New Generation Ceramic Membranes
Company overview

- Cembrane Founders: Silicon Carbide Membrane Pioneers
- Production facilities in Denmark - capacity of 70,000 m²/year
- Patented membrane technology
- Focus to provide ceramic MF/UF membranes + modules to OEM’s for:
  - Drinking water
  - MBR, MBBR, TSE
  - Sandfilter backwash water
  - Pre-RO
Applications

**DRINKING WATER**
Removal of Fe, Mn, As, Ra, TSS, microorganism & bacteria with high flux and recovery

**SANDFILTER BACKWASH RECOVERY**
Turn your waste into a resource while saving space and money

**PRE-REVERSE OSMOSIS**
Improve RO yield and save space

**INDUSTRIAL WASTE WATER**
In MBR, MBBR & TSE even in presence of oil, solvents and high temperature
Evolution of filtration

Sand filter
- Traditional method
- Robust solution
- Very low recovery rate
- Poor permeate quality
- High chemical demand during pre & post treatment due to poor permeate quality

Polymer membranes
- Good permeate quality
- Low flux rate and robustness
- Low recovery rate
- Frequent cleanings
- Excessive use of chemicals
- Short lifetime (3-4 years)
- Not resistant to oil, temperature & harsh chemicals
- Maintenance is labour intensive

NEW GENERATION CERAMIC MEMBRANE
- Good permeate quality
- Long lifetime (>10 years)
- Unprecedented high flux rates
- High resistance towards chemicals & high pressure operation
- Resistant towards ozone
- Highest recovery rate
- Low operating and maintenance cost due to robustness and limited use of chemicals

"Combining the robustness of a sandfilter, with the filtration quality of a polymeric membrane.”
Product scope

- MF/UF Silicon Carbide flat sheet
- Outside-in filtration
- Individual mounting
- Asymmetric structure

- 7,25 m² module
- Submersible
- Highly compact
- Easy to handle and install

- Stackable system
- Framing of air-bubbles for optimal flux
- Good shock absorption
- Highly compact
Product scope

- Simple product program
- Easy to increase capacity through modular principle
- Most compact flat sheet technology
- Simple and cost-effective installation
Heart of the filtration system

- Mandatory pre-screening
- Optional Pre-treatment
- SiC UF Submerged
- Post-treatment

Screening <3 mm
Oxidation
Coagulation
Dissolved air flotation
Absorption
Fine screening

Ozonation
Reverse Osmosis
Drinking water
Industrial use
Cross section of Flat sheet membrane during different operation modes

- **Filtration**: Active membrane layer, Permeate channels, Filtration direction, Cake layer.
- **Cleaning by back-wash or -blowing**: Backflush/Back blow direction.
- **Chemical Enhanced Backwash (CEB)**: Backflush with chemicals/detergents.
## Pore size and filtration spectrum

<table>
<thead>
<tr>
<th>Relative Size of Common Materials</th>
<th>Process for Separation</th>
<th>Micro meters (µm Log scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Metal Ions</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
</tr>
</tbody>
</table>

### Micro meters

- **Aqueous salts**
- **Metal Ions**
- **Colloidal Silica**
- **Virus**
- **Asbestos**
- **Carbon black**
- **Oil emulsions**

### Process for Separation

- **Reverse Osmosis**
- **Nano Filtration**
- **Ultra Filtration**
- **Micro Filtration**
- **Particle filtration**
- **MF/UF**
- **Yeast cell**
- **Diatoms**
- **Bacteria**
- **Coal dust**
- **Giardia cyst**
- **Cryptosporidium**
- **Algae**
- **Granular Activated carbon**

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**Notes:**
- The filtration spectrum is based on the size of particles and the process used for separation.
- MF/UF stands for Microfiltration/Ultraprofiltration.
Technical features
Unique Selling Points of SiC membranes

Features & benefits of SiCFM membrane

- Hydrophilic → clean water permeability of 10,000 LMH/bar
- Anti-clogging → membrane repels negatively charged particles
- Chemically inert → no degradation of membrane from any chemical or solvent
- Durable and robust → 9 on Vickers hardness and can endure temperature of up to 800 °C

Operation features & benefits

- ✓ Highly compact designs
- ✓ High recovery - close to 100% mass balance
- ✓ Minimal maintenance & simple operation
- ✓ Lifetime exceeding 10 years
- ✓ Resistant to solvents, oil, grease, high temperature & high pressure
- ✓ Low energy consumption
Zeta potential

Illustration of anti-clogging & anti-fouling behaviour of the SiC membrane at neutral pH

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Yeast cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>ZnO</td>
</tr>
<tr>
<td>PAC</td>
<td>Manganese Oxide</td>
</tr>
<tr>
<td>Ferric chloride</td>
<td>Iron Oxide</td>
</tr>
<tr>
<td>Anionic + nonionic floc</td>
<td>Silica</td>
</tr>
<tr>
<td></td>
<td>Activated Carbon</td>
</tr>
</tbody>
</table>

*Farsi.Ali – Department of Chemistry and Bioscience, Aalborg University

**Zeta potential**

MEMBRANE HAS A STRONG NEGATIVE CHARGE AT pH 6-9

Limited Bio-fouling

Limited risk of clogging

Extended backwash frequency

Achieved Benefits

STABLE OPERATION & LIMITED MAINTENANCE
Actual fouling behavior of different membrane materials in surface water

Surface Water analysis:

- pH 7.9
- Turbidity 9.7 FNU
- Humic acids 10.3 ppm
- DOC 15.1 ppm
- NPOC 15 ppm
- Iron 0.59 ppm
- SUVA 3.14 Lmg$^{-1}$ m$^{-1}$
### Flux rate

<table>
<thead>
<tr>
<th>Flux rate</th>
<th>Achieved benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low contact angle between water and SiC</td>
<td>Low membrane surface required</td>
</tr>
<tr>
<td>Super hydrophilic surface</td>
<td>Highest flux rate for any membrane material</td>
</tr>
<tr>
<td>Ultrathin membrane layer</td>
<td>Low footprint and compact design</td>
</tr>
<tr>
<td>High porosity substrate (50%)</td>
<td>Low pressure operation → low energy</td>
</tr>
<tr>
<td></td>
<td>High recovery</td>
</tr>
</tbody>
</table>

### Achieved operational flux rates

<table>
<thead>
<tr>
<th>Application</th>
<th>Removal of</th>
<th>LMH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Water</td>
<td>Fe, Mn, Ra, As, TSS</td>
<td>575-1200</td>
</tr>
<tr>
<td>Sea Water pre-RO</td>
<td>Algae, TSS, Oil</td>
<td>200-500</td>
</tr>
<tr>
<td>Surface water</td>
<td>Micro-organism, TSS, Silt</td>
<td>200-600</td>
</tr>
<tr>
<td>MBR</td>
<td>TSS, Bacteria, COD, BOD</td>
<td>45-80</td>
</tr>
<tr>
<td>MBBR</td>
<td>TSS, Bacteria, COD, BOD</td>
<td>100-200</td>
</tr>
<tr>
<td>Treated Sewage effluent</td>
<td>TSS, Bacteria, COD, BOD</td>
<td>100-200</td>
</tr>
<tr>
<td>Sandfilter backwash water</td>
<td>TSS, Micro-organisms, Bacteria</td>
<td>300-500</td>
</tr>
</tbody>
</table>
Chemical resistance of Silicon Carbide

- Silicon Carbide is chemically inert & exhibit close to 0% weight loss in extreme conditions
- Membrane is stable in extreme feed conditions where no other membrane survives:
  - Solvents
  - Ozone
  - pH 1-14 constant exposure
  - Oxidizing agents
- Enables highly effective cleanings
- Long membrane life

**Corrosion test results in liquids. Weight loss in [mg/cm^2 yr]**

<table>
<thead>
<tr>
<th>Test environment*</th>
<th>Temp. °C</th>
<th>Weight loss [mg/cm^2 yr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>98% H₂SO₄</td>
<td>100</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>50% NaOH</td>
<td>100</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>53% HF</td>
<td>25</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>85% H₃PO₄</td>
<td>25</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>70% HNO₃</td>
<td>100</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>46% KOH</td>
<td>100</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>25% HCl</td>
<td>70</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>10% HF plus 57% HNO₃</td>
<td>25</td>
<td>&gt;1000</td>
</tr>
</tbody>
</table>

*Test time: 125 to 300 hours of submersive testing, continuously stirred.

** >1000 mg/cm yr - Completely destroyed within days.

*** 100 to 999 mg/cm² yr - Not recommended for service greater than a month.

**** 50 to 100 mg/cm² yr - Not recommended for service greater than one year.

***** 10 to 49 mg/cm² yr - Caution recommended, based on the specific application. 0.3 to 9.9 mg/cm² yr Recommended for long term service.

****** <2 mg/cm² yr - Recommended for long term service: no corrosion other than as a result of surface cleaning was evidenced.
<table>
<thead>
<tr>
<th>Advantage</th>
<th>Percentage or Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Flux</td>
<td>7-12x</td>
</tr>
<tr>
<td>Longer Lifetime</td>
<td>3-5x</td>
</tr>
<tr>
<td>Lower Footprint</td>
<td>2-4x</td>
</tr>
<tr>
<td>Lower Labour Cost</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Lower Chemical Consumption</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Lower Energy Consumption</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Recovery Rate in Drinking Water</td>
<td>&gt;99%</td>
</tr>
</tbody>
</table>
Pilot unit for demo and test

Features

- Define critical flux rate, maintenance regime & permeate quality in your application
- Fully automated with high quality components
- Integrated air-scouring system
- Easy plug-and-play operation
- Can include on request:
  - online NTU measurement
  - Remote access
  - Data logging
  - Sprinkler system for mechanical cleaning
- Applications: Drinking-, process and waste water
Cembrane installations
Cembrane technology overview

- Most compact membrane technology on the market for water treatment
- Ideal combination of robustness of a sandfilter and filtration quality of a polymeric membrane
- Water recovery above 99% of ground water treatment
- Modular and stackable system – easy add-on or removal of modules
- Mobile installations possible due to shock absorbing design
- Unmatched performance in oil & water separation