xylem

Xylem microelectronics technology suite

Supporting Point of Use systems for critical tools and development of next generation technologies

The technology suite

Xylem is committed to the semiconductor industry and has made significant investments to support the current and future developmental needs of the industry. Xylem's 1,700+ square foot suite was constructed with the purpose of demonstrating our Vanox® POU system – patented advanced oxidation process for point of use applications – for geometries of < 28 nm and development of new technologies for meeting the next generation geometries of < 10 nm. In addition, the suite enhances the existing quality assurance program and development of ion exchange resins for the semiconductor industry utilizing the ultrapure water produced by the POU system.The Vanox POU system was developed to meet the demanding TOC, particle, oxygen, pressure and temperature control requirements of immersion lithography tools at the point of use.

At the heart of the POU system is our patented advanced oxidation process which dynamically responds to changes in feed water TOC levels, adjusts operating parameters, and delivers consistently low TOC product water. This dynamic response can be seen in Figure 1 which shows how the POU system responded to a sudden increase in IPA and kept theTOC level in the product water below the specification of one ppb. Table 1 shows the minimum and typical performance of the Vanox POU system compared to the ITRS (International Technology Roadmap for Semiconductors) guidelines.

TOC injection station

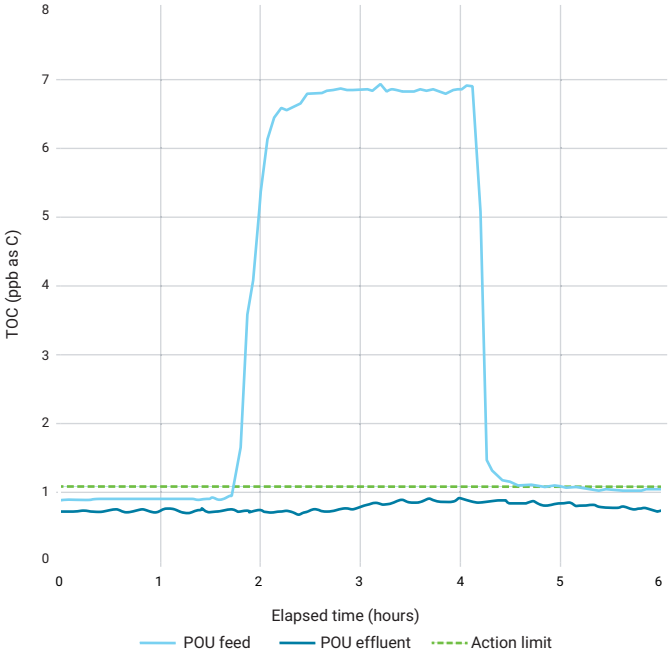
50 nanometer and 10 nanometer particle analyzers

Table 1 - Vanox® POU system performance 15-35 gpm consumption, 60-100 gpm loop

Parameter	ITRS (<28nm)	Vanox minimum performance*	Typical range
TOC	<1 ppb	<1 ppb	0.3 - 0.5 ppb
Metals	<1 ppt	<1 ppt	<1 ppt
Temperature	–	+/- 0.1 ˚C	+/- 0.04 ˚C
Particles	<200 cts/L @ critical size	<100 cts/L @ 0.05 micron	50 cts/L
Dissolved oxygen	<10 ppb	2 - 3 ppb	0.2 - 0.4 ppb
Total silica	<0.3 ppb	<0.1 ppb (reactive)	<0.1 ppb
Dissolved nitrogen	–	1,000 - 3,000 ppb	less than 1,000 ppb
Pressure	–	+/- 0.5 psi (0.034 bar)	+/- 0.5 psi (0.034 bar)

* Actual performance based on feed water levels

Figure 1 - Vanox® POU system demonstration IPA challenge



Demonstration of the TOC reduction is easily accomplished and validated by injecting controlled amounts of organic species into the Vanox POU system feed water. On-line TOC measurements of the both feed water and product water are monitored and recorded. Graphs, such as that in Figure 1, are produced to prove the effectiveness of the POU system's dynamic response in removing TOC to a consistently low level with varying TOC concentrations in the feed water.

Process analytical instrumentation employed to support technology development includes; TOC, nonvolatile residue, and boron. These analyzers are commonly used by top-tier semiconductor companies for reliability, accuracy and consistency in measurement.

Xylem's technology suite employs both the 50 and 10 nm particle analyzers as shown. The 10 nm particle analyzer is used to develop new particle removal technologies to support ITRS needs for sub 10 nm geometries.

Figure 2 - Vanox® system AOP process overview

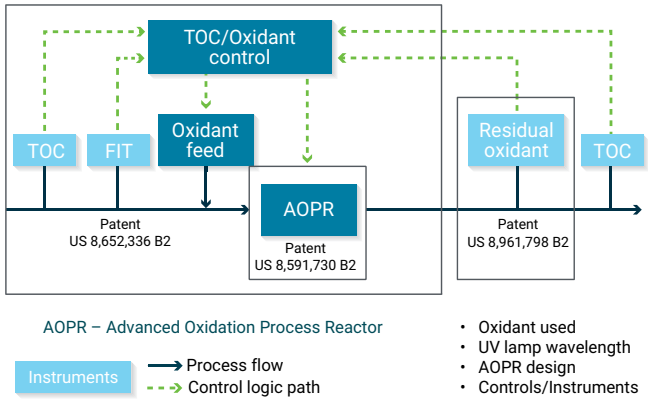
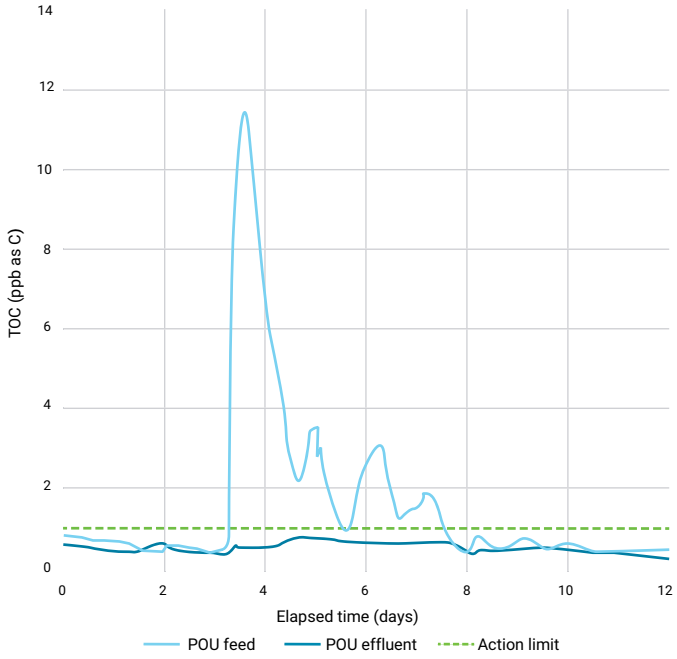


Figure 3 - POU system actual operating data - urea event



TOC reduction

The semiconductor industry has a need to reduce TOCs to a consistently stable low level. Normally this level is < 1 ppb although some are driving to <0.5 ppb because of certain critical tool requirements. Xylem has developed a patented AOP process and supporting technologies to meet this need.

The patented process as illustrated in Figure 2, monitors the inlet TOC and flow. Based on the inlet mass volume of the TOC, a specific amount of oxidant is fed in along with a specific UV dosage to create an oxidizing radical. In addition to this patented technology for monitoring the effluent residual oxidant to protect downstream equipment, the reactor design and lamp was optimized for the process.

The graph in Figure 3 represents the performance of the Vanox System's AOP process on reducing a difficult to remove TOC in a real semiconductor application. The light blue curve represents a real life TOC elevation in the UPW water normally feeding the tools over a four day period. It was well documented that the elevations were urea related. The dark blue curve represents the TOC levels out of the Vanox POU system with AOP integrated into the equipment. The dashed line represents the one ppb guarantee point.

Key points about this equipment other than reliably removing difficult TOCs that the rest of the UPW system was unable to address are:

- the process is very dynamic in that it will adjust as required to the varying feed water quality
- this maintains a constant nearly flat line water quality to the tools.

Vanox® AOP reactor under construction

AOP reactor within the Vanox® POU system

Table 2 - Organic species effectively removed by Xylem's advanced oxidation process

Organic	Tested levels (ppb as C)	Vanox minimum performance* (g/mol)	Boiling point	Polar	Uses
Atrazine	5 - 25	215.68	200	+	Herbicide
Carbaryl	5 - 29	201.22	315	+	Insecticide
Chloroform	5 - 29	119.38	61	–	Chlorine disinfection by-product from contact with NOM
Dioxane	5 - 295	88.11	101.1		Stabilizer, solvent
Formic acid	5 - 30	46.03	101	+	Naturally occurring due to forest emissions, used in the food chain as a preservative, dye industry,cleaning products, etc.
Humic acid	5 - 33	4,000*	--	–	NOM (decaying plant debris)
IPA	5 - 1,000	60.1	83	+	Common organic used in semiconductor fabs that periodically accidentally gets introduced into the UPW supply
Starch	5 - 33	162.07	--	–	Bacterial by-product found in feed water
Tryptophan	5 - 29	204.23	--	+	Amino acid, food supplement
Urea	5 - 30	60.6	--	+	Found in most surface waters to varying degrees depending on geographical locations and agricultural activity

Whether the application is to support POU for low TOC at < 50 gpm or treat the full UPW water to 150-4,000+ gpm, Vanox AOP equipment is available to support the need.

As pointed out in the Table 2 above many organics have been successfully tested for reduction to suitable TOC levels. Some of the organics tested was to validate the process is not TOC specific. If the RO starts to degrade allowing other organics to leak through, it has been demonstrated that Vanox AOP equipment can remove other feed water organics together with manmade organics.

To date when Vanox AOP equipment is used in the process, each of the specific THM's level was found to be below detection level of 50 ppt in the effluent. In addition, IPA was found to be readily removed making it feasible to protect the UPW process from any reclaim excursions from IPA and or to act as a TOC polisher in reclaim applications.

50 nm and 10 nm particle analyzers

Figure 4 - POU demo effluent particle history 50 - 100 nm

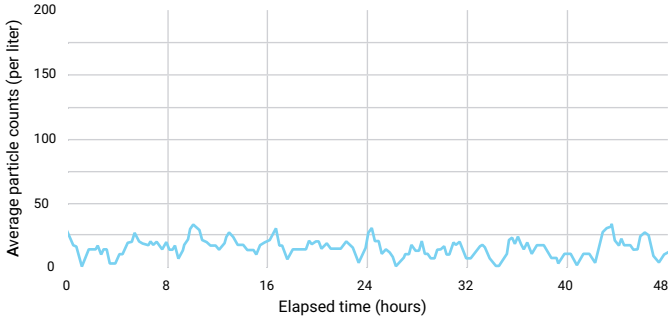
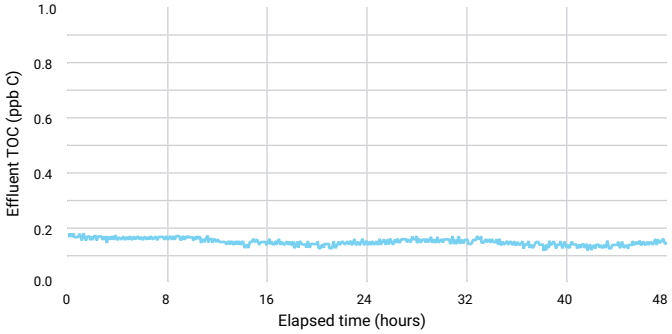


Figure 5 - POU demo effluent TOC history



Particles

Particles in water are an ongoing concern and recently has migrated to a significant issue as the semiconductor industry migrates to sub 10 nm geometries as published by ITRS. There is significant data and technology supporting 20 nm and above using 50 nm particle analyzers. Figure 4 illustrates the POU demo in the technology suite operating well below the 100 cts/L at 50-100 nm guaranteed with the Vanox POU system and exceeds the published ITRS data for 20 nm and above technology.

The recent development of particle analyzers able to measure particles to below 50 nm has created an awareness of significantly higher particle levels in lower particle sizes. Xylem's technology suite employs a conventional 50 nm particle analyzer (picture, left analyzer) and a new 10 nm particle analyzer (picture, right analyzer).

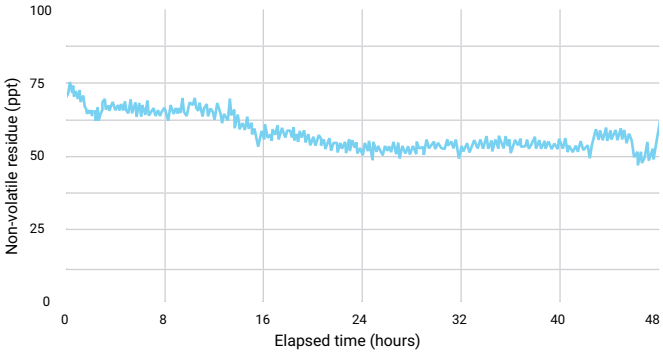
The combined use of the two analyzers allows:

- Review of data for any correlation
- Establish guidelines for existing Vanox POU system demo capability for supporting sub 10 nm geometries
- Development of new technologies for particle reduction with a 10 nm particle analyzer that will also be used to guarantee and monitor provided systems
- Could lead to upgrading of existing Vanox POU system platforms for lower particle levels

Vanox® POU system

Hot Water Conditioning (HWC) cart

Figure 6 - POU demo effluent non-volatile residue history



An important aspect of the particle development work is the technology suite utilizes UPW feeding from the Rockford Laboratory UPW system that closely resembles the quality from existing semiconductor fabs with particles in the level of <500-1,000 cts/L at 50 nm and TOCs typically below 1 ppb as C with TOC being reduced to below 0.5 ppb as C shown in Figure 5. Because of this, the particles present closely represent real particles as compared to injected silica or gold particles for challenging the system. Therefore the data obtained will lead to technologies supporting near real semiconductor operations.

Non-volatile residue (Figure 6) is periodically monitored as the industry is becoming more aware of the importance of this parameter for monitoring the health of the UPW system and for trouble shooting.

Hot water conditioning

The UF is supplied with a rental HWC (Hot Water Conditioning) cart that provides:

- Quick rinse up on residue
- Quick rinse up on particles
- Extends the UF module life to an expected ten years thereby reducing cost of ownership to the customer

The actual benefit of the process is utilizing expansion and contraction of the material to allow the “loosened” particles to be removed by a rinsing action and not by the HWC process itself. Therefore, it aids in particle rinse up. Also, by using hot water, it hastens the rinse up process by leaching out the surface contaminants at a faster rate than under ambient conditions. The process is designed to be gentle on the UF fibers during this more sensitive condition.

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1) the tissue in plants that brings water and nutrients upward from the roots.

2) a leading global water solutions company.

Xylem is a leading global water solutions company dedicated to advancing sustainable impact and empowering the people who make water work every day. Xylem connects diverse capabilities and innovative technologies to provide tailored solutions across the entire water cycle. From moving, treating and measuring water to optimizing and maintaining water systems, Xylem collaborates with customers to solve their most critical challenges. Together, through partnerships with utilities, industrial manufacturers, building operators, and communities, we are building a more water-secure world.

For more information on how Xylem can help you, visit xylem.com.

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