2007 winter

Membrane News Twente

News magazine of the Membrane Technology Group

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Inaugural lecture by Prof. Arian Nijmeijer

On December 13, 2007, Arian Nijmeijer, part-time professor of Inorganic Membranes of the University of Twente, gave his inaugural lecture. The title of his lecture was: Inorganic Membranes: Cornerstones of a durable society. In his lecture, Arian stressed the importance of demonstration projects

and applications in the field for the acceptance of membrane technology. The research on inorganic membranes at the University of Twente focuses on three major research themes. The first aspect of the research is dedicated to advanced ceramic processing, such as the development of two phase composite materials, the application of functional coatings and the preparation of inorganic/organic hybrid materials for a variety of applications. The second research theme is dedicated solid state ionics. This includes (solid oxide) fuel cells, electrodes and electrolytes, membrane reactors, but also the development of dense mixed ionic/electronic conducting membranes for oxygen separation. The third research theme focuses on porous ceramic membranes based on ZrO_2, TiO_2 and SiO_2 for different applications (gas separation, pervaporation, nanofiltration, membrane reactors). Arian Nijmeijer has a MSc and PhD background in Inorganic Materials Science obtained at the University of Twente. In his PhD work he studied the use of inorganic silica membranes for hydrogen removal in membrane steam reformers.

After obtaining his PhD, he joined Shell Global Solutions International BV in the year 2000. He became active in the Innovation and

Research department of Shell Global Solutions, where he was involved in the creation of a membrane technology group, which was established late 2004. The focus of this group is to deploy membrane technology in refineries, chemical plants and exploration and production operations. Since February 1st, 2006, Arian is part-time professor of Inorganic Membranes at the University of Twente.

Honorary doctorate for Professor Ora Kedem

During the Dies Natalis (founding date) of the University of Twente on November 30, professor Ora Kedem (82) received an honorary doctorate of the University of Twente. Ora Kedem is Emeritus Professor on Desalination and Water Treatment Research at Ben Gurion University in Israel and at the Weizmann Institute of Science.

Her academic career started with her first paper in 1951 and still continues after 55 years. She is the most recognized scientist in two very different areas: technical membranes and natural membranes. She has published ground-breaking papers in both fields. She is a person with a strong sense of societal responsibility: she turned her fundamental knowledge on mass transport through biological membranes into the development of desalination membranes to address the problems of water shortage in de Mediterranean area. She has taken political responsibility and started tightening collaborative links between German and Israelian researchers. Her achievements on this matter were awarded with the German Bundesverdienstkreuz. She has been founder and technical director of a spin-off company from the Weizman Institute of Science: Membranes Products Weitzman.

During her long career, Mrs. Kedem has been honoured with many international awards. She is one of the founders of today's Ben Gurion University in Be'er Sheva. Her link with the

University of Twente is long-standing. Prof. Kedem has been scientifically interacting with all three Membrane Technology Chair holders (Smolders, Strathmann and Wessling) over the last 3 decades. According to Professor Wessling, the 'promotor' of the honorary doctorate, Kedem's interest in fundamental research and technological valorization make her a perfect example of an entrepreneurial scientist.

Prior to the official ceremony, the Membrane Technology Group of the University of Twente organized a workshop to the honour of Prof. Ora Kedem. The workshop started with a word of welcome of Matthias Wessling and a dicti amicorum for Ora Kedem from Cees Smolders and Karl Boedekker. The scientific program started with a lecture from Joseph Kost on clinical applications of ultrasound enhanced transport through biological membranes. The program continued with two fascinating lectures on the simplicity of nature: Motomu Tanaka presented his work on transport through cell membranes, whereas Yechiel Shai explained how we could use the principles of nature in our struggle against bacteria and cancer. After lunch the program continued with two presentations on technical membranes and applications with a lecture from Shimon Tal on desalination as a viable resource and an inspiring presentation by Bernd Bauer on the advances of FumaTech on polymer electrolyte membranes for fuel cell applications. The workshop ended with a special word of Heiner Strathmann and Matthias Wessling to the honour of Prof. Ora Kedem.

Micro- and nanostructuring membranes

One of the research clusters of Membrane Technlogy Group is related to controlled structuring of membranes. Within this research cluster we study topics where well controlled structuring of membranes on the micrometer and nanometer length scale is required. The general concept in these projects is all identical; to exploit structuring of membranes to eventually control or enhance mass transport through these membranes. Within these projects, we strongly collaborate with other groups, including Physics of Fluids, Mesoscale Chemical Systems, Molecular Nanofabrication, Physics of Complex Fluids, and Catalytic Processes and Materials.

Enhancing effective membrane area

The corrugations on a membrane surface result in increased membrane area. Especially when the dominant mass transport resistance is situated at or near this structured surface, the increased surface area is directly translated in increased flux. We study this phenomenon in both flat sheet as well as hollow fiber geometries (Figure 1 and Figure 2). Sructured hollow fiber membranes can be prepared by using structured inserts within a conventional spinning

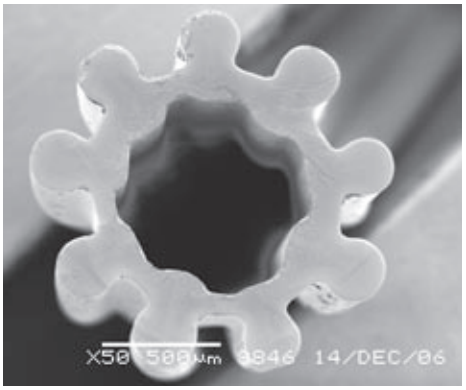

Figure 1: Structured hollow fiber membrane.

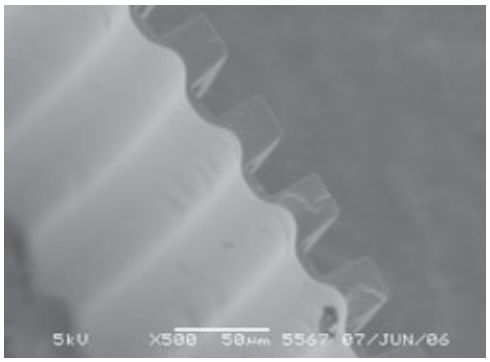

Figure 2: Structured flat sheet membrane.

setup. Flat sheet structured membranes are prepared by regular casting methods on a microstructured (silicon) mold.

Improving hydrodynamics

Static mixing promoting structures can be integrated and fabricated in a single step with the membrane preparation. This results in membranes that have turbulence promoting features on their suface (Figure 3). As such, more degrees of freedom can be used in designing these structures, compared to the conventional spacer structures. The hydrodynamic conditions during filtration experiments strongly influence the formation, or absence, of concentration polarization layers. The tuning of wetting properties can result in slip conditions at the membrane-

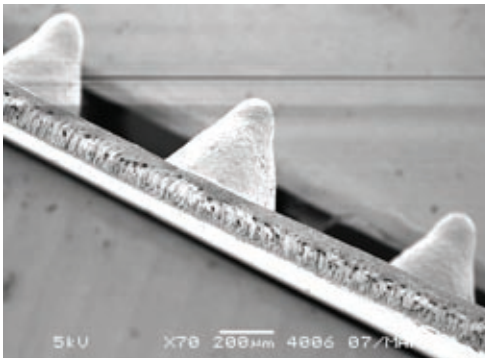

Figure 3: Membrane with integrated static mixers.

liquid interface. Simply stated, when air pockets are trapped between the membrane and the liquid, the boundary conditions become slipping compared to the normal no-slip conditions for wettable surfaces.

By fabrication of well defined structures, wetting can be well controlled (Figure 4 and 5). These well controllable structures are ideal platforms to study also superhdrophobic states, and their transitions, more fundamentally.

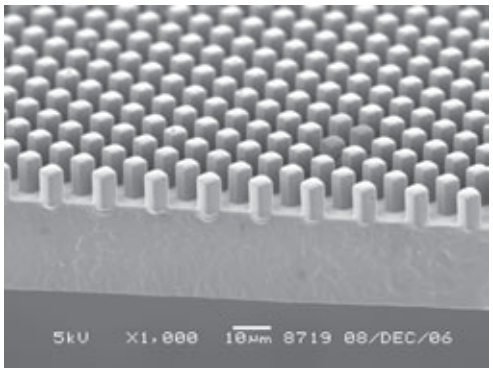

Figure 4: Pillar structure for superhydrophobic properties.

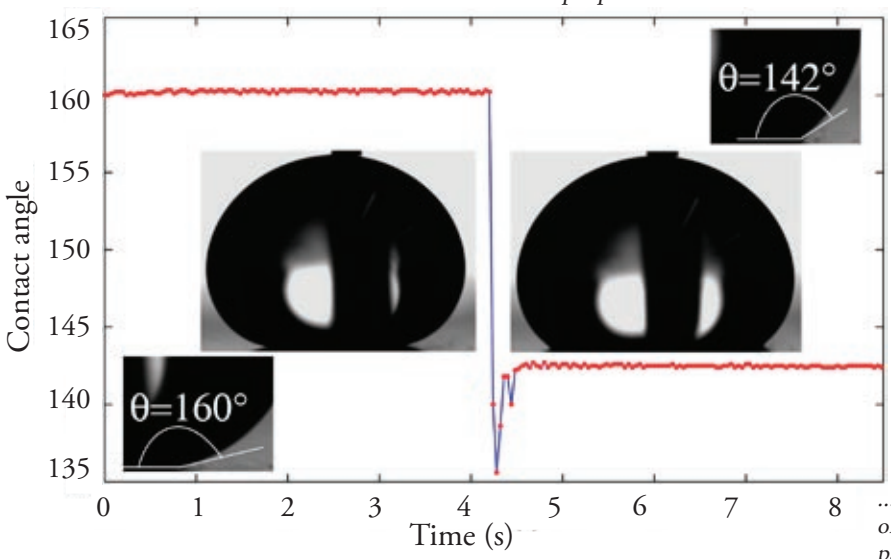

Figure 5: Realtime transition between superhydrophobic states.

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Membrane micro reactors and micro-fluidics

Research within the field of microreactors is strongly emphasizing the integration of unit operations, e.g. mixers, reactors, separators, within a single device. Here, we believe membranes can play a significant role. They can be used for contacting or controlled dosing barriers, selective transport, and adsorption media, for instance. We are currently studying the fabrication and operation of microreactors that incorporate membrane functionality (Figure 6). We do this both with polymeric devices, as well as with ceramic devices. To accomplish this we use microfabrication methods including cleanroom methods and micromilling.

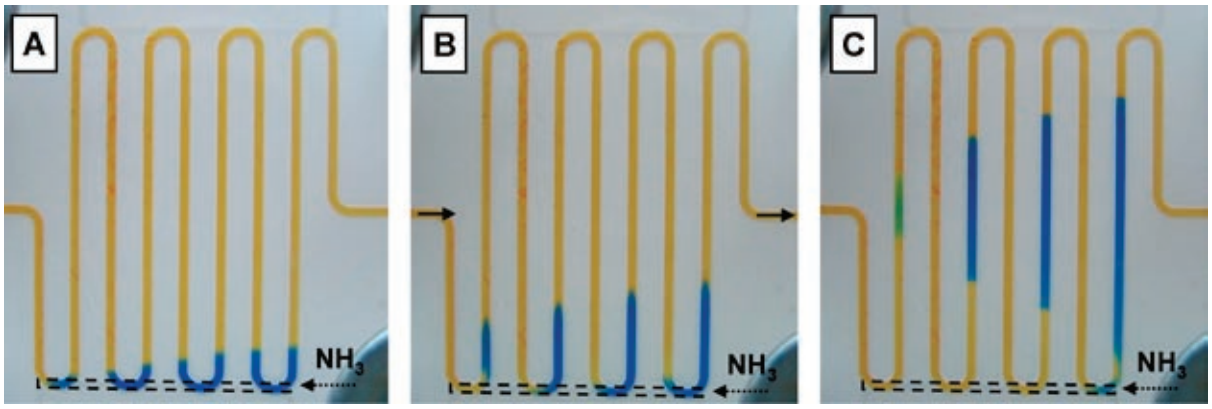

Figure 6: membrane microreactors displaying gas liquid contacting.

"Zipping Wetting"

A continuation of the work described in one of Langmuir's most cited papers (by Laura Vogelaar) led to a new discovery: how liquid spreads between a micropatterned surface. A small water droplet deposited on an array of polymer pillars (see figure 4 on page 3) can be stable in the fakir position (on top of the pillars = Cassie Baxter regime) or can wet the complete surface (between the pillars = Wenzel regime) (Figure 1a). With a high speed camera (10,000 fps) and an optical microscope we were able to observe the transition between these two regimes. The geometry of the surface, e.g. pillar distance and height, influences whether or not the transition takes place (a critical point can be determined) and how fast. For inter-pillar distances close to a critical point a "zipping wetting" occurs: the fluid moves faster in one direction than the other. This creates a square filling pattern under a spherical droplet (Figure 1b). For inter-pillar distances further from the critical point a round pattern appears due to equal speeds in both directions (Figure 1c). Numerical simulations confirm all experimental results (Figure 1d and 1e).

This work was done by Alisia Peters (Membrane Technology Group) and Christophe Pirat, Mauro Sbragaglia and Bram Borkent (Physics of Fluids group) of the University of Twente. The work is published in a Physical Review Letters paper "Spontaneous Breakdown of Superhydrophobicity, PRL 99, 156001 (2007)". More details on this "zipping" effect and more results will be published soon.

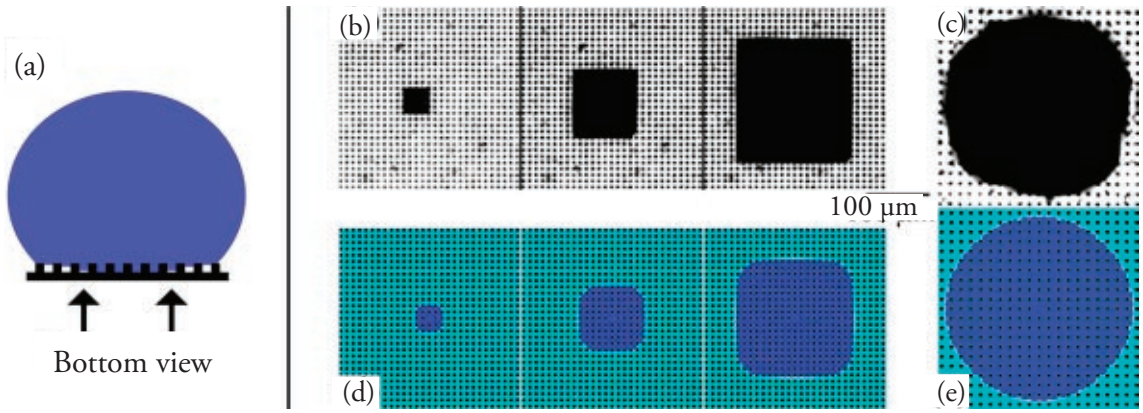

Figure 1. Bottom views of the front evolution of the wetting transition as sketched in (a). In (b) three snapshots for the case with 5 µm pillar spacing are shown, leading to a square-shaped wetted area. In (c) it is a 11 µm pillar spacing, resulting in a circular wetting area. (d) and (e) show results of the corresponding numerical simulations with the lattice Boltzmann method with pillar spacing 5 µm and 11 µm respectively.

Heiner Strathmann awarded the Barrer Prize

Prof. Dr.-Ing. H. Strathmann is awarded the Richard Maling Barrer Prize of the European Membrane Society. The Barrer Prize was created by the European Membrane Society to be given in recognition of exceptional contributions to the membrane field. Prof. Strathmann is the first recipient of the prize, which comes with a medal and a cheque of €10,000.

Prof. Strathmann is a founding member and leader of a scientific and technological community that has made and continues to make significant contributions to the big societal issues of our time, such as health, safe and sufficient water, sustainable energy and sustainable chemical processes. His technical achievements, his commitment to the application of technology to solve real problems, and the energy and enthusiasm he has put into spreading the membrane word around the world have already inspired a whole generation of membrane scientists and engineers, and his work and attitude continue to set an example to today's young researchers.

Academic achievements

Prof. Strathmann has been active in academia since 1962, and has been a prominent force in membrane research and development for much of that time. Even though retired in 1999 from the University of Twente, he remains an enthusiastic advisor and supporter of research groups world wide.

He has published nearly 200 scientific and reviewed papers and in 1979, he wrote the first scholarly book on membrane science and technology in Germany entitled "Trennung von molekularen Mischungen mit Hilfe synthetischer Membranen, Steinkopff, Darmstadt 1979". 35 Ph.D. students graduated under his supervision. Prof. Strathmann is co-founder of the European Membrane Society. Has served to the community as the Editor of the journal Separation and Purification Technology, as well as a member of the Editorial Board of the J. Membrane Science, Desalination, Filtrieren & Separieren, and Gas Separation and Purification.

Industrial achievements

Prof. Strathmann is an entrepreneur par excellence. He has been active in promoting the practical application of new scientific knowledge and new concepts on technical membranes from the beginning of his professional career. He was founder and CEO of the Forschungsinstitut Berghof GmbH which grew over time to an SME of 200 employees. At the Fraunhofer Institute in Stuttgart, he headed the department for Membrane Technology and coordinated industrial development projects. Professor Strathmann is named inventor on 25 patents. His patents on bipolar membranes form the basis of the ion exchange and bipolar membrane products of FumaTech, Germany. Many of his students/collaborators hold strategic positions in multi-national membrane companies or have started their own company. Many companies in his native Germany and around the world have benefited from his consultancy service.

In the organizations and groups that he heads, he creates a sense of freedom and respect that encourages the creativity of the groups and individual scientists working under him. His successful collaborations with many international organizations indicate that others also appreciate his ability to build creative, effective teams. In summary, Professor Strathmann is distinguished by a more than 40-year career of technical excellence, innovation, leadership and service.

Prof. Strathmann will be honoured formally at the 2008 ICOM meeting in Hawaii.

Opening of Meander

On November 23, the president of Shell Nederland, Mr. P. de Wit, officially opened our new building Meander. Prior to the official opening, the participants could attend a symposium

entitled 'the ideal energy mix for the next 100 years', where Prof. Niek Lopes Cardozo presented his vision for the future on nuclear fusion, Prof. Wim Sinke presented the future of Solar power and Prof. Wim van Swaaij discussed the possibilities for biomass. On November 24, people interested in the research performed at the University of Twente and family members of university employees got the opportunity to visit the new building and research labs and to attend many demonstrations in the field of catalysis, membrane technology, process technology and fluid dynamics.

Henny Bouwmeester: Most-cited author

Recently Elsevier has honored Dr. Henny J.M. Bouwmeester with the "most-cited author 2002-2006" award for his paper "Dense ceramic membranes for methane conversion" (published in Catalysis Today 82 (2003) 141-150). The paper discusses the performance characteristics of dense ceramic membranes made of mixed oxygen-ionic and electronic conducting perovskite-related oxides (Figure 1). The separation mechanism of these membranes makes it possible to separate oxygen from air at elevated temperatures (>700 °C) with infinite selectivity. The combination of these membranes with catalytic partial oxidation of methane to syngas in a ceramic membrane reactor provides a method to significantly reduce the capital costs of the conversion of natural gas to liquid added-value products.

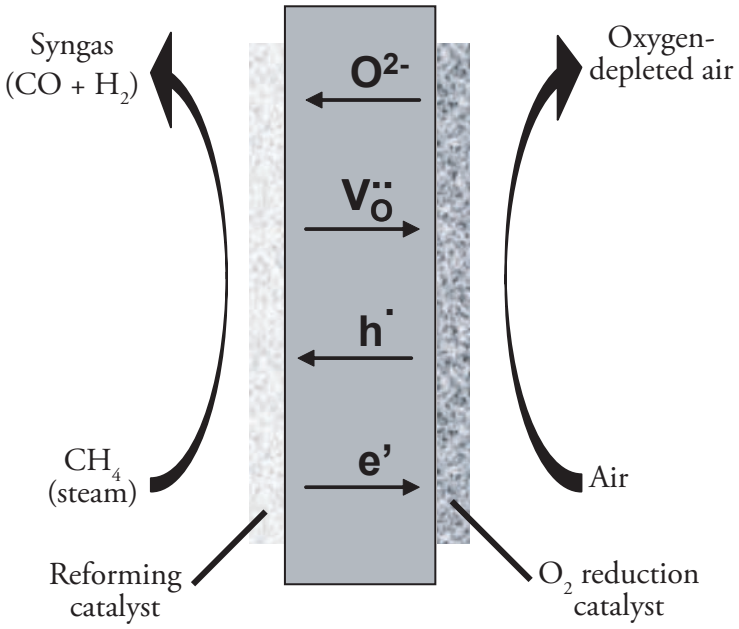

Figure 1: Operating principle of a ceramic membrane reactor with an oxygen selective membrane for the partial oxidation of methane to syngas.

Introducing...

Nanofiltration at extreme conditions

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Mayur is a 26 year old PhD student from India. He finished his MSc in Chemical Engineering at University of Dortmund, Germany. He has experience in gas separation membranes attributable to his MSc thesis topic at Degussa AG, Hanau, Germany. He started his PhD in Membrane Technology Group in August, 2007. His aim is to deliver a 'toolbox' containing robust (chemically stable) nanofiltration membranes for bulk liquid application in chemical industry (organic solvents and aqueous solutions at extreme pH conditions).

New member of the EMI

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Wika Wiratha

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Wika Wiratha was born in Bali, Indonesia and studied Chemical Technology at Hogeschool Utrecht. Before she joined European Membrane Institute (EMI) she worked at Inorganic Materials Science Group for 3 years. Her main activities were the preparation, characterizing and testing of porous and dense membranes. Beside that she assisted in the research for new and improved materials. Last year she worked for EMI Twente as well. She left EMI for 6 months and recently came back for at least two years. As part-time technician she contributes to different confidential projects with large industrial partners.

Membrane scaffolds for 3D cell cultivation

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Since August 1st, Roman is working as a Postdoc in a position shared between Membrane Technology and Tissue Regeneration Group. In his PhD project at Forschungszentrum Karlsruhe, he worked on the 'fabrication of polymer three-dimensional membrane microstructures'. Since then, Roman has been working in the field of flexible fluidic microchips based on thermoformed and locally modified thin polymer films. At the interface between MTG and TR, he is continuing this work developing a chip-sized membrane scaffold for 3D cell cultivation in form of a microcontainer array.

Papers, patents and graduations

Publications

Post, J.W., Veerman, J., Hamelers, H.V.M., Euverink, G.J.W., Metz, S.J., Nijmeijer, D.C. & Buisman, C.J.N., Salinity-gradient power: Evaluation of pressure-retarded osmosis and reverse electrodialysis, Journal of Membrane Science 288, 2007, 218-230.

Geerken, M.J., Lammertink, R.G.H. & Wessling, M. Interfacial aspects of water drop formation at micro-engineered orifices. Journal of Colloid and Interface Science 312, 2007, 460-469.

Patents

Tubular biofuel cell, WO 2007/011206 A1 (2007).

Method for monitoring the degree of fouling of a filter, WO 2006/031099 A1 (2007).

PhD

Jorrit de Jong, April 18 2008: Application of Membrane Technology in Microfluidic Devices.

Wilbert van de Ven, April 24 2008: Optimal saving in membrane operation: Process inspector.

Critical review on medical applications of membranes

A critical review on medical applications of artificial membranes prepared by researchers of the membrane technology group is currently in press in the Journal of Membrane Science (doi:10.1016/j.memsci.2007.09.059). In the paper, specific attention is given to drug delivery systems, artificial organs and tissue engineering. In all cases, the materials, methods and the current state of the art are evaluated and future prospects are discussed.

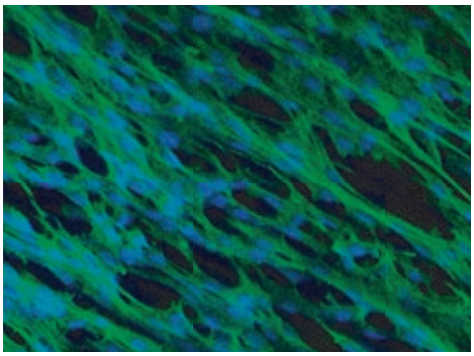


Figure 1. Schematic illustration of cells cultured on micropatterned membrane sheets.

This review shows the important role of membranes in medical applications and highlights the importance of collaboration of membrane scientists with others (biologists, bioengineers, medical doctors etc) in order to address the challenges in this field. For more information, please contact Dr. Dimitrios Stamatialis (d.stamatialis@utwente.nl).

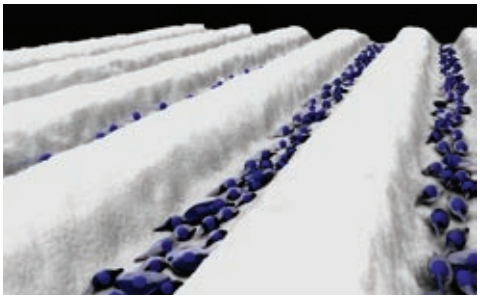
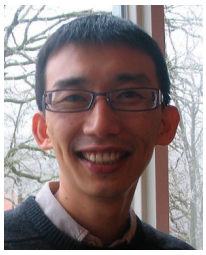


Figure 2. Confocal fluorescence microscopy images of 4 day C2C12 cell cultures on porous PLLA sheets featuring 20 µm wide channels (Cytoskeleton labeled with Bodipy-phallacidine (green) and nucleus labeled with Hoechst (blue).

Introducing...

New member of the EMI



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On 1st October, Jumeng joined the European Membrane Institute Twente as a Postdoc. He is working on the development of chemically and thermally stable membranes for dehydration pervaporation.

He received his PhD in chemistry from Zhejiang University, China in 2003, with a study on hollow fiber membrane contactors. After that, he continued his research on membrane contactors when he serviced as a research fellow in Nangyang Technological University, Singapore. In the past three years, he worked on catalytic membrane reactors and gas separation membranes as a postdoc in Porto University, Portugal.

New member of the EMI

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Erik van de Ven joined EMI Twente on October 1, 2007. Before he worked at the faculty of Engineering Technology for a period of 7 years. During this time he obtained a Master Degree in Chemical Engineering in the field of polymer science at the University of Twente. From 1986 till1999 Erik worked in several companies on the production of Integrated Circuits mainly for process optimizations.

Erik's main interest is in the field of biochemistry and biotechnology. Within EMI Twente he is working on a project to immobilize enzymes on membranes in order to improve the quality and separation of biomolecules, which find their way in biotechnical applications.

Presentation award for Zeynep Çulfaz

During the Dutch MicroNano conference in Wageningen on November 15th and 16th 2007, Zeynep Çulfaz won a prize for her presentation on "Microstructured hollow fiber membranes for ultrafiltration". This year the MicroNed conference was jointly organized with MinacNed with about 200 participants.

Zeynep works within the MicroNed project "Phase Separation Microfabrication". The goal of her research is to exploit microstructuring of hollow fiber membranes to improve filtration performance.

The Membrane Technology Group

Multidisciplinary approach in membrane science and technology

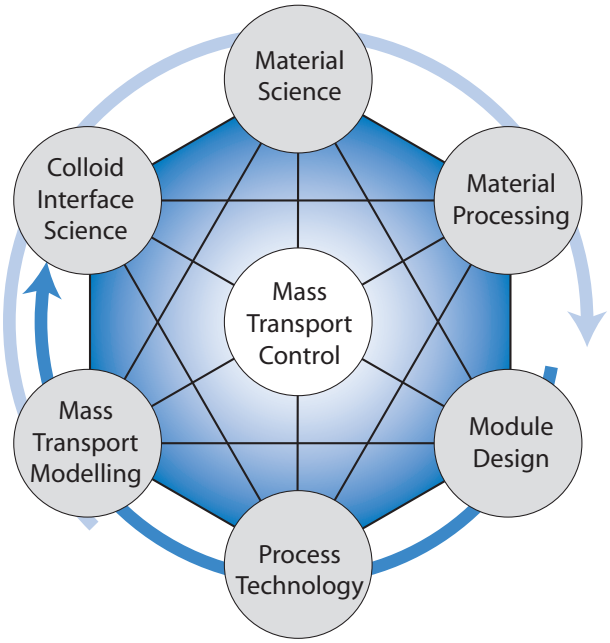
The Membrane Technology Group focuses on the multi-disciplinary topic of membrane science and technology. We consider our expertise as a multidisciplinary knowledge chain ranging from molecule to process. The knowledge chain comprises the following elements:

- 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

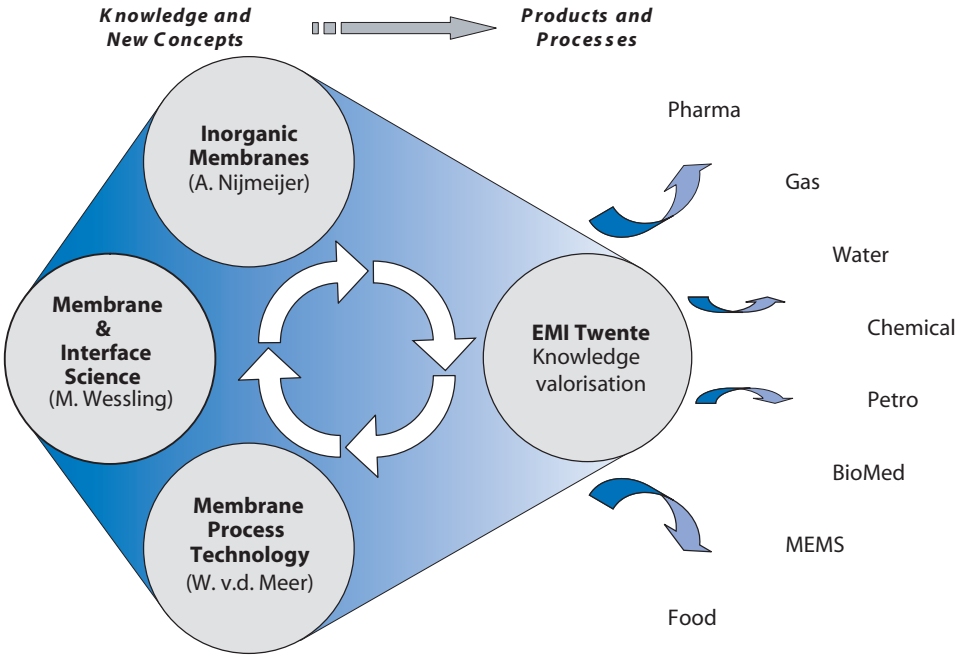
The research clusters are embedded in three research institutes, IMPACT (process technology), BMT (biomedical) and MESA+ (nanotechnology).



Total mass transport control by a multidisciplinary approach. The group of Membrane Science and Technology 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.

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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