Expanded Copper Wastewater Treatment in a Compact Footprint

How Membrion helped Lam Research increase treatment capacity with a 60-square-foot retrofit



35% SAVINGS PER GALLON	5.2 TONS CO2-EQ/ YR REDUCTION	100% IN-SPEC TREATMENT	60 sq.ft. RETROFIT FOOTPRINT

PROJECT SNAPSHOT

Customer: Lam Research

Industry: Semiconductor

Location: Tualatin, OR, USA

Application: Treatment of concentrated copper wastewater

Solution Deployed: Electro-Ceramic Desalination (ECD)

CUSTOMER CONTEXT

Lam Research is a global leader in advanced semiconductor processing equipment, with a strong position in packaging technologies critical to next-generation device architectures.

Its SABRE® electrodeposition tools play a key role in enabling high-performance chips used across data centers, consumer electronics, and artificial intelligence (AI) applications, with Lam's technologies incorporated at multiple stages in the manufacturing of most of the world's semiconductor devices.

Lam Research operates a 52-acre, 4,000-person campus in Tualatin, Oregon, which serves as a major R&D and customer support hub. The facility is used to develop, test, and optimize next-generation semiconductor tools, often under highly dynamic operating conditions driven by rapidly evolving process chemistries and increasing demand for advanced packaging solutions. These activities generate concentrated electrodeposition wastewater streams as part of normal tool operation.



Aerial view of Lam Research's Tualatin, OR facility

THE CHALLENGE

Rapid growth in advanced semiconductor packaging, driven by artificial intelligence (AI), has increased demand for Lam Research's electrodeposition tools, resulting in higher tool utilization and the generation of greater volumes of complex wastewater at the Tualatin facility.

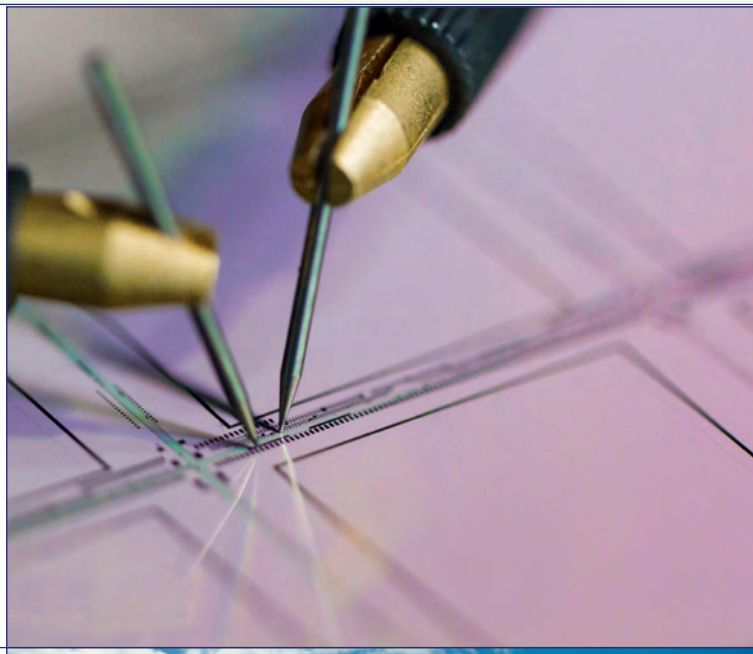
The facility needed to support this increased throughput without the ability to expand its physical footprint, creating a set of technical, operational, and physical constraints that conventional treatment approaches could not address.

Increasing Volume and Variability

Electrodeposition wastewater from SABRE® tools is characterized by high copper concentrations (up to 60 g/L), low pH (0–2), and significant variability (±60%) depending on tool recipe. Traditional approaches are poorly suited for these conditions:

- Chemical precipitation struggles with high, fluctuating metal concentrations
- Conventional ion exchange is not designed for high-loading or multi-metal streams

Any viable solution needed to handle high-strength, variable waste while maintaining consistent performance.



Operational Risk from Offsite Disposal

The facility relied on trucking wastewater offsite, introducing:

- Variable and rising costs
- Dependence on third-party logistics
- Risk of unplanned facility downtime if tank capacity was exceeded

This approach also conflicted with sustainability priorities, as frequent trucking increased greenhouse gas emissions



Severe Footprint Constraints

The site had extremely limited available space of less than 60 sq ft for additional waste storage tanks or treatment infrastructure. Any solution needed to be:

- Compact
- Retrofit-friendly
- Modular for flexibility



THE SOLUTION

Lam Research partnered with Membrion to deploy an on-site treatment system using Membrion's Electro-Ceramic Desalination (ECD) technology under a Water-as-a-Service model.

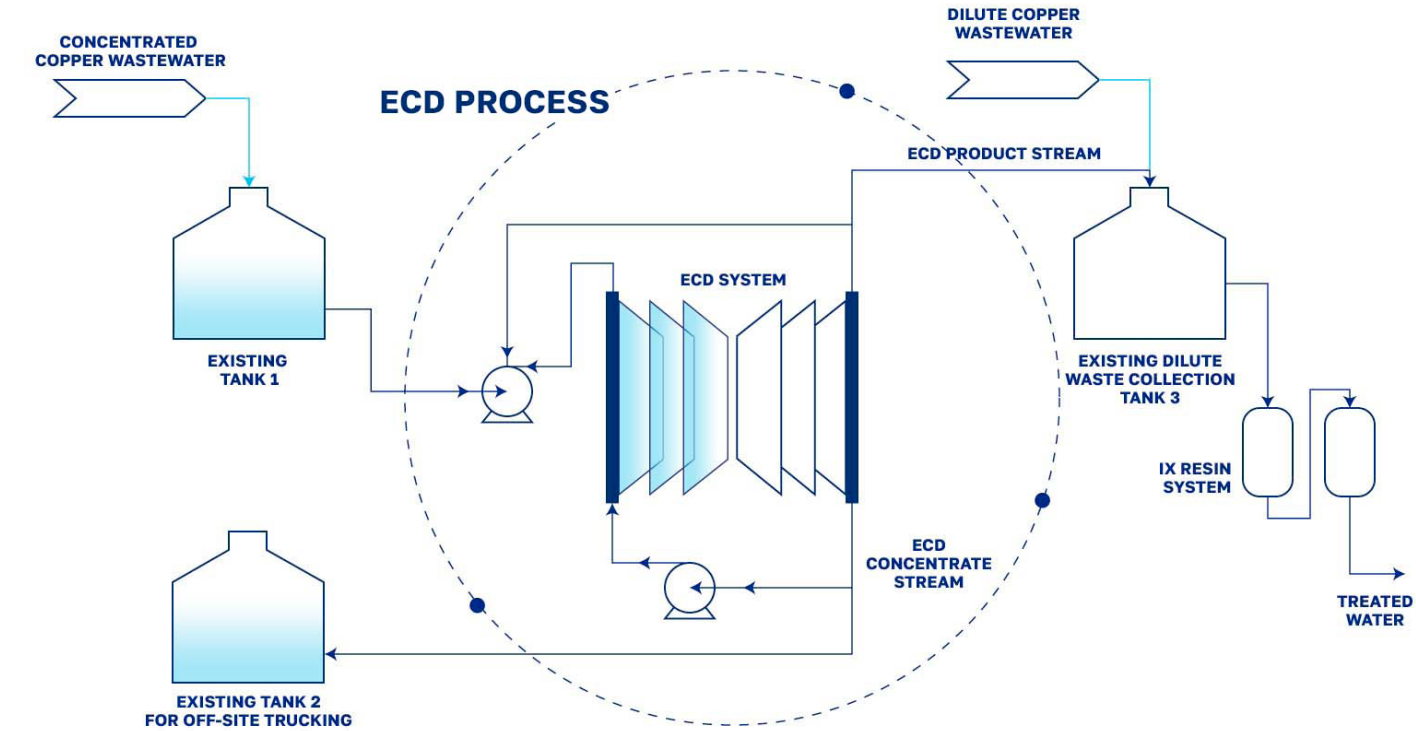
The system was designed to treat concentrated electrodeposition wastewater directly at the source, reducing reliance on offsite disposal while enabling the facility to support increasing production volumes within existing space constraints.



MEMBRION'S ECD SYSTEM
Installed at Lam Research for the treatment of concentrated copper wastewater

ECD is a low-pressure electrochemical process that continuously removes dissolved ions from water and concentrates them into a small-volume stream.

The system uses Membrion's proprietary ceramic desalination membranes, which are specifically engineered to treat high-strength, chemically aggressive wastewaters. The concentrated stream is significantly reduced in volume (60%–70%) and can be managed through offsite metal recovery, reducing trucking frequency; in applications with additional available footprint, this stream can also be further processed for on-site metal recovery.



PROCESS FLOW DIAGRAM OF ECD INTEGRATION AT LAM RESEARCH

Tanks 1 and 2 existed on-site and were used for concentrated copper wastewater collection and storage prior to offsite hauling, respectively. Tank 3 was utilized for dilute copper wastewater (DCW) collection prior to IX polishing and treated water discharge. The ECD process was integrated to use Tank 1 for feed. The ECD product stream required Cu < 100 ppm and was combined with DCW in Tank 3. The ECD concentrate stream went to Tank 2 for off-site metal recovery.

The installed system was deployed to treat up to 250 gallons per day (gpd) of electrodeposition wastewater with high copper concentrations and significant variability, delivering consistent effluent quality despite feed fluctuations and reducing feed variability of ±60% to less than 0.4% in the treated water.

The full system was implemented within a compact footprint (<60 sq ft) and integrated into existing facility operations without requiring major infrastructure changes, allowing the site to expand treatment capacity without expanding the facility. The system was integrated into existing operations, as shown in the process flow diagram (PFD).

Membrion's ceramic membranes offer strong resistance to oxidizers, low pH conditions, and complex additives, enabling reliable operation in environments where conventional ion exchange and precipitation systems are ineffective. This robustness allows the system to treat evolving wastewater compositions as tool chemistries continue to advance.

The system was delivered under a Water-as-a-Service model, converting treatment from a capital expense to an operating expense while aligning performance incentives. This approach reduced upfront risk, enabled rapid deployment, and allowed continuous optimization of system performance over time.

By combining on-site treatment, compact modular design, and chemistry-tolerant membranes, the solution directly addressed the facility's core constraints:

- **Reducing dependence on trucking**
- **Reliably treating highly variable waste streams**
- **Enabling increased wastewater throughput**
- **Operating within a severely limited footprint**

THE RESULTS

The Membrion ECD system demonstrated stable, high-performance treatment of concentrated electrodeposition wastewater under highly variable operating conditions.

The system consistently maintained effluent quality, reduced waste volume, and supported increased wastewater throughput within the facility's existing footprint.

KEY PARAMETER	AVERAGE	MAX
Influent Conductivity (mS/cm)	31.4	72.0
Influent pH	1.4	–
Effluent Conductivity (mS/cm)	1.5	3.0
Influent Copper (ppm)	9,980	18,000
Effluent Copper (ppm)	42	90
Water Recovery (%)	60	71

Variability Reduction and Effluent Stability

The system maintained consistent treated water quality despite significant fluctuations in influent wastewater composition (Figure 1).

Feed copper concentrations varied by approximately ±60% depending on tool operation, while the treated effluent remained highly stable and always below the required limit of 100 ppm Cu. 100% compliant treatment is possible because of the ECD configuration. The system processes the concentrated copper waste in sequential, automated batches.

Batch time automatically varies with copper concentration, making effluent quality highly predictable. This allows the ECD system to manage variations in feed quality by treating the feed water until the desired product quality is reached, regardless of the starting chemistry.

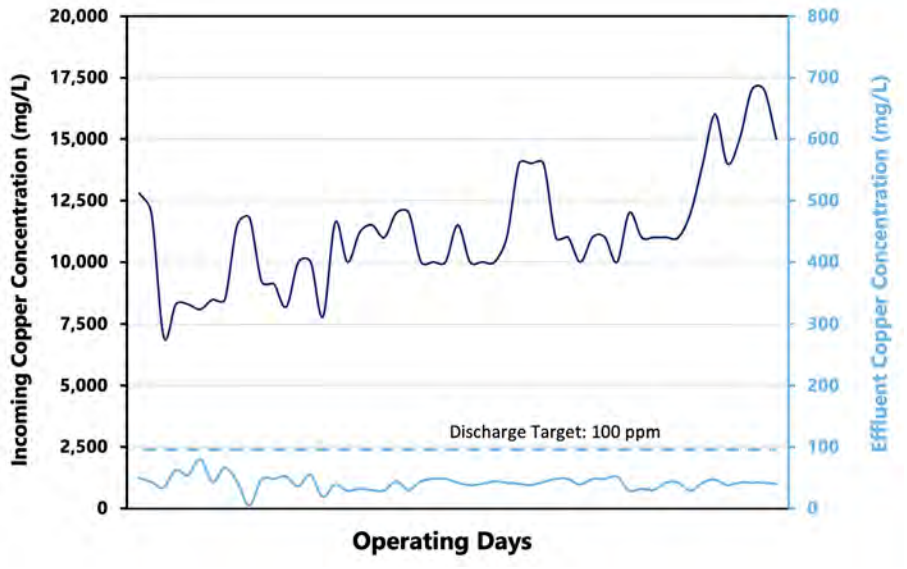


FIGURE 1: FEED VS. DISCHARGE COPPER CONCENTRATION
Influent wastewater exhibited significant variability (±60%) in metal concentration, while the ECD system consistently treated water below the required discharge target, demonstrating robust performance under dynamic operating conditions.

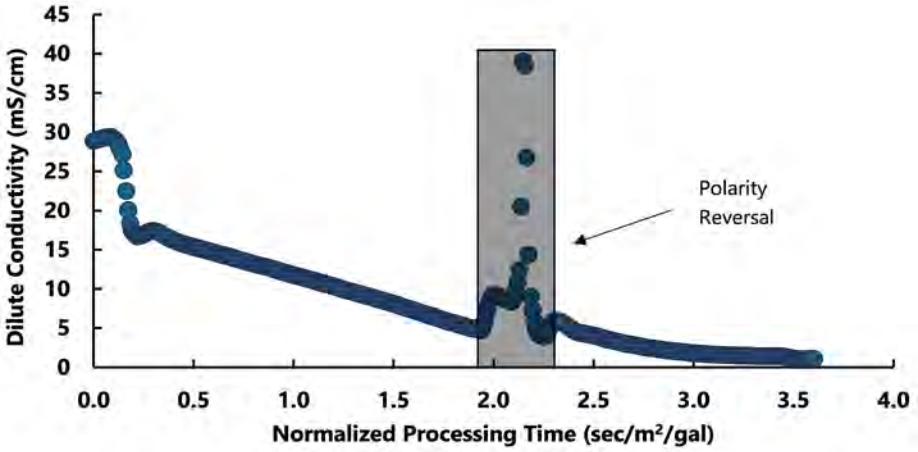


FIGURE 2: TYPICAL ECD BATCH CYCLE
Conductivity is shown over the course of a typical batch time, which has been normalized by the gallons treated and the membrane area. The left side of the graph represents the start of the batch and the right side represents the end of the same batch. In the middle of the batch, there is a spike in conductivity due to an automated and non-chemical cleaning protocol called a polarity reversal. This process temporarily changes the direction of flow and so a small spike in conductivity is seen prior to returning to the expected conductivity of the batch at that time. Polarity reversals do not occur during every batch, nor do they necessarily occur at the same time during a batch cycle.

Treatment Performance

The ECD system effectively removed dissolved copper across a wide range of operating conditions, achieving consistent reduction in copper concentration from high-strength influent streams (Figure 1).

Copper is continuously moved across the membrane (i.e., not an adsorption/desorption process) from the feed stream to the concentrate stream. This happens quickly at the start of the batch and slows down as the concentration of copper gets lower.

Figure 2 shows the conductivity change associated with copper transport during a typical batch cycle. Figure 3 shows the visual change of the feed during a typical batch cycle.



FIGURE 3
Samples taken every 0.4 sec/m²/gal from the ECD system showing the visual reduction of copper in the stream.

Operational Impact

By treating wastewater on-site, the system significantly reduced reliance on offsite disposal by minimizing the volume requiring trucking and stabilizing treatment performance.

Approximately 60% of the wastewater volume was recovered as treated water, reducing the volume of concentrated waste requiring offsite handling by a similar magnitude.

The system supported treatment of up to 250 gallons per day (gpd) of electrodeposition wastewater, allowing the facility to accommodate increased tool utilization and wastewater generation without requiring expansion of existing infrastructure.

OPERATIONAL LEARNINGS & OPTIMIZATION

As a first-of-its-kind deployment, the system provided valuable operational insights that enabled performance improvements over time.

Under the Water-as-a-Service (WaaS) model, Membrion continuously optimized system performance without requiring capital investment or operational disruption, allowing the system to adapt to evolving wastewater conditions and increasing throughput demands.
A key focus area was managing fouling associated with highly concentrated and variable metal streams. Membrion developed a robust clean-in-place (CIP) protocol that used the chemical durability of ceramic desalination membranes, enabling full restoration of system performance following fouling events (Figure 4).

This approach allowed the system to maintain consistent operation even under challenging and evolving wastewater chemistries.

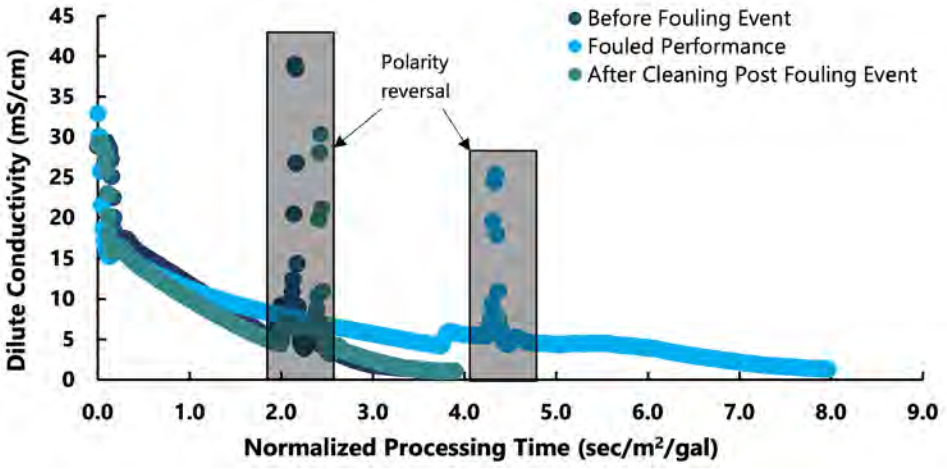


FIGURE 4: RECOVERY OF PERFORMANCE FOLLOWING FOULING EVENT

Performance loss due to fouling was fully reversed following implementation of a CIP protocol, demonstrating the system's ability to maintain stable performance with simple maintenance procedures.

In parallel, Membrion refined system control logic to improve process efficiency and responsiveness to changing feed conditions.

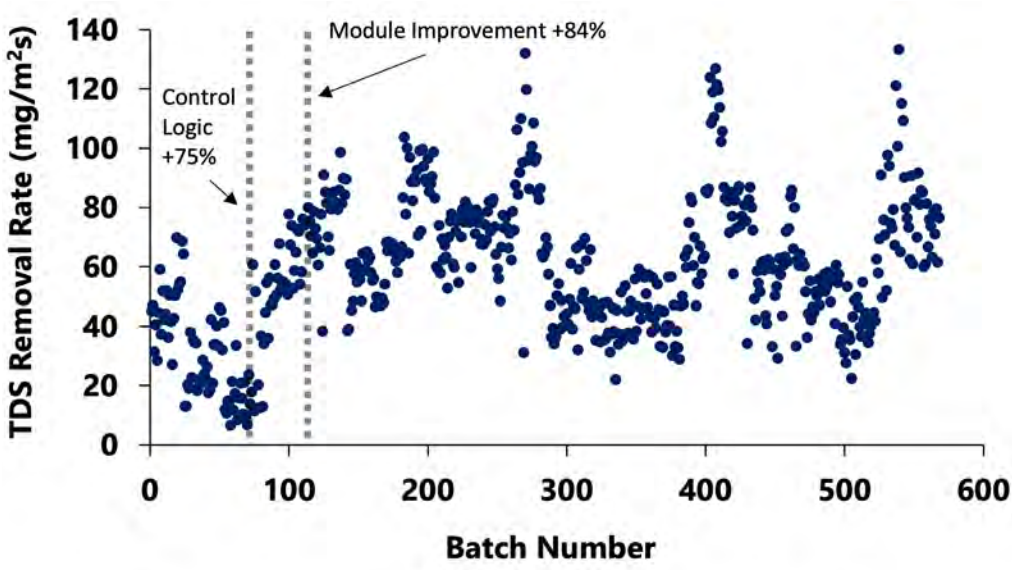
These adjustments required no additional capital investment and enabled more consistent operation across a wide range of incoming wastewater compositions. Targeted module design improvements were also implemented to further enhance system performance, with updated modules deployed as drop-in replacements without disrupting ongoing operations.

These combined optimizations resulted in sustained improvements in copper removal performance over time (Figure 5). Copper removal rates are affected by several factors, including influent copper and pH levels and the time between module cleanings.

FIGURE 5

Continuous optimization of system controls and module design resulted in a sustained increase in copper removal rate, demonstrating the system's ability to improve performance under real operating conditions.

Together, these operational and design improvements resulted in substantial performance gains.



200% **INCREASE IN AVERAGE COPPER REMOVAL RATE**

23% **INCREASE IN TREATED WATER RECOVERY**

3x **INCREASE IN DAILY TREATMENT VOLUME CAPACITY**

These improvements were implemented during ongoing operation, demonstrating the system's ability to adapt and improve without disrupting facility workflows. All enhancements have been incorporated into future system designs, enabling higher baseline performance and faster deployment across new installations.

CONCLUSION AND OUTLOOK

The successful deployment of Membrion's ECD system at Lam Research's Tualatin facility demonstrates the viability of compact, on-site treatment for highly concentrated and variable electrodeposition wastewater.

The system reduced reliance on offsite disposal while supporting increased production demands within a constrained footprint.

While this deployment focused on reducing trucking of concentrated copper waste, the same platform can also be applied to dilute rinse streams and full on-site copper recovery, further reducing waste and enabling resource valorization.

Membrion is actively expanding the system at Tualatin to treat more advanced plating streams containing mixed metals, demonstrating the ability to extend performance within the same system architecture.

As an R&D facility, the Tualatin campus provides a unique environment to observe how plating chemistries evolve over time. This ongoing collaboration allows Membrion to continuously adapt and refine system performance, ensuring the technology remains aligned with next-generation semiconductor manufacturing needs.

Following this deployment, Membrion's ECD technology has been incorporated into Lam Research's engineering guidance as a recommended solution for this wastewater stream, reflecting strong alignment with future tool requirements.

This project establishes a foundation for broader implementation across facilities facing increasing wastewater complexity, where flexible, on-site treatment solutions will play a critical role.

ABOUT MEMBRION

Membrion partners with industrial facilities to solve complex wastewater challenges that conventional treatment systems weren't designed to handle.

With Electro-Ceramic Desalination (ECD) at the core, our solutions selectively remove dissolved salts and metals from difficult wastewater streams, helping facilities recover more water, reduce wastewater volume and get more from existing infrastructure.

Every engagement begins with a clear understanding of the facility's wastewater conditions, treatment goals and operational constraints.

From technical evaluation and pilot testing through full-scale deployment, Membrion works alongside customers to prove performance and design the right solution for real-world conditions.

