A 3,000 m³/day Tubular Membrane Filter (TMF™) System Installed in Korea for Wafer Backgrinding Water Reclamation

Location: Cheongju, Korea  
Application: Wafer Backgrinding Wastewater Reclamation  
Capacity: 3,000 m³/day  
Project Engineering: Veolia Water Korea, Ltd, JM Tech, Ltd  
System Commissioning: July, 2013  
End User: One of the largest semiconductor manufacturing companies in Korea

Abstract Introduction

About Wafer Backgrinding Wastewater

During the deposition, etching and intermediate CMP stages, the thickness of a semiconductor integrated circuit wafer is typically kept at three or more times greater than required for the final device. The extra thickness ensures handling strength and geometric stability during those manufacturing processes. Prior to IC packaging, the wafer is ground to final thickness in a “backgrinding” process. Large amounts of ultrapure water are used for rinsing off the fine silicon particles and cooling the wafer during the grinding operation and this is discharged from the wafer packaging facility.

This wastewater contains primarily high value ultrapure water, silicon and colloidal silica particles. In some cases, a small amount of grinding additive fluid may be present. If the fine particles can be removed, the treated water is exceptionally pure due to the resulting low TDS (low conductivity) and can be recycled. The packaging facility’s ultrapure water making costs are reduced by introducing this recycled water to intermediate or tertiary purification stages. Wastewater discharge costs are also reduced.
Challenge and problems with conventional treatment processes for this wastewater:

**Filtration With Hollow Fiber UF:**
1. Large amounts of very small and sharp silicon particles results in high turbidity loading.
2. Sharp particles can cut and damage the hollow fiber resulting in unpredictable and poor filtrate.
3. Low recovery rate due to frequent back wash with permeate water.
4. Membrane flux is difficult to completely recover with chemical cleaning due to poor chemical resistance of the hollow fiber UF elements. Membrane fouling substances (silicon/silica/organics) can't be removed with high concentration chemical cleaning solutions.

**Coagulation And Sedimentation With Clarifier**
1. Very tiny particles tend to remain suspended in water and not settle (even with large amounts of coagulants added).
2. At times, Hydrogen gas bubbles are released due to caustic soda dosage together with coagulant (which is necessary for precipitation). This makes efficient sedimentation harder to achieve.
3. Chemical dosing changes the water characteristics, especially the TDS level which can increase significantly. This high TDS water may not be economical to recycle.
4. Lengthy process if water reclamation is desired.
5. Filtrate quality not as high compared to membrane filtration
6. Unstable performance of clarifier systems.

**Solution For This Project**
Using the Porex Filtration 0.05 µm Tubular Membrane Filter (TMF™) modules, Veolia built a simple system for the solid/liquid separation process without the need for any chemical dosing. This filtered water is then sent to a RO system for ionic silica removal only, not for desalination, since the original influent water conductivity is less than 10 µs/cm. The RO product water is then sent back to the workshop for reuse as DI water. The slurry from the Porex TMF system is sent to the facility's central wastewater system for further treatment.
**Wastewater Information**

Backgrinding wastewater: The influent suspended solids concentration is 500 to 1,000 mg/l. A disc centrifuge analysis below shows that most of the particles are larger than 50 nm (0.05 µm).

![](handle.png)

The mixed raw wastewater has a brown appearance with numerous very fine particles in the liquid (water in left bottle in the picture below, water in right bottle is filtrate water from the TMF system).

![](handle.png)

The system capacity is designed at 3,000 m³/day. Currently the plant utilizes 2,000 m³/day and as their processing volume grows they will utilize the entire 3,000 m³/day capacity.
When Used To Treat Backgrinding Wastewater:

1. Combined with filter press, this system will divide the wastewater into two parts: filtrate water and dewatered sludge cake. There is no concentrated or reject water sent to drain. This results in a nearly 100% recovery rate (if the squeezed water returns to the main reclaim system).

2. No chemicals are dosed into the wastewater. Therefore sludge can be reused with appropriate processing.

3. No pretreatment stage. The entire system operates based on simple, physical solid/liquid separation.

4. Excellent filtrate water quality: particles larger than the membrane pore size will be rejected. The treated water quality is equal to UF product water.

5. The uniquely designed TMF membrane tube has very high abrasion resistance. The membrane is not destroyed by sharp silicon particles — normally that’s the most significant problem when attempting to use hollow fiber UF membranes for this type of wastewater. Hollow fiber breakage or plugging happens due to random particle shape, high solids concentration, small lumen diameter, and lack of a membrane supporting substrate layer.

6. Ease of maintenance. The system can be designed for automatic operation, and can be turned to service mode from standby mode at any time.

7. The Porex Tubular Membrane Filter (TMF) has high resistance to fouling compared with hollow fiber membranes. TMF membrane flux can be restored since very strong chemical solutions can be used during CIP (Clean In Place).

8. Less space is required for a TMF system.

9. Ability to expand: water capacity can be enlarged by simply adding more TMF skids or modules.
Process Schematic

TMF System Information

Module Specification: The newest module configuration from Porex, the 61-tube TMF modules were applied in this system. Specifications of this module include:

- 61 half-inch membrane tubes in each module
- Membrane pore size of 0.05 µm
- 4.25 m² effective membrane filtration area per module
- PE substrate tube with PVDF membrane
- PVC module housing

Module quantity and array:
- 4 skids (3 in service and 1 standby)
- 36 modules per skid, 4 trains, 9 modules in series in each train (Total of 144 modules in the system).
- Each skid is designed to treat 1,000 m³/day of wastewater.

Process Description

The backgrinding (B/G) wastewater is collected in the equalization tank and is then pumped to the TMF concentration tank (also called circulation tank). Then the water is fed into the Porex TMF unit for solid/liquid separation. Most of the water stream will recycle between the TMF modules and concentration tank in a cross-flow filtration process. Filtered water is sent to a separate product water tank and fed into a RO system for ionic type silica removal. It is then reused as DI water. Silicon particles that are rejected by the TMF membranes accumulate in the concentration tank during operation. Typically, the partially concentrated liquid is continuously bled off at a set rate. Currently this stream, and approximately 95 m³/day of RO reject water, are sent to the existing wastewater station for further treatment.

No chemicals are fed into the system during normal service.
About Microfiltration

Microfiltration is a cross flow, pressure-driven membrane separation technology designed to remove submicron (and larger) suspended solids from water supplies. It differs from conventional (“dead-end”) filtration in that with a cross-flow process, a portion passes through the membrane, becoming “permeate”, while the remainder exits the system as “concentrate”, carrying away almost all of the suspended solids.

The following illustration compares these two processes.

The microfiltration membranes used in this application are POREX Tubular Membranes, depicted below.

The mechanism of microfiltration is depicted below.
The UF membranes used in this application are Porex® TMF tubular membranes, depicted below. The tubes are ½” I.D., with a polyethylene substrate supporting a PVDF (polyvinylidene fluoride) layer with 0.05 µm pores. A TMF membrane module is shown.

Each membrane module consists of 61 tubes, 72” in length enclosed inside an 8” diameter PVC housing.

Specifications:

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing Diameter</td>
<td>8” Sc40</td>
</tr>
<tr>
<td>Permeate Port (Qty 2)</td>
<td>Diameter 2.875 x 1.89” L pipe stub</td>
</tr>
<tr>
<td>Concentrate Ports</td>
<td>8” pipe Anvile Gruvlok groove</td>
</tr>
<tr>
<td>Mounting Required</td>
<td>Horizontal; 2 point</td>
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<tr>
<td>Module Length</td>
<td>72”</td>
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<tr>
<td>Number of Tubes</td>
<td>61</td>
</tr>
<tr>
<td>Nominal ID</td>
<td>0.5” (12.7 mm)</td>
</tr>
<tr>
<td>Nominal OD</td>
<td>0.79” (20.07 mm)</td>
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<tr>
<td>Total Active Surface Area</td>
<td>45.75 ft² (4.25m²)</td>
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<tr>
<td>Filtrate Volume</td>
<td>6.55 gallons (24.78 ltr)</td>
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<tr>
<td>Concentrate Volume</td>
<td>3.73 gallons (14 ltr)</td>
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<tr>
<td>Total Volume</td>
<td>10.28 gallons (38.78 ltr)</td>
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<tr>
<td>Potting</td>
<td>Solvent Cement</td>
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<tr>
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<td>Polypropylene</td>
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</tr>
<tr>
<td>Preservative (Shipping)</td>
<td>Propylene Glycol</td>
</tr>
<tr>
<td>Membrane</td>
<td>PVDF</td>
</tr>
</tbody>
</table>

The feed flow is down the center of the tube (lumen feed) with the permeate passing through the tubular wall and collected from the area around the outside of the tubes inside the housing.
Views of the TMF installation
Construction was completed and system commissioning began in July 2013. The system capacity is designed at 3,000 m³/day.

The system performance has met or exceeded the original design specifications.

- **Flux**: 210 to 270 liters per square meter per hour (lmh). Designed at 210 lmh when stand by unit is in operation, 270 lmh when stand by unit is idle.
- **Recovery**: 95% (designed at 95%)
- **Operating pressure**: 1.5 to 3.0 bars (designed at 5.0 bars)
- **Operating linear velocity**: 1.5 to 2.5 meters/second (m/s) (designed at 4 m/s)
- **CIP frequency**: once per 2 to 4 months (designed at once per month)
- **Permeate water quality**: Between 0.02 NTU to 0.1 NTU (designed at <0.5 NTU)
- **Suspended solids concentration in the circulation tank**: is maintained at approximately 2% to optimize performance.

Three additional reasons this system operates above expectations:

1. There is very low organic concentration in the influent water since the end user does not add any chemicals during their backgrinding process. Organic additives can affect membrane flux and CIP frequency.

2. Substantially all of the particles in this particular wastewater are larger than the membrane pore size. This results in excellent permeate turbidity value since virtually all particles are retained by the tubular membranes.

3. Outstanding process and mechanical design, combined with skilled construction ensured optimal performance of this system.
Summary

The backgrinding process generates fine, abrasive silica particles that must be removed prior to the water being further processed for reuse in the plant. While other treatment processes limitations and disadvantages, the Porex Tubular Membrane Filter (TMF™) has been tested and verified as superior in this application.

As a unique total solution of backgrinding wastewater reclamation, Porex TMF was selected and installed as a key component in this system. Exceptional membrane structure and properties make it possible to get outstanding filtrate quality together with 95% recovery rates in a simplified treatment process.

This system not only reduces wastewater discharge volume, but also recovers a large amount of high-quality DI water. By saving in these two areas the end user estimates that this plant will ultimately save approximately $1,000,000 USD per year in reduction of ultrapure water usage and sewer discharge fees.

The Porex TMF membranes were supplied by SI Membranes of Seoul Korea, and the system was constructed by JM Tech Co., Ltd., also based in Korea.

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