and site conditions.

The second most important source of organics is from ion exchange resins in the treatment system. They are, after all, beads made of organic polymers. Resin fines from physical breakdown can find their way into process if they are not removed via properly sized filtration. Chemical breakdown of resins can produce trace contaminants: Sulfonic acids from Cation resins and amines from anion resins. In addition, traces of processing solvents may also be released. These contaminants may include inorganic constituents in their structure such as chloride and sulfates. Additional sources of organic contamination are directly in the process and distribution system, including pump lubricants, pump seals, polishing resins, and system dead legs.

Contaminant Detection

Conductivity is the common and economical measurement for detection of ionic contaminants—usually minerals and ionic salts. Conductivity will detect organic acids and bases but is insensitive to the majority of organic contaminants. For this reason, total organic carbon (TOC) analyzers oxidize organics to a completely oxidized, ionic form as carbonic acid in order to detect them by conductivity. The delta in conductivity before and after oxidation gives a measure of the difference in conductivity readings and a TOC measurement is provided.

On-Line TOC by UV Oxidation/Conductivity

- $C_xH_yO_z \xrightarrow{UV} CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

  - Hg lamp emits **185 nm** and **254 nm** UV light
  - Light, chemicals, surfaces, and time move the reaction forward
  - Accurate conversion of temperature and conductivity is required

Monitoring the TOC in the UPW system after the deionization stage is an important checkpoint for organics to prevent them from entering the polishing and distribution loop. Additional measurements upstream and downstream can help diagnose where the organics are breaking through, e.g. whether it is a reverse osmosis membrane failure or ion exchange resin deterioration or a pump failure. Further measurement in the distribution loop reduces the risk of organic contamination in the production process.

Ultrapure water is usually produced by the multistage treatment of a potable water supply. Organic compounds in the feedwater are both naturally occurring and synthetic. The former are mainly a complex mixture of Fulvic and humic acids and tannins derived from the decomposition of leaves and grasses or from peat or marsh areas. In addition, there are bacteria, other living creatures, and their by-products. Sources of synthetic compounds include industrial waste and domestic waste such as detergents, solvents, and oils, together with agrochemicals such as fertilizers, herbicides, and pesticides.

Since the water is treated to make it suitable for domestic or industrial use, many of the impurities are removed but others are introduced, for example, plasticizers from plastic pipes and tanks. Other compounds are generated by reactions with treatment chemicals such as chlorine and ozone. During treatment of the feedwater to produce Ultrapure water, organic compounds are removed by a combination of some or all of the following techniques: reverse osmosis, micro-filtration, ion exchange, absorption, and UV photo-oxidation. These remove the majority of contaminants, leaving small amounts of a wide variety of impurities.

Measurement of TOC in UPW systems

Microbial contamination can result in the loss of millions of dollars in defective wafers and chips. While a direct correlation between organics in the water system and microbial contamination is difficult, organic levels are a significant indicator of the 'health' of the water system. Organics provide a food source for any bacteria that may exist in the distribution system, storage tanks, and the process technology or treatment modules. Accurate, fast and convenient measurement of the organic level in a UPW system can save millions of dollars in lost product.

The new 5000TOC sensor and 550TOC analyzer provide the performance needed to meet these requirements, while offering the added benefits of continuous online measurement in a low-maintenance, industrial package with proven Multi-Parameter technology. The 5000TOC sensor interfaces directly with the 770MAX instrument, which provides additional measurement parameter capability. The 770MAX is the 'gold measurement standard' for the electronics industry and the 5000TOC sensor increases the significance of this Multi-Parameter platform.

TOC testing has been a standard for the Semiconductor industry for many years but because of the cost and inconvenience of some analyzers it was employed in only a limited number of points on the UPW skid and distribution loop. The 5000TOC sensor and 770MAX multi-parameter instrument package make multiple testing points not only economical but outstanding investments for risk reduction and improved yields.

Using the 5000TOC sensor throughout the UPW skid to monitor the integrity of reverse osmosis membranes, the effectiveness of TOC destruct UV lamps, resin bed performance and organics shedding is a cost-effective way to improve the performance of the UPW pad.

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Pure and Ultrapure water production requires the monitoring of organic contamination throughout the treatment process. The 5000TOC sensor provides continuous, fast, and reliable monitoring of TOC levels from post RO waters to point-of-use. With continuous on-line measurements, the 5000TOC sensor ensures TOC excursions will not be missed.

The Thornton 5000TOC Sensor with 770MAX Multiparameter Instrument provides an ideal and economical analytical package. The 770MAX can accept 3 other analytical sensors in addition to TOC, including conductivity, pH, ORP or dissolved oxygen, plus pressure, tank level or two flow sensors. The 770MAX can also interface with two 5000TOC sensors, leaving two additional smart channels for conductivity, pH or DO measurement and two pulsed flow channels are also available. See Thornton data sheets ML0067 for more information on the 770MAX Instrument and ML0103 for more information on the 5000TOC Sensor.

Mettler-Toledo Thornton, Inc.
36 Middlesex Turnpike
Bedford, MA 01730 USA
Tel: +1-781-301-8600
Toll-Free: 1-800-510-PURE

Customer/Technical Service
Tel: +1-781-301-8690
Toll-Free: 1-800-642-4418
Cust Service Fax: +1-781-271-0214
Tech Service Fax: +1-781-271-0675

info@thorntoninc.com
www.thorntoninc.com

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