END-USER PERSPECTIVES

ON Semiconductor outlines challenges for tough new discharge regulations

The microelectronics giant is contending with new wastewater regulations around copper and fluoride, affecting its treatment processes in various parts of the globe. GWI finds out the opportunities on offer to both meet these standards and enable more reuse.

Headquartered in Phoenix, Arizona, USA, ON Semiconductor is a leading supplier of semiconductor-based solutions, and has been manufacturing cutting-edge solutions for industries such as automotive, communications, computing, consumer, industrial, medical, aerospace and defence applications for over 20 years.

The company has around 34,000 employees worldwide, and operates 22 manufacturing facilities across North America, Europe, and Asia. Around half of these sites are high-tech wafer fabrication operations (fabs), and half are assembly and test organisations (ATOs) where the wafers are cut, assembled into the final product, and tested before being shipped to the customer. As a business that has grown substantially through mergers and acquisitions, ON Semiconductor's manufacturing facilities can vary greatly in terms of their processes, technology requirements, and water treatment systems.

In 2016 the company set a water sustainability target of reducing normalised water consumption at their operations by 5% by 2020. They easily exceeded that goal, managing to reduce water consumption by 17.3% at their wafer fabs, and by 10.5% at their ATOs – in part through water reclamation systems and process optimisation.

GWI talks to Brad Herbert, part of ON Semiconductor's Global Facilities team, about the challenges of overseeing process water and wastewater treatment at the company's sites across the globe, as well as the opportunities that have arisen from having such a varied facilities network. ■

ON Semiconductor

Answered by: Brad Herbert, Global Facilities Team

What are your main sources for process water?

Our process water source can vary based on location, but generally it is provided by the municipality. At our locations in industrial parks, they often supply water that has had some sort of pretreatment.

Our Gresham, Oregon, fab site receives water from the City of Gresham and Portland Water Bureau, which is fed by the Bull Run Reservoir. It's one of the cleanest surface water sources in the country, in terms of conductivity. There's a challenge we've encountered, however, because the city of Gresham and Portland Water Bureau supplement this reservoir water with well water. The blend ratio is dependent on seasons, as well as some other factors, and can vary anywhere from 100% surface water to 100% well water – as occasionally happens if the reservoir is shut down due to contamination or pipeline issues. While the surface water is low conductivity and fairly low in silica, the well water is high conductivity and high in silica, and we always have to be prepared to adjust our treatment strategies based on the type of water we receive from the city at any given time.

What is water used for in your production process?

At our fabs, we use ultrapure water (UPW) in our processes. It's pretty traditional ultra-high purity water – 18 megohm-cm, low total organic carbon (TOC), low silica, low particles – and is used mainly for typical fab processes like wet benches and the chemical-mechanical polishing process with high-purity requirements. The water used in direct processes at our assembly and test organisations (ATOs) is not what we would consider to be ultrapure water, it's more like deionised or reverse osmosis deionised water. It's typically 14-16 megohm-cm, and there isn't as much concern about TOC, silica or particles as it used mainly in our plating operations and sawing processes. A lot of process water on our ATO side is used by the saws that cut up the wafers and the final packages, and by back grinders. Around two-thirds of the water consumed at our sites is used in production processes, where water comes into direct contact with the wafer. The other third is for domestic and industrial uses, such as exhaust scrubbers, cooling towers, boiler feed, humidification, and other indirect operations.

How do you treat your process water?

No two sites are the same, so the ▶

GLOBAL VIEW

Brad Herbert has to deal with many different water challenges at ON Semiconductor's facilities.

Source ON Semix

> "All of our facilities use an RO in their process, that is the heart of every system, but they are all configured in slightly different ways.
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ON Semiconductor's facility at Gresham in Oregon is one of the company's primary fabs.

approach to treating process water varies across our operations. Typically, most sites have a pretreatment system that is optimised for their specific water source and usually involves traditional technology such as multimedia filters, carbon filters and cartridge filters. Often this pretreatment will include a coagulant or pH adjustment, or maybe an anti-scalant before the RO, but that's site-specific. All of our facilities use an RO in their process, that's the heart of every system, but they are all configured in slightly different ways.

Our preference is to use two-pass RO, though some sites have single-pass. Each site runs them a little bit differently, and they are tailored to the facility's system requirements and the availability of resources and labour there, as well as any cost and water-use goals. For instance, some sites run the RO membranes to failure and then replace them, some sites clean their RO membranes in place, others pull them and send them out for cleaning. Our operations can vary greatly across the board, but the one commonality is that RO is definitely part of the treatment process.

Usually, after the RO stage there's a primary treatment system using ion exchange and UV, or sometimes de-gas. We have several different ways of managing the ion exchange at this point, and each facility makes the technology and process choices that work best for them. Some sites use EDI and others use resin that is regenerated either in-place, or off-site using portable vessels. There are operational challenges that come with in-situ resin regeneration, such as managing the chemicals, and some sites prefer to ship the vessels out to a vendor for regeneration. Whether a site chooses to use EDI is dependent upon their equipment and maintenance capabilities. EDI also seems to be a little less robust, as far as upsets go – it's harder to recover an EDI, but if you have resin and there's an upset, you can change out the resin fairly quickly.

How do you treat your wastewater? Can you walk us through the wastewater treatment process at one of your plants?

As with our process water, there's no real standardised plan of record for how we treat our wastewater – it varies from site to site depending on the different process needs, as well as regional wastewater discharge requirements. To give an example of one of our wastewater treatment processes, at our Gresham facility we have a fluoride treatment system. The spent process water is first collected in a large equalisation tank as there is a lot of variation in load when we have bath dumps or quartz cleaners and we try to flatten out those spikes. Then we add calcium chloride as the water goes through a series of reaction tanks, raising the pH ▶

KEY FIGURES

Annual revenue	$5.52 billion (2019)
Annual production	75.7 billion units (2018)
Annual water withdrawal	12.4 million m³ (2018)
Annual water consumption	6.99 million m³ (2018)
Recycled water volume	5.46 million m³ (2018)
Water efficiency rate	0.598 litres per unit in fabs; 11.327 litres per unit at ATO (2018)

Source: ON Semi

to 9-10, and adding a polymer to precipitate calcium fluoride which then settles out as a sludge in a lamella clarifier. The calcium fluoride sludge is pressed out in a filter press and sent to a landfill or cement kiln. Some sites use lime for the fluoride treatment process, which is messier and the lime-handling systems are labour intensive, but it's an easier process as you only need to control the dosage based on pH. With calcium chloride you need to know fluoride concentrations so proper instrumentation is required. The chemical used is typically dependent on each site's preference and what is available locally.

One of the main challenges we see in the fluoride treatment systems is scaling. Though we have looked at a lot of different high-tech solutions for fluoride, we always end up back with the traditional chemical treatment and settling technology.

We also implement different ways of treating for copper. In Gresham we used to treat dilute copper wastewater with pH-adjust and ion exchange resin, and that seems to work pretty well. However, higher copper concentrations in the system mean higher expenses in changing out the ion exchange resins. A number of our sites use copper hydroxide precipitation, and we generally prefer this method as it's pretty straightforward.

What are your main challenges when treating the wastewater?

The big challenge is the different discharge limits at our different sites. Some of our sites discharge to an industrial park, some to a municipality, and some discharge direct to a local river or other body of water. Limits are always getting tighter, and we have to keep a close eye on any new discharge standards to make sure we're staying ahead of them by adopting new processes or retrofitting our existing technologies. Recently, one of our sites in Asia had to meet new total nitrogen limits, and after running some pilots the best approach we could identify was actually a large bioreactor system to treat the waste stream that contained the trace amounts of ammonia and nitrogen.

At another one of our sites in Asia the fluoride discharge limit was reduced to 5ppm, which is very strict, and we had some concerns about maintaining our discharge standards because none of the treatment systems we piloted were meeting our goals. We identified a key issue as the fact that our drains weren't very segregated – 30-40 different process tools had fluoride in their waste streams, and they were all ending up in the same place as the non-fluoride waste streams. This created a wastewater stream that was high flow, low fluoride concentration, and full of other constituents. The diversity of this wastewater stream proved difficult to treat. Installing a new drain network in an operating fab can be extremely challenging, but the team did a great job designing and installing one by working closely with factory schedules to mitigate production impacts. At the end, we were able to properly segregate the fluoride wastewater streams and treat those newly separated streams with traditional chemical precipitation.

One of the challenges we're still working on right now is adapting to the new copper discharge standards that the Philippines will roll out next year. Currently, their limit for copper is 1ppm, but it's about to go down to 0.04ppm and we're struggling to meet that with the technology available to us. We are looking at newer technologies right now, especially ion exchange systems, though they have their own challenges with waste streams.

What technologies do you deploy to recycle water?

Recycling water is a big concern of ours, especially at our ATOs, which are usually in areas that have tight restrictions on water use. Before implementing a water recycling system, we model our water usage across the site – from source to discharge – which allows us to identify potential areas of impact. Because manufacturing equipment is set up to optimise production, not save water, we work with our process teams to collect data surrounding similar kinds of tools – idle flows, bath flows, cycle times – and set benchmarks so we can figure out if there's a way we can get by with lower flows and still achieve our process goals.

At our ATO sites, there's a lot of reuse of saw waste. It's pretty good water for recycling, but it contains surfactant, which can pose a challenge. The saw particles them- ▶

FROM USA TO THE WORLD

While headquartered in Phoenix, AZ, ON Semiconductor has operations across the world.

Source: ON Semi

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selves are straightforward to remove with ultra-filters or micro-filters, but treating surfactant typically requires carbon filters.

At some of our fabs, our water recycling strategy includes systems that allow us to reuse our clean process rinses. At our Gresham plant, a lot of our process tools have the ability to select a different wastewater drain depending on what process the tool is running, enabling us to separate out the water used when the tool is doing its cleaner rinses such as the second, third, and idle-flow rinses. The recycle system then treats that water using UV, carbon filters, cartridge filters, and RO, allowing it to be recycled as UPW.

We're also starting to recover RO reject at more sites. By running the first-pass RO reject through a separate Brine Recovery RO, we can use that water again within the system.

How do you approach the process of piloting new technologies?

We are currently planning on piloting technologies that would allow us to recycle the water from our copper waste treatment system. We have also had a lot of success in piloting existing technologies and instrumentation within our systems in order to better optimise them. A good example of this is at our Gresham site, where we have multimedia filters as part of our pretreatment system. We recently went in and set up multimedia filter pilots where we tried different coagulants and adjusted our methodologies for backwash frequency, and then monitored particles in turbidity. We've been able to dial-in our multimedia filter operation a bit better and have gotten more water efficient by doing so.

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We've also been looking at piloting some of the newer RO low-pressure membranes to see what kind of energy savings we might see with those systems, as well as optimising our existing RO through an audit process with a pretreatment chemical supplier.

There has been a lot of discussion about the Industrial Internet of Things. Have you looked into solutions that could help you with your water resources and wastewater management?

As we get into some of our newer wastewater treatment projects, we're definitely looking at these types of solutions for monitoring our systems, and collecting and managing data across our global operations. While having so many facilities with different processes and requirements creates challenges, it has also presented us with a unique benchmarking opportunity. Any process hurdle we come across at one site has very likely been seen and addressed already at another site that might be setup and run slightly differently. This gives us a golden opportunity to collect and compare metrics from all these sites, and use best-practices at one site to optimise processes at the others. Hopefully we will be able to leverage this strength across all aspects of our operations, including in our training programmes. ■