2006 winter

# Membrane News Twente

news magazine of the Membrane Technology Group

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# Membranes on the move!

Spring next year (2007) the Membrane Technology Group (Membranes & Interface Science, Inorganic Membranes and the EMI Twente) will move to a new building: Meander. The name of this new building is chosen because the new building meanders around the trees in that area. The location is very close to the location of the current building of Chemical Technology and it is connected to the Horst tower, which is the location were all the teaching activities of the faculty of Science & Technology are concentrated. The Meander will host several other research groups. Most of these groups belong to the research institute Impact, which focuses on process technology and more specific on Sustainable Energy and Smart Devices & Materials. The pictures on this page show a glimpse of the new building. More information will be published in the summer edition of this news letter with an announcement of the official opening. We plan to combine the opening with a small symposium on Membrane Science & Technology.

◁,◁▽ The new officers with the meeting room in the middle. The large number of windows in the building makes it very light and comfortable.

The new labs are equipped with state-of-the art furniture and systems. Analysis, general labs and pilot plant boxes are now separated. ▷,▽▷


**Picture by Alisia Peeters - March 2005**

A failure to make a membrane gives a good motive for a Christmas greeting

**Picture of the Month Competition**

The picture of the month is chosen from all the pictures that were taken in the MTG group during the last month. The winner receives free drinks for one night and gets to pick the winner from next month's contributions. All the winners can be found on the website www.membrane.nl

# Emulsification with micro-engineered devices

Maik Geerken

**A relative new emulsification process is cross-flow membrane emulsification using micro-fabricated nozzle plates with a defined nozzle size and distribution. This technique requires less energy, generates less stress to the ingredients, and produces narrower drop size distributions.**

In this process, the dispersed phase is forced through a porous membrane into the flowing continuous phase as depicted schematically in Figure 1. While the drops are inflated the shear force applied by the continuous phase increases with the increasing drop diameter. Finally, at a certain diameter the drops detach and new drops start to grow from the nozzles.
The micro-nozzle plates can be fabricated out of ceramics, metals and polymers using different micro-engineering tools. In this study, cleanroom-fabricated silicon nitride plates (Fig. 2A), laser-drilled stainless steel plates (Fig. 2B) and phase separation micromolded polymer plates (Fig. 2C) were used. The aim of using micro-engineering tools is to fabricate defined nozzle sizes and distances between the nozzles to controll the emulsification performance.
Beside the geometry the wetting properties are an important factor. For oil-in-water emulsification a hydrophilic surface is needed whereas for water-in-oil a hydrophobic surface is required. For the later one this is illustrated in Figure 3 showing successful water drop formation in case of a hydrophobic nozzle plate (A) and water outflow and accumulation of water into huge bulbs on the hydrophilic surface of the nozzle plate (B).
Emulsification experiments were conducted at low cross-flow velocities (< 0.08 m/s) and low pressure differences (Δp < 250 mbar) in order to observe optically the drop formation process and to determine the drop sizes, drop formation time, drop formation rate and number of drop forming nozzles. For water-in-oil emulsions 1 wt% Span85 and for oil-in-water 1 wt% Tween 20 were used as emulsifiers. Table 1 shows some achieved average drop sizes and the corresponding standard deviations. All nozzle plates showed high number of active nozzles at relative low applied pressure differences (60-100 %) resulting high dispersed phase flows (water/oil: up to 4500 L $h^{-1}m^{-2}bar^{-1}$; oil/water up to 90 L $h^{-1}m^{-2}bar^{-1}$).

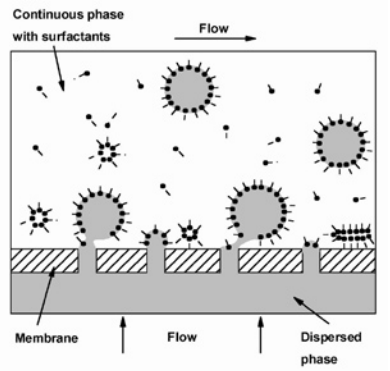


Figure 1 - Schematic illustration of the cross-flow membrane emulsification

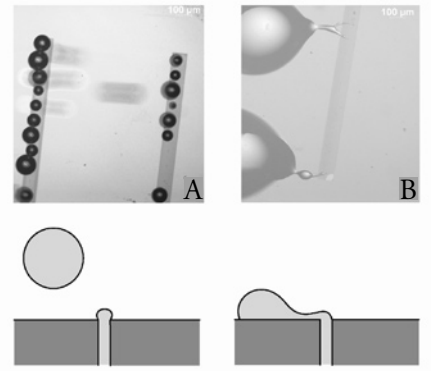


Figure 3 Emulsifying water into surfactant containing hexadecane with a hydrophobized (A) and with an unmodified SixNy nozzle plate (B) under the same process conditions. Below, schematic representations of the drop formation processes are shown

From the values shown in Table 1 it can be concluded that monodisperse drops (S.D. < 5 %) are not produced. This is addressed to the fact that growing drops change locally the flow field, which influences adjacent growing drops resulting in different drop sizes. Compared to conventional porous membranes the micro-engineered nozzle plates show more active pores at lower applied pressure differences because of their short nozzle lengths (see Figure 2) resulting in lower flow resistances. This overall leads to higher dispersed phase flows.

Table 1 - Average water and oil drop diameters

| Nozzle plate | Nozzle diameter [μm] | Type of emulsion | Average Drop size [μm] | S.D. [%] |
|---|---|---|---|---|
| Hydrophobic $Si_xN_y$ | 3.5 | water/oil | 140 | 8.8 |
| Hydrophobic Aluminium | 6.0 | water/oil | 154 | 7.9 |
| Stainless Steel | 4.3 | oil/water | 113 | 12.4 |
| PES | 5 | oil/water | 68 | 18.2 |

## More information

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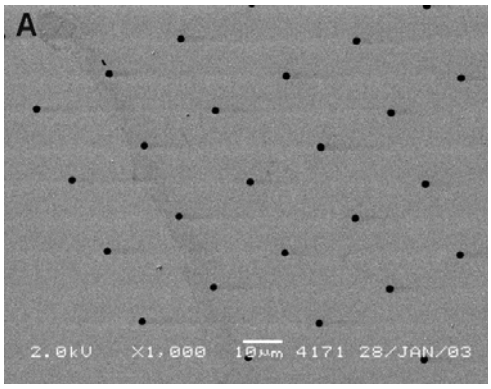
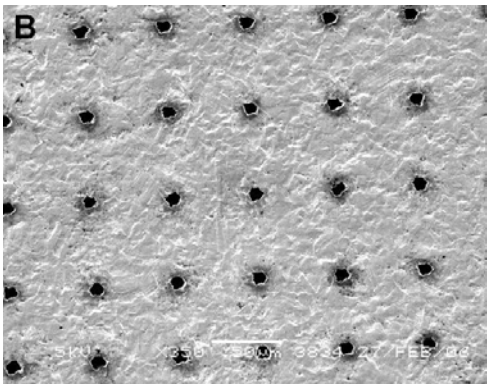
**Literature**

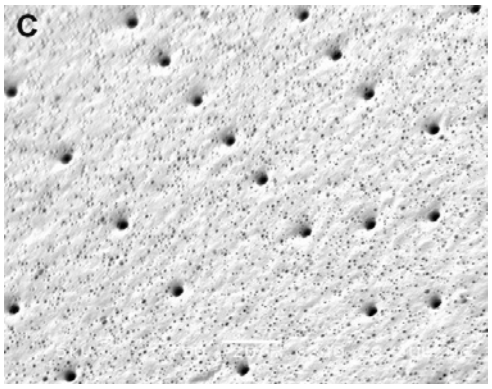
M.J. Geerken, R.G.H. Lammertink, M. Wessling, Colloids and Surfaces A 292 (2007) 224-235




Nozzle diameter - 3.5 ± 0.03 μm
Nozzle to nozzle spacing - 35 μm
Nozzle length - 1 μm




Nozzle diameter - 4.3 ± 0.4 μm
Nozzle to nozzle spacing - 150 μm
Nozzle length - 50 μm




Nozzle diameter - 5 ± 0.3 μm
Nozzle to nozzle spacing - 30-50 μm
Nozzle length - 10 μm

Figure 2a-c - SEM Images and typical dimensions of cleanroom-fabricated silicon nitride nozzle plates (A), laser-drilled steel nozzles (B), phase separation micromolded polyethersulfone (PES) nozzle plates (C)

## Publications

**Saiful, Z. Borneman, M. Wessling**, Enzyme capturing and concentration with mixed matrix membrane adsorbers, *Journal of Membrane Science 280 (2006) 406-417.*

**Y. Zhang, Z. Borneman, G-H. Koops, M. Wessling**, Adsorption behavior of cation-exchange resin-mixed polyethersulfone-based fibrous adsorbents with bovine serum albumin, *Desalination 192 (2006) 224-233.*

**D.F. Stamatialis, N. Stafie, K. Buadu, M. Hempenius, M. Wessling**, Observations on the permeation performance of solvent resistant nanofiltration membranes, *Journal of Membrane Science 279 (2006) 424-433.*

**M. Gironès, L.A.M. Bolhuis-Versteeg, R.G.H. Lammertink, M. Wessling**, Flux stabilization of silicon nitride microsieves by backpulsing and surface modification with PEG moieties, *Journal of Colloid and Interface Science 299 (2006) 831-840.*

**A.V. Volkov, D.F. Stamatialis, V.S. Kothimsky, V.V. Volkov, M. Wessling, N.A. Platé**, Poly[1-(trimethylsilyl)-1-propyne] as a solvent resistance nanofiltration membrane material, *Journal of Membrane Science 281 (2006) 351-357.*

**A.V. Volkov, D.F. Stamatialis, V.S. Kothimsky, V.V. Volkov, M. Wessling, N.A. Platé**, New membrane material for SRNF applications, *Desalination 199 (2006) 251-252.*

**K. Bélafi-Bakó, D. Búcsú, Z. Pientka, B. Bálint, Z. Herbel, K.L. Kovács, M. Wessling**, Integration of biohydrogen fermentation and gas separation processes to recover and enrich hydrogen, *International Journal of Hydrogen Energy 31 (2006) 1490-1495.*

**Y. Zhang, Z. Borneman, G-H. Koops, M. Wessling**, Studies of adsorption of bovine serum albumin on resin mixed pes fibrous adsorbents, *Acta Polymerica Sinica 2 (2006) 350-355.*

**M. Gironès i Nogué, I.J. Akbarsyah, L.A.M. Bolhuis-Versteeg, R.G.H. Lammertink, M. Wessling**, Vibrating polymeric microsieves: Antifouling strategies for microfiltration, *Journal of Membrane Science 285 (2006) 323-333.*

**D.F. Stamatialis, H.H.M. Rolevink, G.H. Koops**, Transdermal timolol delivery from a Pluronic gel, *Journal of Controlled Release 116 (2) (2006) e53-e55.*

## Ph.D.

**Dana Sterescu (May 10, 2007)**

Synthesis and preparation of a new generation gas separation membranes

**Saiful (May 24, 2007)**

Mixed matrix membrane adsorbers for protein and blood purification

## Bachelor/Master of Science

### Master

**Lisanne Deprez-Toeter (November 1, 2006)**
Optimization of clean, coal-based polygeneration through the application of advanced membrane technology.

### Bachelor:

**Nienke Ruepert (September 5, 2006)**
Porous capillary emulsification

**Willem Jan van Dijk (October 18, 2006)**
Improved permeation set-up for dehydration membranes

**Gert Jan de Beus (September 18, 2006)**
Electro-membrane processes as alternatives for the sulphur removal at Anglo Platinum

**Jeroen Zijp (September 22, 2006)**
Influence of operating conditions on the performance of DOW-NF membranes for the treatment of spent nickel electrolyte

## Open Positions

### Employment Opportunities

**For various projects we are searching for new membrane enthusiasts. A short description is given below. Detailed descriptions of some of the positions can be found on the website (www.membrane.nl). More information on all positions can be obtained by sending an email to membrane@utwente.nl.**

### Ph.D. Positions

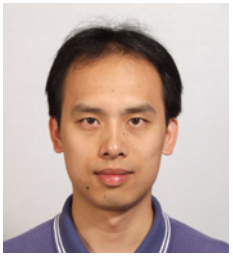
- **2 Ph.D. students in the field of gas separation**
- **2 Ph.D. students in the field of organic solvent nanofiltration**
- **1 Ph.D. student in the field of electrochemical energy devices**

### Research positions

Within the EMI Twente we are looking for two researchers with a Ph.D. or M.Sc. degree.

# Introducing...

## High temperature creep behavior of dense ceramic membranes for oxygen separation



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Jianxin is a new postdoc from China. Before he joined the group, he worked on mixed-conducting oxygen permeable membranes for his PhD at the University of Science and Technology of China. He started his postdoc project in November, 2006, which focuses on the high temperature creep behavior of dense ceramic membranes for oxygen separation.

## Phase Separation Microfabrication in a Continuous Process

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Zeynep is a 26-year old PhD student from Turkey. She finished her Bachelor and Master studies in Middle East Technical University in Ankara, Turkey. She started her PhD in membrane technology group on September 1, 2006. She will work on the upscaling of phase separation microfabrication method to make microsieves into a continuous system.

## Fast, online detection of bacteria in drinking water systems

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Petra is 27-years old PhD. student from Czech Republic. She studied Environmental engineering/ Water Technology at the Institute of Chemical Technology in Prague, but did her Master thesis at the Royal Institute of Technology in Stockholm. In September 2005 she started her PhD. project at Wetsus in cooperation with University of Twente. Her aim is to develop a system for rapid online detection of harmful bacteria in drinking water systems within several hours.

## High temperature creep behavior of dense ceramic membranes for oxygen separation

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Weihua was born in Beijing, China at January 1st, 1978. He obtained his Bachelor degree from the University of Science and Technology of China (USTC) at July, 2001, and worked for three years in China. At August 2004, he went to Singapore for his master study. He finished Applied Chemistry at the National University of Singapore (NUS) this year.

His Ph.D. topic is the Micro Solid Acid Fuel Cell. The majority of the work includes developing new superprotonic solid acid materials, and fabricating thin solid acid membrane. In this project, he cooperates with Dr. A. Bandarenka who will develop the model which describes the electrochemical properties of the new materials.

## Stability of high temperature composite membranes for pervaporation

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On the 3rd July, Clara joined the European Membrane Institute Twente as a postdoc. She had finished her PhD on Chemical Engineering at the University of Cantabria (Spain) one year before, with a study of the performance of ceramic membranes on the dehydration of organic solvents by pervaporation. Then, she went to work with Prof. Asaeda at Hiroshima University, to improve her knowledge on membrane synthesis. Now, she came back to Europe, where she is working on the development of chemically and thermally stable membranes for dehydration by pervaporation.

## Inorganic membranes for Pervaporation

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Julius is 27 years old origin from Lithuania. He received his PhD in material science research field from the University of Montpellier 2, Montpelier, France. PhD project was concentrated on zeolite crystal and membrane preparation under microwave irradiation.
He started his post-doc project in October. The project concerns inorganic membrane preparation by a sol-gel method and their application for liquid separation by pervaporation..

# New assistant professor Louis van der Ham

**On the 1st of September Louis joined the membrane technology group as assistant professor with main responsibilities in the field of process technology education in the Bachelor and Master phase in collaboration with colleagues and PhD's. His background is a MSc and Ph.D. in the field of process technology obtained at the University of Twente and teaching/research experience in different research groups.**

## Courses

**Process technology**
This course focuses on basic knowledge of and elementary insight into mass and energy balances, reactors, separation processes (e.g. distillation), product design, process design, process economy and process safety.

**Introduction to Chemical Technology**
Insight and knowledge of the previous course are deepened and broadened by a series of lectures on distillation column design, data retrieval and estimation, literature search, safety, and economics. Then, groups of three students assess an industrial process by searching the open literature, write a report on their findings, and visit a site where the process is actually in operation. Discussion of these reports with the company's process engineers (as their future peers) crowns the effort.

**Separation Technology**
*(in collaboration with Hans Bosch and Wytze Meindersma)*

Separation Technology teaches the students the description and design of important industrial separation processes like:
- Equilibrium-based processes: distillation, absorption, stripping, extraction
- Rate-based processes: adsorption, ion exchange, drying, crystallisation
- Mechanical separations: liquid/liquid, solid/liquid, gas/liquid and gas/solid separations

**Thermodynamics and Flowsheeting**
This course teaches the students the principles of flowsheeting, the application of flowsheeting software and the advantages but also the limits of these programs. At the end of the course the students should appreciate and be able to work with the flowsheeting tools, but also be aware of the pitfalls linked to working with these programs. A thoughtless use of flowsheeting will very quickly lead to science fiction.

**Process Plant Design**
Louis assists professor Henk van den Berg with this master course .

## Research

Louis' current research activities originate from the separation technology group and contain 4 PhD projects:
- solvent impregnated resin (SIR) applications for removal of contaminants like MTBE and phenol (Bernd Burghoff) or aldehydes (Katarina Babic) from water and separation of racemic mixtures (Katarina Babic),
- adsorption processes for regenerative recovery of homogeneous catalysts via the RFA concept (Tanja Djekic) and low-cost detergent ingredient removal for sustainable decentral usage of rinsing water (Natasja Schouten, Wetsus).

Louis with students on a trip to Shell


Hylke's award winning presentation at the Euromembrane 2006


## MNT- Information

Membrane News Twente is published two times per year. The aim is to inform the membrane community about the activities of the Membrane Technology Group.

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# Prizes won at the Euromembrane

**At the Euromembrane 2006 in Italy's Giardini Naxos, 2 prizes were rewarded to members of the membrane technology group.**
Hylke Sijbesma presented his work on 'Water vapor selective membranes for flue gas dehydration' and was awarded a NanoMemPro Presentation Award for "New ideas for industrial applications". In his presentation, Hylke discussed the implementation of membranes in the flue gas stream of a coal-heated power plant. By removing a part of the water vapor, the need for reheating of the flue gas is eliminated, resulting in an increase of the power plants efficiency and at the same time makes water re-use possible.
Bernke Papenburg received the VCH-Wiley award for her clear presentation on 'Micro-patterned membrane sheets for tissue engineering scaffolds'. Bernke works on fabrication of micro-patterned porous sheets to design 3D tissue engineering scaffolds to grow tissue. The micro-pattern enables control over cell alignment increasing organization, and therefore, functionality of tissue. Additionally, inner-porosity of the sheets, in combination with the 3D design, should enable sufficient nutrient supply to the cells.

# The Membrane Technology Group

## Multidisciplinary approach in membrane science and technology

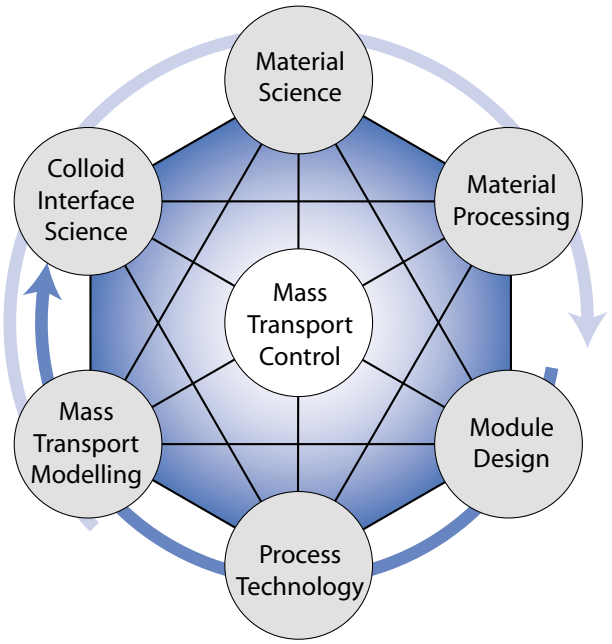
The Membrane Technology Group focuses on the multi-disciplinary topic of membrane science and technology. We consider our expertise as a multidisciplinary knowledge chain ranging from
molecule to process. The knowledge chain
comprises the following elements:

- Colloid and interface science
- Macroscopic mass transport characterization and modeling
- Material Science
- Material Processing
- Module and system design
- Process technology

The research team is assembled such that permanent staff members cover one or more of the disciplines involved. The majority of the research deals with separation of molecular mixtures and selective mass transport. Our research program distinguishes four application clusters:

- Sustainable Membrane Processes
- Water
- Biomedical and Life Science
- Micro Systems Technology

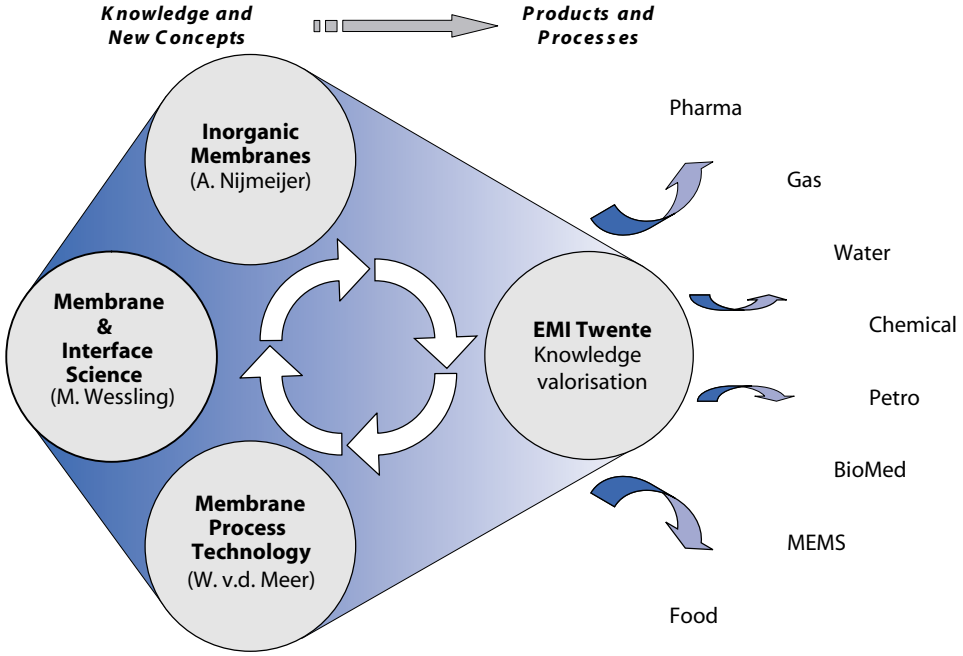
The research clusters are embedded in three research institutes, IMPACT (process technology), BMT (biomedical) and MESA+ (nanotechnology).




**Total mass transport control by a multidisciplinary approach.** The membrane & Interface science group together with the Membrane Process Technology and the Inorganic Membranes groups cover the full spectrum of mass transfer phenomena in membrane separation. From the very small scale to module and process design the combined knowledge of the groups can handle any membrane related problem.

## Knowledge transfer and utilization

Over the past years, our group has focused especially on knowledge utilization and transfer. We experienced that the time scales for research progress are extremely different in industry and academia. Even within industry a significant difference exists in time-scales between small and medium enterprises and multi-national cooperations. We have adjusted our organization structure such that we can distinguish between long-term scientific activities and short-term technology transfer. We have established the European Membrane Institute (EMI) Twente for this purpose.
The EMI performs research and development work on new membrane products and processes. The work often focuses on the production of a tangible deliverable.




**Bringing new knowledge and concepts to the market.** The traditional discrepancy between the needs of the industry and the research performed within universities is bridged by the establishment of the European Membrane Institute.